BULLETIN OF THE BINGHAM OCEANOGRAPHIC COLLECTION

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Peabody Museum of Natural History
Yale University

Volume XVI, Article 2

STUDIES IN ICHTHYOLOGY AND OCEANOGRAPHY OFF COASTAL PERU

BY

James E. Morrow

Gerald S. Posner

Issued December 1957
New Haven, Conn., U. S. A.

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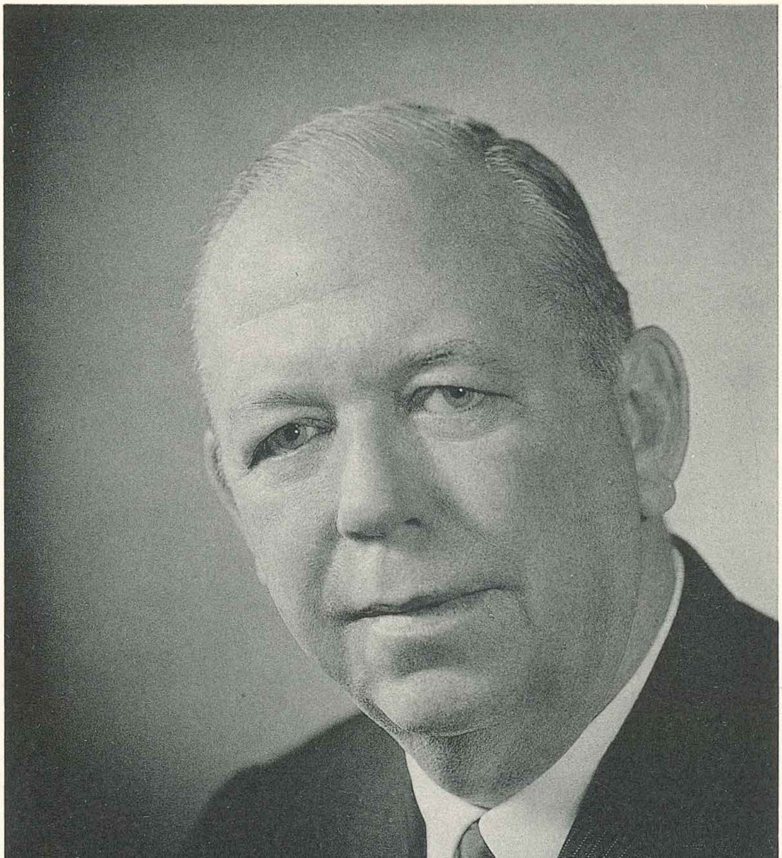
[1] An abstract in Russian will be found at the end of each paper.



IN GRATITUDE TO

WENDELL W. ANDERSON
Yale 1922

These five contributions in ichthyology and oceanography would not have been possible save for his efforts • With this publication we acknowledge in small measure his tireless endeavor and generous contribution to the growth and development of his university, particularly in the field of marine science

SHORE AND PELAGIC FISHES FROM PERU, WITH NEW RECORDS AND THE DESCRIPTION OF A NEW SPECIES OF *SPHOEROIDES*

By

James E. Morrow

ABSTRACT

The shore and pelagic fishes collected along the coast of Peru by the Yale South American Expedition of 1953 are arranged in a systematic, annotated list. One new species, *Sphoeroides andersonianus*, is described. Twenty-one species new to the Peruvian fauna are noted and the ranges of four species already known from Peru are extended by as much as 600 miles. The possible relationship between the presence of tropical fishes in this area and the occurrence of El Niño is discussed. It is concluded that invasions at such times make little if any permanent contribution to the ichthyofauna of Peru.

INTRODUCTION

This annotated list of fishes from Peru is one of the contributions of the Yale South American Expedition of 1953. The Expedition had three primary objects: a study of the biology of the big-game fishes of the area, particularly the Istiophoridae; a study of the oceanography of the Peruvian coastal area; and collecting specimens for future exhibition in the Peabody Museum of Natural History of Yale University. To achieve these objectives, the expedition's equipment included four vessels: the Marise, a commercial fishing vessel 63 feet long converted into a laboratory ship; two fishing launches equipped expressly for deep-sea angling; and a large motor sailer that was used as living quarters.

Leaving Panama on February 20, the Marise, under command of Captain Harold McLaughlin of Mystic, Conn., proceeded to Cabo Blanco, Peru for the purpose of unloading heavy gear and setting up a base. Because of bad weather it was impossible to accomplish this mission until March 5, after which the MARISE rejoined the main body of the expedition on March 7, on the Cope Bank off Ecuador. The expedition was based at Cabo Blanco, Peru, from March 10 until April 19. During this period, the collecting of small fishes was carried out in such time as could be spared from other work. On April 19 the MARISE left Cabo Blanco for an extended cruise to the south (see Fig. 1), during which some collecting was done at Lobos de Afuera Islands. No further attempts were made to collect fishes until the MARISE reached Pisco on April 30. During the next week, two days were spent in collecting intensively in and around Pisco Bay and in Bahia Independencia. The MARISE began her homeward journey on May 6. Reaching Callao on the seventh, she encountered some delay while she was hauled out for scraping and painting; a few fishes were collected or purchased in this period. Resuming the northward cruise on May 16, the next opportunity to collect small fishes occurred at Lobos de Afuera Islands on May 19 and 20. Here, a day and a half of intensive work yielded a large sample. No further collecting was done, and when the MARISE arrived at Panama on May 27, the expedition was secured.

Throughout the course of the expedition, collections were made by any means at hand. Although most of the specimens were taken by seining, good use was also made of a light and dip-net at night, rotenone in tide pools, and small otter trawls. Also, a few specimens were purchased from or given to us by local fishermen. While the small trawls used on the bottom in shallow water yielded only two specimens, nets set as deep as 400 m in deep water produced a number of specimens of mid-depth fishes which are reported in another paper in this issue.

The shore and pelagic fish collection includes 3,817 specimens, consisting of 3,766 preserved specimens, 8 plaster casts, 8 photographs, and, in the case of Istiophoridae and Thunnidae, records of 35 specimens in the form of detailed notes made from fresh fish. The nearly-four-thousand individuals encompass 105 species in 48 families and 16 orders. The most recent monograph of the marine fishes of Peru, that of Hildebrand (1946), includes a total of 264 species. Although the present collection represents somewhat less than half that number, nevertheless it adds 21 species new to Peru and one new to science, bringing the total number of species known from Peru to 286.

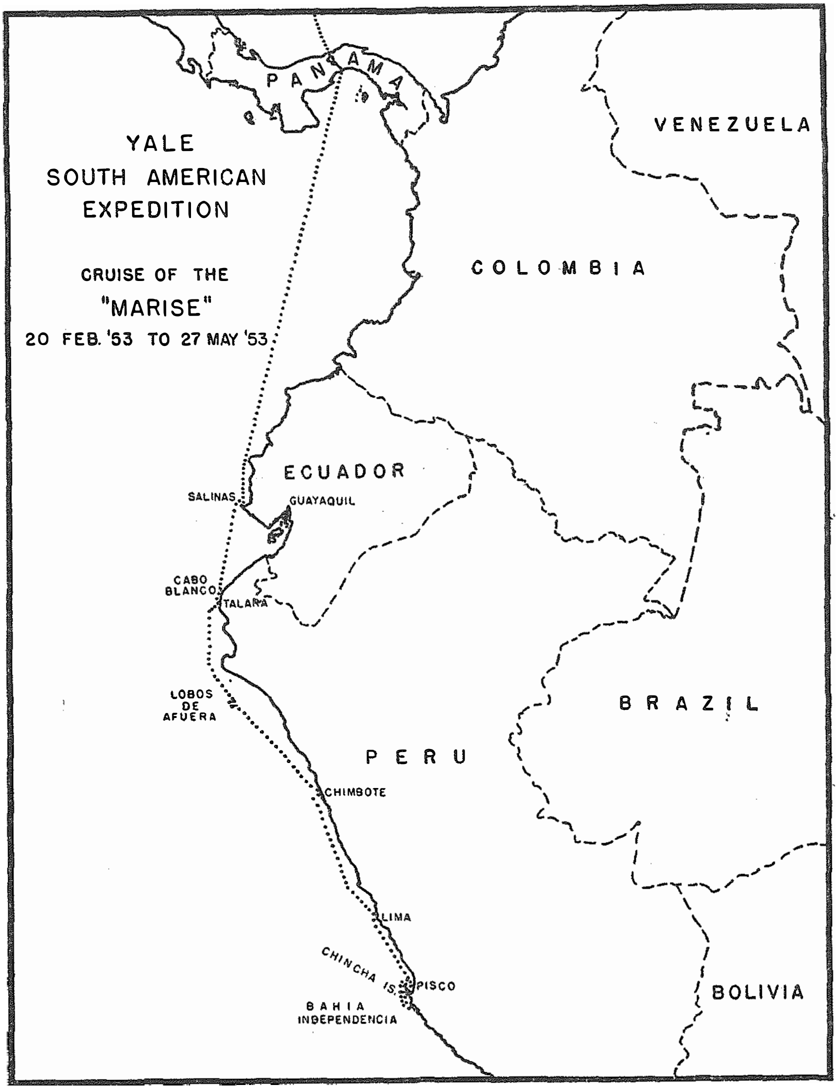


Fig. 1. The cruise of the Marise, February 20 to May 27, 1953.

NEW SPECIES

Order Tetrodontiformes

Family Tetrodontidae

Sphoeroides andersonianus, n. sp.

A total of 222 individuals, 15.1 to 51.6 mm S. L., were seined at Lobos de Afuera Islands. The specimens have been compared with representative specimens of related species in the Bingham Oceanographic Collection and in the U. S. National Museum and with published descriptions. Apparently the present species is one previously unknown. It is number 102 in the subsequent list. A specimen 46 mm S. L. has been selected as the holotype and is shown in Fig. 2[1]; there are 17 cotypes and 204 paratypes. The holotype and cotypes are in the Bingham Oceanographic Collection, catalog numbers 3734 and 3735 respectively.

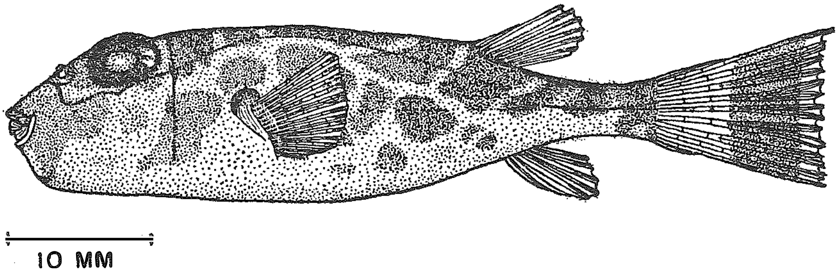


Fig. 2. *Sphoeroides andersonianus*, n. sp. Holotype, 46 mm to base of caudal.

Description: Proportional measurements in standard length and in head and as percentage of standard length. Description based on the 222 specimens noted above.

Standard length: 15.1–51.6 mm.

Body: depth at pectoral base 3.73 (3.32–4.36) in S. L.; 26.9% (22.9–32.1%).

Caudal peduncle: least depth 5.47 (4.33–7.00) in head; 7.0% (5.9–8.0%).

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[1] The following proportions and enumerations apply to the holotype. Sex ♀; D. 8; A. 7; P. 16; C. 1/4 + 4/2. In standard length: head length 2.75 (36.4%); depth of body 3.67 (27.3%). In head: caudal peduncle 4.69 (21.3%); snout 2.31 (43.3%); eye 3.35 (29.5%); interorbital 6.57 (15.2%); longest dorsal ray 2.34 (42.8%); longest anal ray 2.61 (38.3%); longest pectoral ray 2.38 (42.1%).

Head: length 2.60 (2.32–2.80) in S. L.; 38.5% (36.0–43.2%).

Snout: 2.46 (2.03–3.26) in head; 15.7% (12.0–18.2%).

Eye 3.47 (2.87–4.82) in head; 11.2% (7.6–13.9%).

Interorbital space: 6.39 (5.10–7.58) in head; 6.1% (4.5–7.6%).

Dorsal fin: rays 8; height of longest ray 2.27 (2.01–2.65) in head; 16.8% (14.0–18.8%).

Pectoral fin: rays 16 (15–17); longest rays 2.39 (2.16–2.68) in head; 15.9% (14.3–17.9%).

Anal fin: rays 7; longest rays 2.69 (2.31–3.03) in head; 14.1% (12.6–16.0%).

Caudal fin: rays 1/4 + 4/2, sometimes 2/3 + 4/2 in small specimens.

Body robust, about as wide as deep at pectoral base. Head large, its width equal to its depth at eyes and proportionally greater in small specimens. Dorsal profile curving rather abruptly at eyes, straight to slightly concave before eyes. Snout moderate. Eye large, proportionally larger in small individuals than in larger ones. Interorbital flat. Mouth small, transverse; lower jaw included. Dental plate in each jaw with horizontal striations, as though built up in layers. Lips rather thick, with numerous cutaneous folds.

The lateral line is easily discerned though not prominent, beginning in a transverse branch on the snout before the nostril but not meeting the corresponding branch from the other side. This portion of the line forms two branches; one turns anteriorly, loops downward and backward and passes beneath the eye, where there is a shallow notch in the line; the other passes backward over the eye and joins its fellow just behind the eye. Another branch, given off at this point, extends ventrally to the level of the lower edge of the pectoral base. The main portion of the lateral line continues posteriorly in a smooth curve, at first high on the back but reaching the middle of the sides behind the dorsal fin. An accessory branch crosses the back opposite the pectoral fins.

Spinules present everywhere on body except around mouth; smallest on sides, largest on belly. No dermal flaps.

Dorsal fin moderate. Anal smaller than dorsal, its origin slightly behind that of dorsal. Pectoral broad; margin of upper two thirds of fin quite straight. Caudal truncate. Caudal peduncle depressed.

Color in formalin. Dark gray above, white beneath. Back with pale lines arranged in irregular concentric ellipses: the smallest is in front of the dorsal; the next larger reaches the dorsal origin posteriorly, about to the pectoral base anteriorly; the next larger is visible on the back of the head as a cross-bar, extends downward and backward near the pectoral base, disappears into the white of the belly but then reappears and crosses the caudal peduncle just behind the dorsal; one or two pale cross-bars are on the caudal peduncle; another is sometimes present just behind the eye; the ellipses are connected by numerous irregular branches. Sides plain in small individuals, larger ones becoming marked with dark blotches not as large as eye. A black spot above each eye. Pectoral base dark. A dusky area on lower side of belly and caudal peduncle, beginning at anus and extending backward to caudal. A dark "V" in caudal area, its apex at end of anal. Caudal pale, with a dusky bar across terminal half; margin pale. Other fins all more or less pale.

S. andersonianus may be separated from *S. annulatus* and *S. sechurae*, the other two Peruvian species of the genus, by the following key:

a. Spinules absent from snout, from region behind dorsal and anal, and along middle of sides........................*S. annulatus.*
aa. Spinules present everywhere on body, extending forward on snout and backward on caudal peduncle behind dorsal and anal.
  b. Eye small, 5.25–8.0 in head; pectoral with 14 or 15 rays; caudal formula 2/3 + 4/2............................*S. sechurae.*
  bb. Eye large, 2.87–4.82 in head; pectoral with 15–17 rays, usually 16; caudal formula usually 1/4 + 4/2......*S. andersonianus.*

The species is named for Wendell W. Anderson of Detroit in recognition of his stimulation in advancing marine research.

NEW RECORDS AND EXTENDED RANGES

In the list of new records, the number preceding each species name refers to the position of that species in the subsequent annotated list. Twenty one species, believed to be new to the fauna of Peru, are now recorded from that area:

4. *Mobula lucasana* Beebe and Tee-Van
9. *Anchoa exigua* (Jordan and Gilbert)
15. *Muraena insularum* Jordan and Davis
16. *Echidna nocturna* (Cope)
17. *Myrichthys tigrinus* Girard
21. *Hyporhamphus gilli* Meek and Hildebrand

22. *Hyporhamphus snyderi* Meek and Hildebrand
23. *Fodiator acutus* Valenciennes
32. *Chaenomugil proboscideus* (Günther)
44. *Trachurops crumenophthalmus* (Bloch)
50. *Oligoplites refulgens* Jordan and Starks
54. *Lutjanus guttatus* (Steindachner)
56. *Eucinostomus californiensis* (Gill)
57. *Eucinostomus elongatus* Meek and Hildebrand
74. *Abudefduf analogus* (Gill)
80. *Rupiscartes atlanticus* (Valenciennes)
82. *Hypsoblennius piersoni* Gilbert and Starks
84. *Homesthes caulopus* Gilbert
91a. *Makaira ampla mazara* (Jordan and Snyder)
96. *Parathunnus sibi* (Temminck and Schlegel)
98. *Kishinoella zacalles* Jordan and Evermann

The ranges of four species, already known from Peruvian waters, have been extended in greater or lesser degree by the results of the collection, as follows:

6. *Albula vulpes* (Linnaeus), 350 miles southward.
62. *Menticirrhus rostratus* Hildebrand, 600 miles southward.
79. *Ophioblennius mazorkae* Hildebrand, 350 miles northward.
86. *Malacoctenus afuerae* (Hildebrand), 500 miles southward.

LIST OF SPECIES COLLECTED

In the following list, orders and families are arranged according to the classification of Berg (1940). For the most part, detailed descriptions of the various species are to be found in "A descriptive catalog of the shore fishes of Peru" by Samuel F. Hildebrand (1946). Therefore descriptions have been omitted here except for species new to Peru. Even then, only such information is given as is deemed necessary or desirable to distinguish the newly-recorded species from others already known from the area. References of specific application are included where appropriate. Wherever possible, colloquial names in both Spanish and English have been supplied in addition to scientific names. Colloquial names, for the most part, have been gleaned from conversations with local fishermen. However, free use has also been made of the works of Evermann and Radcliffe (1917), Hildebrand (1946), Walford (1937), and others.

Order Lamniformes

Family Rhincodontidae

1. *Rhincodon typus* Smith. Whale Shark.

A small individual about 20 feet long was photographed in the harbor at Cabo Blanco. Recorded by Günther (1884) from Callao; several other references apparently deal with the same record. Known from the warmer parts of the Atlantic, Pacific and Indian oceans.

Family Carcharinidae

2. *Scoliodon longurio* (Jordan and Gilbert). Sharp-nosed Shark.

Two young individuals, 389 and 367 mm long, were taken on handlines in the harbor at Talara. Known from Mexico to Peru. Although Hildebrand (1946) remarked, "This genus is now for the first time recorded from Peru," it is apparent that the statement is in error. The species was recorded by Tortonese (1939), which reference was also listed by Hildebrand.

Family Sphyrnidae

3. *Sphyrna zygaena* (Linnaeus). Cruz; Hammerhead.

One small specimen was purchased from a local fisherman at Cabo Blanco and prepared for exhibition. Found in warm waters, probably throughout the world.

Order Rajiformes

Family Mobulidae

4. *Mobula lucasana* Beebe and Tee-Van. Manta, Mobular; Ray.

One specimen, an immature male approximately six feet from tip to tip of the wings, was harpooned near Cabo Blanco by Captain McLaughlin. Only the head of the specimen has been preserved, but there are also a number of color photographs. The specimen agrees well with Beebe and Tee-Van's (1938) description, differing only slightly in color. Whereas the type specimen is described as being blackish gray or bluish gray, the Yale specimen was distinctly deep blue-black on the dorsal surface, fading through light blue to white on the under side. Known from San Lucas Bay, Mexico; presumably it is also present along the west coast of Central America and is now reported from Peru. It is easily distinguished from the true *Manta* by the ventral position of the mouth.

5. *Manta hamiltoni* (Newman). Manta, Manta Raya; Manta.

One large female, nearly 18 feet from tip to tip of the wings and weighing approximately 2800 pounds, was harpooned off Cabo Blanco, brought ashore and prepared for exhibition. The specimen agrees closely with modern descriptions (e.g., Beebe and Tee-Van, 1941), particularly with respect to the immaculate white shoulder patches.

Because of the similarity of mantas from all parts of the world, the generally inadequate descriptions, and the difficulty of securing specimens, the classification of these fishes is in an uncertain state and the matter of synonymy presents something of a problem. While it is beyond the scope of the present paper to enter into a detailed discussion of this matter, a few remarks are in order.

The earliest proper description of *Manta birostris* was in 1798 by Donndorf, cited by Bigelow and Schroeder (1954), who state that all records of *Manta* from the Atlantic are referable to this species. In the Pacific and Indian oceans, however, the situation is much more clouded. At least ten species, supposedly distinct from *M. birostris,* have been reported from those areas and two more have been recorded from the Pacific Coast of the Americas. Of these last two, the name *Manta raya* of Baer (1899), from northern Peru, should not be considered; it is a local colloquial name, sometimes applied to *Mobula* as well as to *Manta,* and was used in the colloquial sense by Baer. The other name, *M. hamiltoni* (Newman, 1849), may, according to Bigelow and Schroeder, be separated from *M. birostris* of the Atlantic by its color pattern. *M. birostris* is supposed to have dark markings in the shoulder patches, while in *M. hamiltoni* these dark spots are absent.

On the basis of color pattern and locality of capture, the Yale specimen should probably stand as *M. hamiltoni.*

Although large rays of this family appear to be quite common along the northern coast of Peru, *Mobula* has not been reported heretofore from these waters and *Manta* is mentioned only rarely. Aside from the reports of Baer and of Beebe and Tee-Van, noted previously, the only other records seem to be those of Bini and Tortonese (1955) and of Murphy (1923). Without being able to identify genus or species, Murphy remarks that, near the Guañape Islands (8° 35′ S), "*mantas,* or large rays, were seen leaping from the water into the air. Ordinarily these somersaulting fishes are to be observed only in the extreme northern waters of Peru, north of Point Pariña. Their jumping is a common phenomenon in the tropical ocean off Ecuador. Near La Plata Island (1° 16′ S), for instance, the writer noted them in great abundance on September 5, 1919, and again in early February, 1920. The commander of the *Huasco* (Captain Herbert Gregory) maintained that the migration of the jumping rays down the Peruvian coast as far southward as Salaverry and the Guañapes is always coincident with other manifestations of El Niño."

Order Clupeiformes

Family Albulidae

6. *Albula vulpes* (Linnaeus). Bonefish, Ladyfish.

A total of 20 juveniles between 24.5 and 52.4 mm S. L. as well as 18 flat, ribbon-shaped, leptocephalus-like larvae 31.5 to 64.5 mm long were taken at Cabo Blanco, Talara, and in Paracas Bay. Reported from Talara by Hildebrand and Barton (1949) and from Máncora and Chimbote by Bini and Tortonese (1955), the specimens from Paracas Bay extend the known range of this species by about 350 miles to the south.

Family Clupeidae

7. *Opisthonema libertate* (Günther).

Eight specimens, 34.6 to 63.1 mm S. L., were taken with light and dip-net at Cabo Blanco and Talara during March and April. Known from Mexico to Galapagos Islands and Peru, but apparently not numerous in Peruvian waters.

8. *Ethmidium chilcae* Hildebrand. Machete.

Six specimens 179 to 222 mm S. L. were purchased from a fisherman at Callao. Known from the coast of Peru. Hildebrand (1946) has discussed in some detail the relationships of this species with similar ones from Chile and Mexico, and he concluded that they are probably different.

Family Engraulidae

9. *Anchoa exigua* (Jordan and Gilbert). Anchovy.

A single larva, 19.6 mm S. L., taken under a light in Talara Harbor on March 9, appears to belong to this species. Previously known from Mazatlán, Mexico, to La Plata Island, Ecuador, this is a new record of the species. It may be separated from *A. naso* as follows:

A. exigua	*A. naso*
Depth 5.1 to 5.8.	Depth 4.4 to 5.0.
Anal 18 to 21.	Anal 20 to 24.
Eye 2.75 to 3.3 in head.	Eye 3.5 to 4.0 in head.
Pectorals short, not reaching base of ventrals.	Pectorals long, nearly or quite reaching base of ventrals.

10. *Anchoa naso* (Gilbert and Pierson). Anchoveta; Anchovy.

A total of 18 specimens was obtained at Cabo Blanco and Talara, ranging from 24.1 to 42.0 mm S. L. Known from Peru north to Panama.

11. *Engraulis ringens* Jenyns. Anchoveta; Anchovy.

Three specimens, 60.7 to 212.0 mm S. L., were taken at Lobos de Afuera Islands, Callao, and Bahia Independencia. Known from Peru and Chile.

Order Scopeliformes

Family Synodidae

12. *Synodus scituliceps* Jordan and Gilbert. Lizardfish.

One juvenile, 45.0 mm S. L., was taken under a light at Talara. The specimen is pale yellow except for a thin dark bar across the base of the caudal and a row of six brownish round spots, each slightly larger than the eye, ventrally along each side; the first of these spots is located almost wholly within the gill chamber, the last just in front of the anal fin. Known from Mexico to Peru. Meek and Hildebrand (1923) also included Galapagos Islands in its range, citing Jordan and Bollman (1890) as their authority. However, the latter authors stated that their specimens came from "Pacific ocean, off coast of Colombia; . . . also from Guaymas." The error doubtless stemmed from a misinterpretation of the title of Jordan and Bollman's article, "Descriptions of new species of fishes collected at the Galapagos Islands and along the coast of the United States of Colombia, 1887–'88."

Order Cypriniformes

Family Ariidae

13. *Galeichthys jordani* (Eigenmann and Eigenmann). Bagre; Sea Catfish.

One specimen, 61.4 mm S. L., was taken in a seine at Cabo Blanco. Known from Panama to Peru, quite common about Cabo Blanco;

here, like catfishes in many parts of the world, it furnishes much sport for small boys.

Order Anguilliformes

Family Muraenidae

14. *Gymnothorax weineri* Sauvage. Morena; Moray.

Two specimens, 571 and 524 mm long, were purchased from a local fisherman at Lobos de Afuera Islands. Known only from coastal waters of Peru.

15. *Muraena insularum* Jordan and Davis. Morena; Moray.

One specimen (Fig. 3) 516 mm long was the gift of a fisherman at Lobos de Afuera Islands. Previously known only from a few specimens from Galapagos Islands, this is a rather remarkable new record.

Body compressed, thickness at vent about two thirds depth at vent. Tail more strongly compressed, tapering to a rounded point. Length anterior to vent 1.76 in T. L. (56.8%). Depth 8.5 in T. L. (11.8%); 4.8 in length before vent (20.8%); 1.5 in head (66.6%). Head 5.5 in T. L. (18.2%); 3.1 in length anterior to vent (32.2%). Snout slightly projecting, 5.8 in head (17.2%). Eye laterally placed; 13.4 in head (7.5%); 2.5 in snout (40%). Mouth large, nearly terminal. Gape reaching well behind eye, 2.7 in head (37%). Tube of anterior nostril rather short, not reaching upper lip when drawn downward. Tube of posterior nostril over anterior margin of eye, well developed, a little longer than anterior nostril. Gill opening nearly horizontal. Distance before dorsal 4.4 in length anterior to vent (21.7%).

Teeth in a single row in each jaw, of moderate size, about 8 to 10 on each side of each jaw. Vomer with a single row of five small canines set well back on the shaft (Fig. 3B).

Color in formalin dark brown with light tan mottlings. Head much lighter than rest of body, marked with fine dark brown reticulations on dorsal and lateral surfaces. A series of about four straight dark brown lines extend from region of angle of mouth towards gill opening, which is situated in a prominent dark spot. Under side of throat and belly profusely decorated with small white spots, these continuing the length of anal fin. A dark mark preceded by a light spot in corner of mouth. The Yale specimen has been compared with the type and with another specimen in the U. S. National Museum. Al-

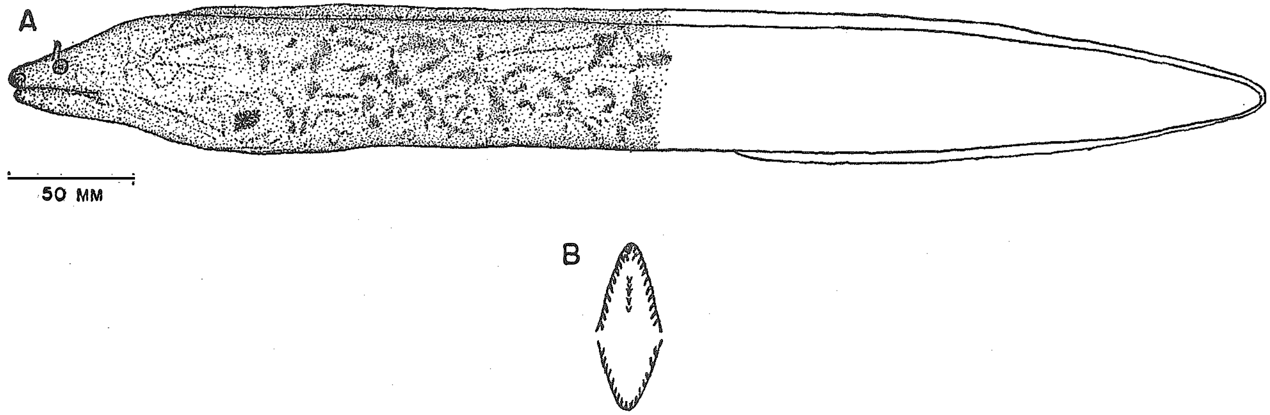

Fig. 3. *Muraena insularum* Jordan and Davis. *A*, From a specimen 516 mm long. *B*, Diagram of the teeth of *M. insularum*.

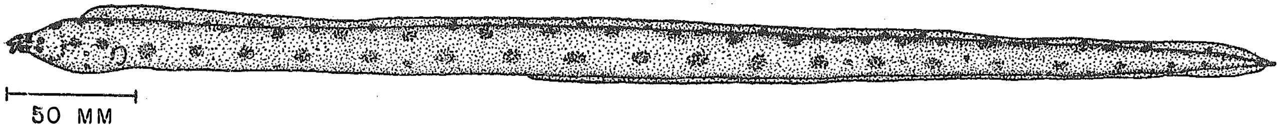

Fig. 4. *Myrichthys tigrinus* Girard. From a specimen 490 mm long taken at Cabo Blanco, Peru.

though all three differ slightly in coloring, there can be no doubt that all belong to the one species.

16. *Echidna nocturna* (Cope). Morena; Moray.

One specimen 627 mm long was captured in a tide pool at Lobos de Afuera Islands. Known from Mexico to Galapagos Islands but not previously reported from Peru. *Echidna* is easily separated from other muraenoids by the blunt molar-like teeth. Within the genus, *E. nocturna* is quickly set off by its color, a dark slaty black with numerous small white or yellow spots.

Family Ophichthyidae

17. *Myrichthys tigrinus* Girard.

A single individual 490 mm long (Fig. 4) was taken at Cabo Blanco under a light. Known from west coast of Mexico to Ecuador and listed from Galapagos Islands by Storey (1939). Now also recorded from Peru.

Girard (1860) described this species with the type locality "Adair Bay, Oregon." However, there is no such place, and the known tropical distribution of the species makes Oregon a most improbable locality. It is much more likely that the type locality was actually Adair Bay, Sonora, Mexico, at the northern end of the Gulf of California. Harry (1948) reached the same conclusion.

Body long and slender, but slightly compressed. Trunk and tail subequal. Depth about 26 in T. L. (3.8%). Head somewhat swollen, about as wide as deep, 11.9 in T. L. (8.4%). Snout flat, upper jaw projecting for about a third of its length beyond the lower, about 5.5 in head (18.2%). Eye small, 15 in head (6.7%). Anterior nostrils tubular, depending from ventral side of upper lip. Teeth small, blunt, in bands on jaws and vomer.

Dorsal arising on nape, well in advance of gill opening, its anterior portion somewhat elevated. Anal fin originating immediately behind anus. Both fins continuing posteriorly almost to tip of tail, which is hard and pointed. Pectorals short, broader than long.

Color in formalin orange-brown; two rows of large dark spots on sides and back, an incomplete row on base of dorsal, and another on ventral surface of tail; a few smaller spots on top and sides of head, more and still smaller spots on throat and belly.

Storey (1939) has tabulated the measurements of a graded series of this species and has found that some rather notable differences appear in several proportions as total size changes.

Order Beloniformes

Family Scomberesocidae

18. *Strongylura stolzmanni* (Steindachner). Picuda, Aguja; Needlefish.

A partially digested specimen about 200 mm long was found in the stomach of a Dorado (*Coryphaena hippurus*) taken off Talara. Ranges from Gulf of California to Peru and to Galapagos Islands.

Family Hemiramphidae

19. *Hemiramphus saltator* Gilbert and Starks. Balao; Halfbeak.

Three juveniles, 22.0 to 23.5 mm S. L., were taken with a light and dip-net at Cabo Blanco and probably belong to this species. Known from Mexico to Galapagos Islands and Peru, but recorded only once before from the last locality.

20. *Hyporhamphus unifasciatus* (Ranzani). Choele: Halfbeak.

Twelve specimens, 35 to 130 mm S. L., from Cabo Blanco and Talara. Only a single specimen has been obtained previously from Peru, that being taken by R. E. Coker at Capon and described by Evermann and Radcliffe (1917) and by Hildebrand (1946). Apparently rather rare in Peruvian waters; ranges from Gulf of California to Galapagos Islands and Peru.

21. *Hyporhamphus gilli* Meek and Hildebrand. Halfbeak.

Most numerous of the Halfbeaks in the collection, 82 specimens between 26.0 and 130.5 mm S. L. were taken at Cabo Blanco and Talara with light and dip-net. Previously known from Mexico to Galapagos Islands but now recorded from northern Peru. The following description is based on 18 individuals between 63 and 130.5 mm S. L.

Body elongate, compressed. Depth 7.5 to 9.5 in S. L. (10.5–13.3%). Head depressed above, 4.3 to 4.7 in S. L. (21.2–23.2%). Mandible produced, equal to or slightly shorter than rest of head from tip of upper jaw, 3.5 to 5.4 in S. L. (18.5–28.5%). Snout 2.4 to 2.9 in head (34.5–41.7%). Eye moderate, 3.9 to 4.7 in head (21.2–25.6%). Interorbital about equal to eye, 3.8 to 4.8 (20.6–

26.3%). Gill rakers slender, closely set, 28 to 34 on lower limb of first arch. Scales moderately adherent, 50 to 55 in a midlateral series. Dorsal (14 or 15) and anal (15 or 16) similar, scaly at least at base in small specimens, almost entirely so in larger individuals. Ventrals small, inserted only slightly behind midbody, the distance from origin of ventrals to caudal base being 2.1 to 2.2 in S. L. (45.5–47.6%). Caudal forked, lower lobe large.

Color in formalin whitish. Back with numerous brown punctulations, densest on scale edges. Three rows of dark dots, or three dark lines, along back. Sides with a dark band. Snout and mandible black. Caudal and margins of dorsal and anal dusky, other fins pale.

22. *Hyporhamphus snyderi* Meek and Hildebrand. Halfbeak.

Six specimens from 47.8 to 81.5 mm S. L. were taken under a light while anchored at Cabo Blanco or Talara. Known from Lower California and Panama, the range is now extended to Peru.

Body very elongate, slightly compressed. Depth 9.7 to 10.8 in S. L. (9.3–10.3%). Head depressed above, 4.7 to 5.0 (20.0–21.2%). Mandible strongly produced, 2.6 to 3.4 in S. L. (31.2–38.4%). Snout short, 2.9 to 3.2 in head (31.2–35.4%). Eye moderate, 3.8 to 4.4 in head (22.7–26.3%). Interorbital equal to or slightly greater than eye, 3.7 to 4.4 (22.7–27.0%). Gill rakers slender and closely set, 33 to 37 on lower limb of first arch. Scales markedly deciduous, mostly missing on all specimens, 54 to 56 in a longitudinal series. Dorsal and anal similar, naked. Ventrals small, inserted behind midbody, the distance from ventral origin to caudal base 2.3 to 2.4 in S. L. (41.6–43.4%). Caudal forked, the lower lobe larger.

Color in formalin whitish, with brown punctulations on back, these most numerous at scale edges. Three rows of brown dots, or three dark lines, along middle of back. Mandible and edge of upper jaw black. Caudal and margins of anterior rays of dorsal and anal dusky, rest of fins pale.

Family Exocoetidae

23. *Fodiator acutus rostratus* (Günther). Sharp-chinned Flyingfish.

Two specimens, 45.5 and 134.1 mm S. L. The smaller was taken with light and dip-net, the larger (Fig. 5) flew on board at night, both at Cabo Blanco. This species appears to be of rather wide

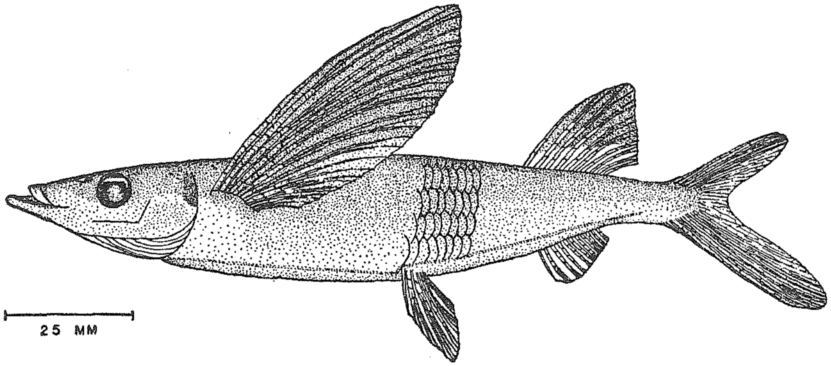

Fig. 5. *Fodiator acutus* Valenciennes. Specimen 134.1 mm S. L. which flew aboard the Marise at Cabo Blanco.

distribution in warm seas, being known from Angola, both shores of Central America, Panama, Galapagos Islands and Hawaiian Islands. However, it has not been found in Peruvian waters until now. Both Atlantic and Pacific subspecies have recently been re-examined (Morrow, 1957).

24. *Danichthys rufipinnis* (Valenciennes). Volador; Flyingfish.

A single specimen, 129 mm S. L., flew aboard the Marise on the night of March 18 about 12 miles west of Cabo Blanco. The range of this species is uncertain, but it appears to be more or less confined to the western coast of South America.

25. *Cypselurus* sp. Volador; California Flyingfish (?).

Two large specimens, 309 and 291 mm S. L., came aboard during the night of April 29. The smaller was heard to strike the deck shortly after the Marise had left St. 119 (12° 53′ S, 76° 48′ W, time 2115 hours) and the larger was found on deck the following morning, when the position was 13° 24′ S, 76° 31′ W.

The specimens in hand appear to belong to the species designated by Hubbs and Kampa (1946) as "2. *Cypselurus* (*Cheilopogon*) species." The species has been described in a manuscript by Myers and Wade, and, since Dr. Myers (personal communication) expects to publish the description in the near future, no further details will be given here.

The specimen listed by Nichols and Murphy (1922) as *Cypselurus californicus* from Central Chincha Island and doubtfully synonymized with *Danichthys rufipinnis* by Hildebrand (1946) as well as with the *C. californicus* reported by Bini and Tortonese (1955) from Chimbote, probably belong to this species also. Other specimens apparently belonging to this species have been recorded from the Chincha Islands in Peru; off Masafuera Island, Chile; Galapagos Islands; and at Clarion Island, off Mexico.

Order Gadiformes

Family Gadidae

26. *Merluccius gayi* (Guichenot). Peje-palo; Hake.

Two individuals of 128 and 133.2 mm S. L. were taken in a midget otter trawl at St. 109 (9° 35′ S, 78° 26′ W) from a muddy bottom in 46 fathoms of water. Although this trawl was used a number of times at various places, these two specimens were the only fish taken with it. Known only from coastal waters of Peru and Chile.

Order Syngnathiformes

Family Fistulariidae

27. *Fistularia corneta* Gilbert and Starks. Aguja; Trumpetfish.

Eight specimens from 158.5 to 210.1 mm long were taken with a seine at Caleta de Manoa on Lobos de Afuera Island. This is only the second record of the species from Peru, the first being that of Hildebrand (1946), who had specimens from Chilca and Sechura Bays and Punta Pariña. Ranges from Mexico at least as far south as Peru.

Family Syngnathidae

28. *Syngnathus acicularis* Jenyns. Aguja; Pipefish.

Thirty one individuals, both juveniles and adults, between 44.5 and 125.0 mm S. L. were seined at three localities in Paracas Bay. Of these, 27 were taken on a beach about a quarter of a mile east of the town of Paracas. Originally described from Valparaiso, Chile, it has been reported as far north as the Gulf of California.

Order Mugiliformes

Family Sphyraenidae

29. *Sphyraena idiastes* Heller and Snodgrass. Picuda, Aguja; Barracuda.

Thirty six small specimens from 46.6 to 128.5 mm S. L. were obtained by seining at Lobos de Afuera Islands, and a large individual of 600 mm was purchased from a fisherman there. Known from Peru and Galapagos Islands.

Family Mugilidae

30. *Mugil cephalus* Linnaeus. Lisa; Mullet.

A large number (406) of specimens was secured by seining, dipnetting under a light, and by treating tide pools with rotenone. It was found all along the Peruvian coast, from Cabo Blanco in the north to Bahia Independencia, the southernmost point reached by the expedition. A fine series of 118 individuals was taken in the lower reaches of the Pisco River.

Hildebrand (1946) recognized *M. rammelsbergi* Tschudi as distinct from *M. cephalus* Linnaeus on the basis of Tschudi's statement, "Die Zahne sind sehr zahlreich, aber fein," and he went on to remark that "The teeth, although fine in *M. cephalus,* can scarcely be defined as 'very numerous'."

Peruvian specimens of these two species from the collection of the U. S. National Museum as well as a paratype (USNM 77586) of *M. peruanus* Hildebrand have been examined. This last specimen seems to be indistinguishable from individuals of similar size labelled *M. rammelsbergi*. The only clear difference that appears between specimens labelled *M. rammelsbergi* and those marked *M. cephalus* is in the matter of dentition. In the USNM specimens of *M. rammelsbergi,* the teeth are arranged in a broad band, nearly or completely covering the whole width of both upper and lower jaws. In *M. cephalus,* by contrast, the teeth of the upper jaw are in a narrow band, composed of two or three rows at the symphysis and narrowing to one or two rows at the angle of the mouth; in the lower jaw there are no teeth at all except in one specimen which has a single short row of about five teeth on each side near the angle. Also, in *M. cephalus* the surface of the lower jaw is flat, or nearly so, while in *M. rammelsbergi* it is rounded.

The specimens collected by the Yale South American Expedition present something of a problem. Not only are typical *cephalus* and *rammelsbergi* forms found but also every conceivable degree of intergradation between the two, as shown in Fig. 6. Fig. 6A shows the typical *cephalus* dentition, with a single row of teeth on the upper

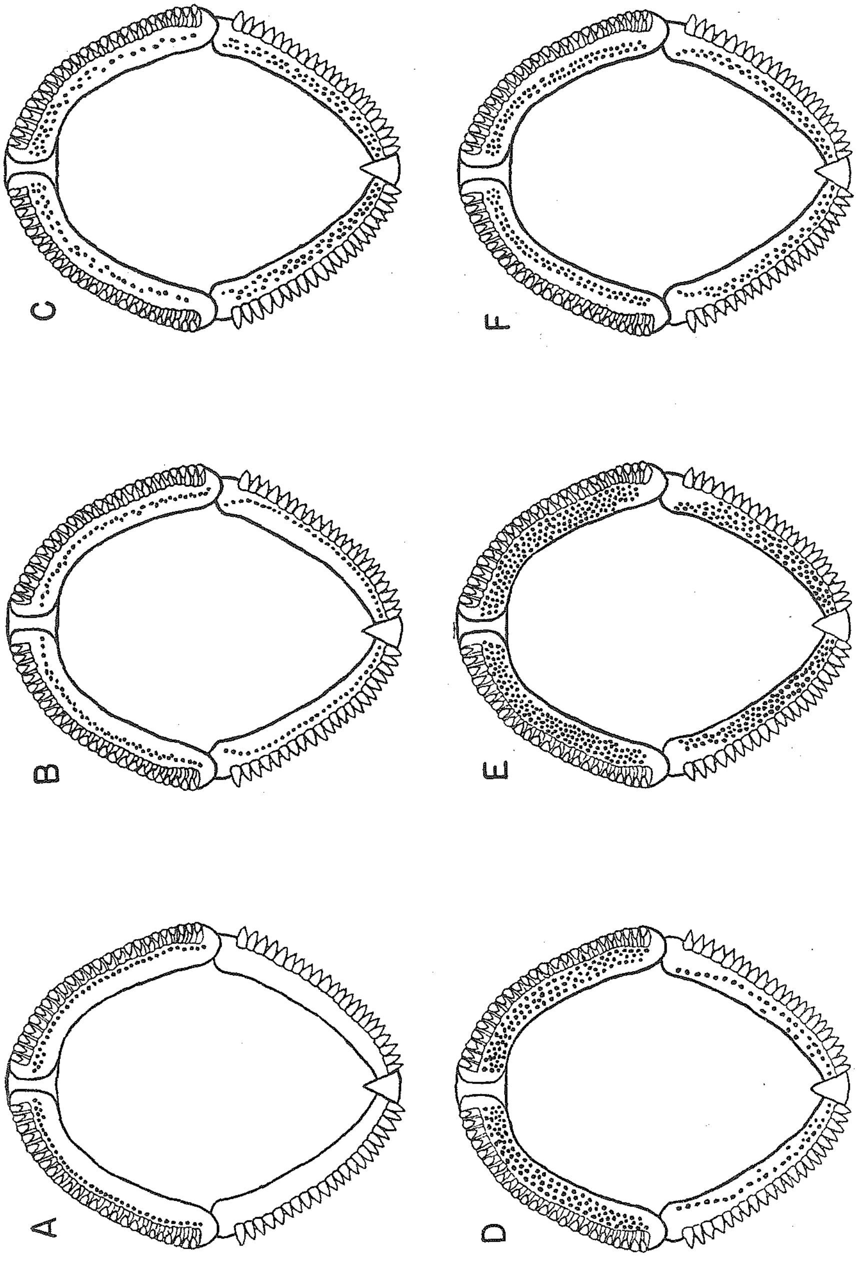

Fig. 6. Dental conditions in *Mugil cephalus* Linnaeus. *A* and *B*, conditions found in *M. cephalus*. *C* and *D*, variants toward the *rammelsbergi* type. *E*, *rammelsbergi* type of dentition. *F*, variant from the *rammelsbergi* type. See text for discussion. Drawn by Louis L. Mowbray II.

jaw and none on the lower. Fig. 6B is also a *cephalus* condition, but with either a partial or complete row of teeth on the lower jaw. Fig. 6C and 6D are variants towards the *rammelsbergi* condition; C has a narrow band of teeth on the upper jaw, as in *cephalus,* with a moderate or even wide band of teeth in the lower jaw, as in *rammelsbergi;* in D, these conditions are reversed. Fig. 6E shows the typical *rammelsbergi* dentition with a wide band of teeth in each jaw, while 6F is a variant therefrom, the toothed bands being wider than those typical of *cephalus* but not as wide as those of *rammelsbergi.* The distribution of these various dental conditions is shown in the following table:

	cephalus				*rammelsbergi*		
Dental type	A	B	C	D	E	F	Other
Percentage of specimens	51.9	23.5	8.2	8.8	5.1	1.7	0.8

It is seen that the types illustrated include more than 99% of the 377 specimens examined (29 very small juveniles not included). Two of the three individuals included as "Other" had a broad band of teeth in the upper jaw and none in the lower; the third was abnormal with no jaws at all.

From examination of the completely intergrading dental conditions and from inspection of the table above, it is apparent that type E, the condition characteristic of *M. rammelsbergi,* represents merely one of the more extreme conditions of individual variation, occurring in the present sample with a frequency of about 1 in 20. It is not possible to distinguish with certainty between type A and type E on the basis of any characteristic other than teeth. The relative width of the mouth, a characteristic used by Hildebrand to separate the two species, is not at all constant in the Yale sample. Since the dentition shows so great and perfect a degree of intergradation, it is felt that *M. rammelsbergi* Tschudi is not a valid species and must be returned to the synonymy of *Mugil cephalus* Linnaeus. However, if further studies of the mullets should show that the relative numbers of *cephalus*-type and *rammelsbergi*-type forms remain more or less constant, then we ought not to rule out the possibility of genetic control.

31. *Mugil curema* Valenciennes. Lisa; Mullet.

Like the previous species, this mullet was taken frequently, 209 individuals being collected under a light or with a seine at Cabo Blanco, Talara, and Lobos de Afuera Islands. Known from Gulf of California to Chile.

32. *Chaenomugil proboscideus* (Günther). Mullet.

One specimen, 68.5 mm S. L., was taken at Lobos de Afuera Islands (Fig. 7). Previously known from the Pacific Coast of Central America, Mexico to Colombia, and from Galapagos Islands, this is the first record of this species from Peru.

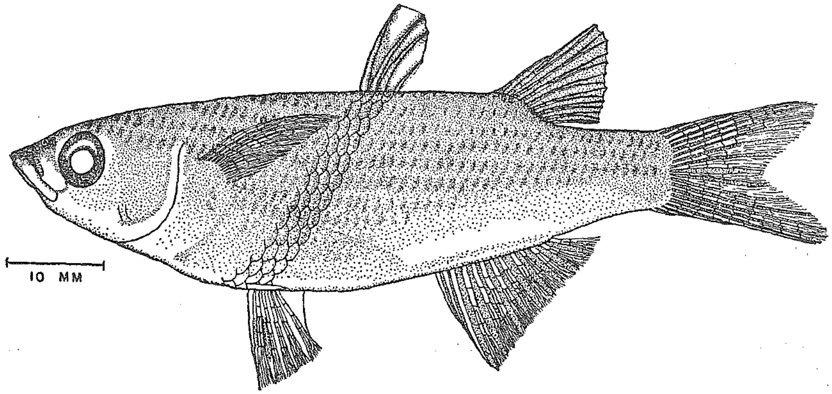

Fig. 7. *Chaenomugil proboscideus* (Günther). From a specimen taken at Lobos de Afuera Islands.

Body compressed; dorsal profile nearly straight, ventral profile rather strongly convex. Depth 3.18 in S. L. (31.4%). Head somewhat compressed, 3.56 in S. L. (28.1%). Snout pointed, longer than eye, 3.14 (31.8%). Eye without adipose lid, 3.86 (25.9%). Interorbital broad, convex, scaly, 2.21 in head (45.2%). Mouth oblique, narrow, longer than broad. Upper jaw projecting, upper lip thick, premaxillaries protractile. Maxillary almost reaching eye. Gill rakers moderately long, slender, 24 on lower limb of first arch. Teeth small, in bands on outer portions of both jaws. Scales 43, large, edges finely serrate; dorsals, caudal and anal scaly. First dorsal (IV–I, 8) with strong spines, originating about midway between anterior margin of eye and caudal base. Entire second dorsal approximately over posterior two thirds of anal. Pectoral 1.15 in head (87%). Anal III, 10, outer margin slightly concave.

Color in formalin gray above fading through silvery on sides to white below. Most scales with a patch of brown on outer edge, forming brown bands along each row of scales. Ventrals pale except for a small patch between spine and first two rays. Dorsal spines and membrane adjacent to them dusky, the rest of dorsal membrane pale. Second dorsal, anal, caudal and pectorals dusky.

Family Atherinidae

33. *Austromenidia regia* (Humboldt and Valenciennes). Pejerrey; Silverside.

Fifty two specimens were taken with a seine at Lobos de Afuera Islands and in the surf at the mouth of the Pisco River; one more was taken under a light in Callao Harbor. Ranges along Pacific Coast of South America from vicinity of Lobos de Tierra Islands southward. Possibly it is represented by a separate species in the southern portion of the range, although Hildebrand (1946) considered the observed differences to be of not more than subspecific value. These differences may well be the result of temperature variations between the northern and southern portions of its range.

34. *Nectarges nocturnus* Myers and Wade. Silverside.

Four hundred ninety one specimens, mostly postlarvae and juveniles, were captured with a seine or under a light. They range from 12.0 mm (taken at Talara) to 75.0 mm S. L. (taken at Cabo Blanco) and were found at Cabo Blanco, Talara, several places in Paracas Bay, at the mouth of the Pisco River, and in Bahia Independencia. Ranges from Ecuador at least as far south as Bahia Independencia (14° 08′ S).

Order Polynemiformes

Family Polynemidae

35. *Polynemus approximans* Lay and Bennett. Barbudo; Threadfin.

This species was taken only at Cabo Blanco, where 134 individuals, 33.0 to 72.0 mm S. L., were seined in the surf. One of these has seven free rays in the left pectoral fin rather than the usual six. Ranges from southern California to northern Peru.

Order Perciformes

Family Serranidae

36. *Alphestes fasciatus* Hildebrand. Companero de Mero, Mero.

One specimen, 199 mm S. L., was obtained from a fisherman at Lobos de Afuera Islands. Known from this location and also from Galapagos and Cocos Islands.

A specimen in the Bingham Oceanographic Collection, labelled *Alphestes multiguttatus*, from the San Diego Rocks in the Gulf of California, appears to be identical with the Peruvian specimen in almost every respect. Following Hildebrand's comparative table, neither specimen can be placed certainly in either species, suggesting that *fasciatus* may not be a valid species.

37. *Epinephelus labriformis* (Jenyns). Murique; Grouper.

Two specimens from tide pools at Lobos de Afuera Islands are 53.2 and 45.9 mm S. L. One individual is dark brown, nearly black, with little or no evidence of pale spots. The other is a rather light brown, the pale spots scattered over the body being quite evident. Ranges from Gulf of California to northern Peru and Galapagos Islands.

38. *Cratinus agassizii* Steindachner. Pluma; Gray Threadfin Bass.

One specimen was caught on a hand-line at Cabo Blanco. It is represented in the collection by a color photograph. Recorded from northern Peru, Ecuador and Galapagos Islands.

39. *Paralabrax humeralis* (Valenciennes). Trambollo, Cabrilla Fina; Peruvian Rock Bass.

One large specimen, 284 mm S. L., purchased from a fisherman at Lobos de Afuera Islands, is tentatively assigned to this species. The specimen differs from the typical in having XI rather than X dorsal spines. However, it also has one less than the usual number of dorsal rays, suggesting that this may be merely a variation in the dorsal fin. The specimen was compared with 21 others in the U. S. National Museum. Except for the dorsal counts, there seems to be no difference.

Color of the specimen from a Kodachrome before preserving, dark above, white below, a large white spot on side below anterior portion of soft dorsal. Bright orange spots scattered on head and in a large cluster on operculum. Dorsal, anal and caudal fins dark, ventrals somewhat lighter. Pectoral orange-red, with a longitudinal black stripe above middle rays.

Known from coasts of Peru and Chile. Meek and Hildebrand (1925) and Hildebrand (1946) report this species as being known also from Panama. However, this report seems to be based upon an interpretation of Steindachner's (1876) specimens of *P. albomaculatus* from Panama as *P. humeralis*. Examination of Steindachner's figure of *P. albomaculatus* indicates that such an interpretation is erroneous. The figure shows a fish whose pectoral fin has a convex margin and 16 rays. In *P. humeralis*, the margin of the pectoral is straight or slightly concave, and there are normally 18 rays.

40. *Paralabrax callaensis* Starks. Cabrilla; Southern Rock Bass.

A specimen 250 mm S. L. was secured with the specimen of *P. humeralis* at Lobos de Afuera Islands. Occurs only along coast of Peru.

41. *Diplectrum conceptione* (Valenciennes). Camotillo, Camote.

A single individual, 79.8 mm S. L., was taken in a small wire trap in Talara Harbor. This is the only specimen that was caught in these traps, although three were fished nightly for a period of nearly two weeks at Talara and Cabo Blanco. Ranges from Chile to northern Peru.

42. *Paranthias furcifer* (Cuvier). Cabinsa; Creole Fish.

A specimen 247 mm S. L. was obtained from a fisherman at Lobos de Afuera Islands. Ranges from Gulf of California to northern Peru and Galapagos Islands; also Cuba to Brazil in the Atlantic. The Peruvian specimen was compared with two in the Bingham Oceanographic Collection from Agua Verde Bay, Lower California. All three specimens are of the same species.

Hildebrand (1946) tentatively recognized three species of *Paranthias* from the east and west coasts of the Americas and from the Galapagos Islands. The three specimens discussed here agree best with *P. pinguis* as redefined by Hildebrand. However, there are a sufficient number of discrepancies between our specimens and the descriptions given by Hildebrand so that for the present it seems best to record these specimens as *P. furcifer*. It is evident that further examination of the genus is needed.

Family Carangidae

43. *Decapterus afuerae* Hildebrand. Jurel Fino; Mackerel Scad.

Three specimens, 71.3 to 72.7 mm S. L., were seined at Lobos de Afuera Islands. Definitely known only from the type material and the present specimens, all from the same location. Hildebrand (1946) gave the range of this species as "Northern Peru and probably to Baja California."

44. *Trachurops crumenophthalmus* (Bloch). Big-eyed Scad.

Two specimens, 134.3 and 153.7 mm long, were taken by dip-netting under a light while at anchor at Cabo Blanco. Although this species is widely known from nearly all warm seas and has been recorded from La Plata Island, Ecuador by Seale (1940), it does not appear to have been found in Peruvian waters until now (Fig. 8).

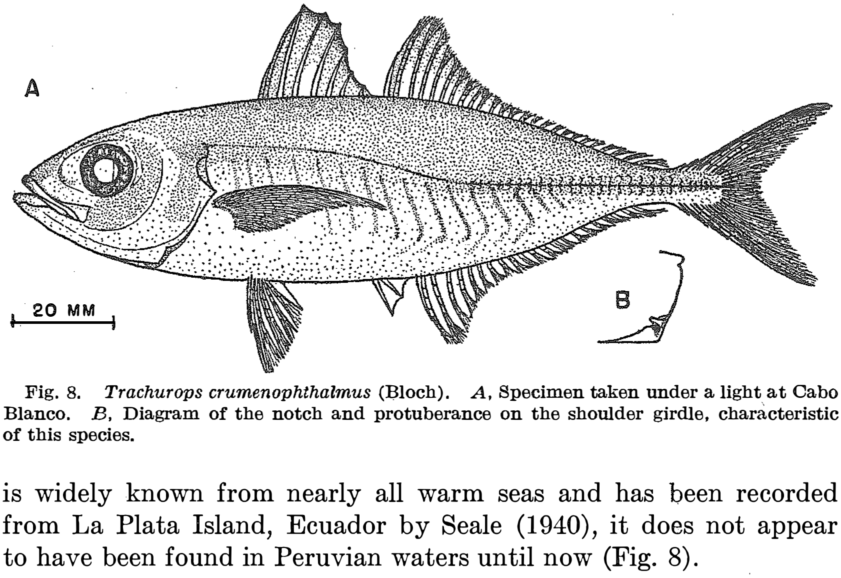

Fig. 8. *Trachurops crumenophthalmus* (Bloch). *A*, Specimen taken under a light at Cabo Blanco. *B*, Diagram of the notch and protuberance on the shoulder girdle, characteristic of this species.

Body compressed, rather slender, dorsal and ventral profiles evenly rounded. Depth 6.0–6.7 in S. L. (14.9–16.6%). Head 5.5–6.3 in S. L. (15.8–18.2%). Snout moderate, 3.6–4.2 in head (23.8–27.7%). Eye large, 3.6–3.7 (27.0–27.7%), with prominent adipose lids. Interorbital 4.3–4.6 (21.7–23.2%). Mouth moderate, oblique, maxillary reaching under anterior third of eye. Gill rakers slender, 9 + 27–28 on first arch. Teeth fine, in a narrow band in upper jaw; a single row of larger canine-like teeth in lower jaw. Lateral line with a long low arch beginning under second dorsal, ascending in a smooth curve to level of eye. Chord of curved part more or less equal to straight part of lateral line. Scutes 25–29, rather small.

Anterior portion of second dorsal and anal elevated, more or less falcate. D. VIII–I, 23 to 25; A. II–I, 21 or 22. Pectorals falcate, reaching about to origin of second dorsal. Ventrals small, barely reaching vent.

Shoulder girdle with a prominent notch and protuberance located under lower corner of gill cover (Fig. 8B). This character alone will distinguish this species from all other members of the family.

Color in formalin silvery brown above fading into yellowish-white below. Yellowish blotches behind and below eye and around corner of mouth. A yellowish line along base of anal. Ventrals and anal pale, all other fins dusky. Pectoral axil black. Brown lines along myotomes on lower part of sides.

45. *Caranx hippos* (Linnaeus). Cocinero, Chumbo; Jack Crevally, Horse-eyed Jack.

One specimen taken on hook and line at Cabo Blanco was prepared for exhibition. Known from both coasts of tropical America, probably ranging world-wide in warm seas.

46. *Caranx caballus* Günther. Cocinero, Jurel; Green Jack.

One specimen from Cabo Blanco was prepared for exhibition. Known from southern California to Peru.

47. *Trachinotus rhodopus* Gill. Pampano Fino; Pompano.

The expedition took six specimens, 31.2 to 46.6 mm S. L., at Cabo Blanco. Ranges from Gulf of California to northern Peru and Galapagos Islands. It appears to have been recorded only once before from Peru, by Hildebrand (1946). It is much less common than the following species, which it resembles rather closely.

48. *Trachinotus paitensis* Cuvier. Pampano; Pompano.

Sixty five specimens, ranging between 25.5 and 95.5 mm S. L., were taken in such diverse localities as Cabo Blanco, Talara, Lobos de Afuera Islands, Paracas, and Bahia Independencia. Ranges from west coast of Mexico to Peru, possibly as far south as Valparaiso, Chile.

49. *Chloroscombrus orqueta* Jordan and Gilbert. Bumper.

All specimens in the collection (184) were taken in Talara Harbor with light and dip-net. They range in size from 36.4 to 73.0 mm. Known from Gulf of California at least as far south as Chilca, Peru.

50. *Oligoplites refulgens* Jordan and Starks. Leatherjacket.

Dip-netting under a light yielded 30 specimens at Cabo Blanco, 21.2 to 63.0 mm long, and one of 69.5 mm at Talara. Known from Panama to Ecuador, but not previously recorded from Peru (Fig. 9).

Body much compressed, slender, elongate. Depth 4.1–4.8 in S. L. (20.8–24.4%). Head without pores, 3.9–4.4 in S. L. (22.7–25.6%). Snout moderate, 3.2–3.8 in head (25.3–31.2%). Eye 4.0–4.3 (23.2–25.0%). Mouth oblique, maxillary not reaching past middle of eye, usually under anterior third of eye, 2.2–2.6 in head (38.4–45.4%). Gill rakers 5–7 + 18–21, including rudiments, on first arch. Teeth small, present on jaws, vomer, palatines, and tongue, those in upper jaw in a broad band, those in lower jaw in a narrow band with an outer row of close-set, compressed, incisor-like teeth. Dorsal IV or V–I, 19 to 21; spines of first dorsal connected by a membrane at base. Anal II–I, 19 to 21. Soft dorsal and anal only slightly elevated anteriorly. Ventrals short, not reaching vent. Pectorals short. Caudal deeply forked.

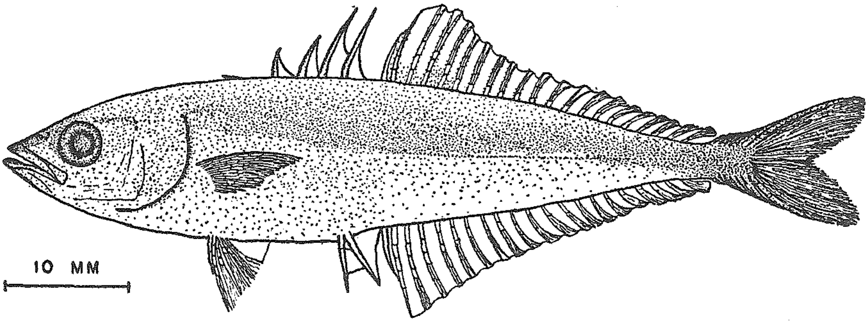

Fig. 9. *Oligoplites refulgens* Jordan and Starks. Specimen 69.5 mm T. L., taken in the harbor at Talara, Peru.

Color in formalin dark olive above, yellow to white on sides and belly. Caudal dusky, other fins pale.

This species differs from *O. mundus* (reported from Callao by Tortonese, 1939) notably in having a much smaller mouth and a slimmer body. In *O. mundus*, the maxillary extends backward well behind the posterior margin of the eye, and the body is much deeper, the depth being contained only 2.7 to 3.1 times in the standard length.

51. *Vomer declivifrons* Meek and Hildebrand. Reloj; Lookdown.

A single large specimen, 357 mm long to the base of the caudal, was caught off Talara. Known from Baja California to Peru.

Family Nematistiidae

52. *Nematistius pectoralis* Gill. Peje-chino; Roosterfish.

Several specimens were caught on rod and line in the surf near Cabo Blanco. One was prepared for exhibition while photographs of others are in the collection. Known from southern California to Peru.

Family Coryphaenidae

53. *Coryphaena hippurus* Linnaeus. Dorado; Dolphin, Dorado.

Two juveniles, 36.8 and 40.0 mm S. L., are in the collection. The larger was taken in the harbor at Talara, the smaller at St. 39 (04° 28′ S, 82° 24′ W). A number of adults were caught on hook and line, one of which was prepared for exhibition. World-wide distribution in warm seas.

Family Lutjanidae

54. *Lutjanus guttatus* (Steindachner). Spotted Rose Snapper.

The Caleta de Manoa at Lobos de Afuera Islands was the source of nine specimens, 36.7 to 56.8 mm S. L., taken in a seine. Not previously known from Peru, the species ranges from Guaymas, Mexico, to Ecuador and Peru.

Body compressed, back elevated. Depth 2.7 to 2.9 in S. L. (34.5–37.0%). Caudal peduncle moderate, compressed, its depth 3.3 to 3.8 in head (26.3–31.8%). Head compressed, 2.3 to 2.6 in S. L. (38.5–43.5%). Profile before dorsal nearly straight. Snout pointed, 2.9 to 3.4 (29.4–34.5%). Eye 3.2 to 3.6 (27.8–31.3%). Interorbital narrow, 4.4 to 5.8 in head (17.3–22.7%). Mouth slightly oblique, terminal. Maxillary reaching pupil, 2.4 to 2.5 in head (40.0–41.7%). Gill rakers 5–7 + 14–15, including rudiments. Teeth fine, in bands on jaws; four enlarged canines anteriorly in upper jaw, other smaller ones laterally. Vomerine teeth in an anchor-shaped patch with a distinct backward extension. Teeth in bands on palatines and tongue. Preoperculum serrate, serrae slightly enlarged at the angle. Scales ctenoid, 7 rows between lateral line and origin of dorsal, 45–52 series above lateral line; scale rows above lateral line oblique (Fig. 10). Dorsal X, 12. Anal III, 8.

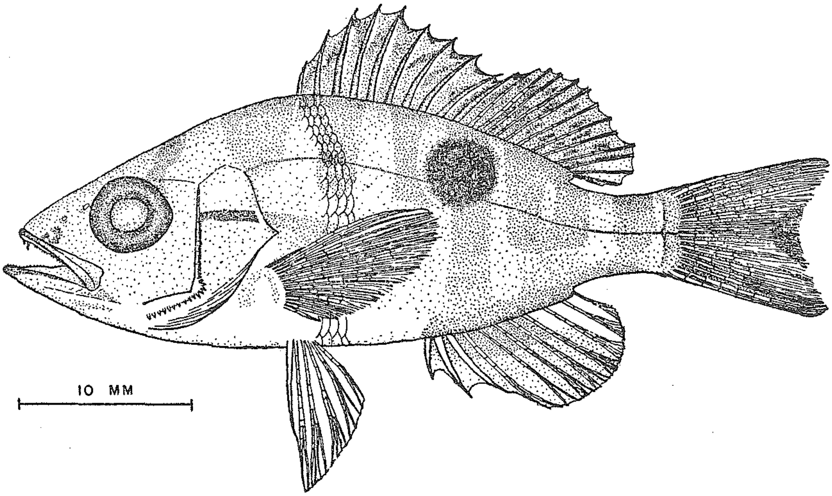

Fig. 10. *Lutjanus guttatus* **(Steindachner). From a specimen 38 mm S. L. from Lobos de Afuera Islands.**

Color in formalin, grayish above, pale beneath. Six or seven gray bars above lateral line, a large dark spot on and above lateral line below first rays of soft dorsal. A dark spot or streak crossing operculum behind eye. Dorsal and caudal dusky, other fins pale.

55. *Lutjanus argentiventris* (Peters). Yellow-tail Snapper, Schoolmaster.

Nine small specimens, 25.2 to 46.5 mm S. L., from Lobos de Afuera Islands. Known from Baja California to northern Peru.

Family Leiognathidae

56. *Eucinostomus californiensis* (Gill).

Twenty nine individuals, 28.6 to 59.9 mm S. L., were taken with a seine at Lobos de Afuera Islands. Previously known from California to Ecuador and Galapagos Islands. It is not certain whether or not the *Gerres dovii* stated by Steindachner (1876) to occur as far south as Callao was identical with the present species. Three lots of *E. californiensis* in the U. S. National Museum contain notes "*Eucinostomus argenteus* 1/12/49 S. F. H." It is apparent that the group stands in need of careful revision.

The following description is based on ten specimens, 41 to 58 mm S. L. See also Fig. 11.

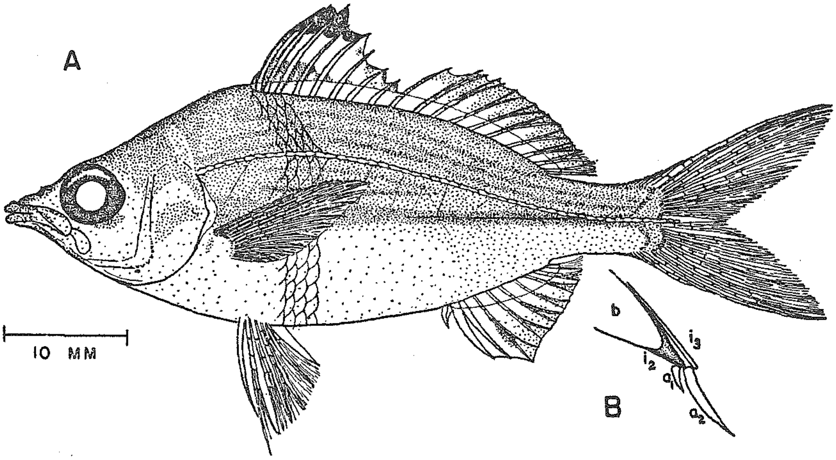

Fig. 11. *Eucinostomus californiensis* (Gill). *A*, specimen 53 mm S. L. from Lobos de Afuera Islands. *B*, air bladder (*b*), interhaemal spines (i_2, i_3), and anal spines (a_1, a_2).

Body compressed, anterior profile nearly straight, back elevated. Depth 2.8–3.0 in S. L. (33.3–35.7%). Head 3.0–3.3 in S. L. (30.3–33.3%). Snout 3.3–3.8 (26.3–30.3%). Eye 2.9–3.2 in head (31.3–34.5%). Mouth small, maxillary reaching front of eye. Premaxillaries notably protractile, premaxillary groove open, linear. Opercle and preopercle entire. Gill rakers short, 5–6 + 8 on first arch. Dorsal IX, 10, spines not strong, elevated in front, dorsal rays about as long as longest spines. Anal III, 7, second spine much stronger than third and about as long. A prominent sheath along bases of dorsal and anal. Second interhaemal spine enlarged into a hollow cone which receives posterior end of air bladder (Fig. 11B). Pectorals short. Ventrals short, not quite reaching vent.

Color in formalin, silvery gray above with suggestions of darker on each horizontal scale row; pale below. Tip of snout dark. A longitudinal gray streak along middle of side. Membrane between second to sixth dorsal spines black at the tip. Pectorals and ventrals pale, other fins slightly dusky.

57. *Eucinostomus elongatus* Meek and Hildebrand.

Six individuals, 44.5 to 67.5 mm S. L., were seined at Lobos de Afuera Islands. Known from Panama, possibly also from Galapagos Islands, and now reported from Peru.

Similar in appearance to *E. californiensis*, to which it is most closely related, but differing from that species as follows: Body not especially compressed, its depth 3.4–3.8 in S. L. (26.3–29.4%). Eye somewhat smaller, 3.3–4.0 in head (25.0–30.3%). Dorsal spines weak, second anal spine scarcely, if at all, stronger than the third.

58. *Gerres cinereus* (Walbaum). Chavela; Mojarra.

One tiny juvenile, only 16.5 mm S. L., was taken with a light and dip-net at Talara. Found on the Pacific Coast of the Americas from Baja California to Peru.

Family Pomadasyidae

59. *Anisotremus scapularis* (Tschudi). Chita, Sargo; Sargo.

Sixty five specimens between 31.5 and 61.2 mm in standard length were taken at Lobos de Afuera Islands and at two places in Paracas Bay. Known from the coast of Peru and also recorded from the Galapagos and Cocos Islands.

60. *Xenichthys rupestris* Hildebrand.

Two specimens, 46.7 and 48.5 mm S. L., and four larger ones, 82.8 to 92.8 mm S. L., were taken around Lobos de Afuera Islands. Hildebrand (1946) gave as a character of the genus "margin of preopercle entire." However, the Yale specimens have the preopercular margin serrate, and Gill's (1864) original description of the genus states: "Preoperculum pectinated behind, the teeth higher up progressively directed upwards." Previously it was known only from the type material and a few specimens recorded by Bini and Tortonese (1955) from Chimbote, Mâncora and Punta Sal.

Family Sciaenidae

61. *Menticirrhus cokeri* Evermann and Radcliffe. Muchachita (?); Kingfish.

Three specimens, 21.3, 25.7 and 60.5 mm S. L., were taken at Bahia Independencia and Bahia Paracas. Known only from Peru. This species may be identical with *M. ophicephalus* (Jenyns) from Chile, there being nothing in Jenyns' (1842) description to separate them. However, until comparative material becomes available, it seems better to let the present specimens stand as *M. cokeri*.

62. *Menticirrhus rostratus* Hildebrand. Muchachita (?); Kingfish.

A single specimen, 70.4 mm S. L., was seined at Paracas. This species was formerly known only from the type material, taken at Paita. The present specimen thus extends the known distribution of the species by more than 600 miles to the southward.

63. *Cynoscion stolzmanni* (Steindachner). Corbina; Weakfish.

One specimen caught at Cabo Blanco was prepared for exhibition. Known from Panama to Peru.

64. *Sciaena fasciata* (Tschudi). Burrito; Croaker.

A total of 298 specimens, all small juveniles between 10.8 and 41.0 mm long, were seined at Bahia Independencia and at several locations in Bahia Paracas. Inhabits the coasts of Peru and Chile.

65. *Stellifer minor* (Tschudi). Mojarilla; Drum, Croaker.

Beach seining at Paracas yielded 807 juveniles between 9.3 and 26.0 mm S. L. Known from Peru and Chile.

Family Sparidae

66. *Calamus brachysomus* (Lockington). Marotilla; Porgy.

Three individuals were seined at Lobos de Afuera Islands, 40.0 to 60.2 mm S. L. Gulf of California to Peru; reported from the latter locality only once before, by Hildebrand (1946). Apparently this species is not numerous on the coast of Peru, although known to occur at least as far south as Bahia Independencia.

Family Mullidae

67. *Pseudupeneus grandisquamis* (Gill). Goatfish, Surmullet.

Eleven specimens, 49.5 to 70.9 mm long, were taken in a seine at Lobos de Afuera Islands. Previously known from Gulf of California to Panama, and from Chilca and Chimbote in Peru.

Family Kyphosidae

68. *Doydixodon laevifrons* (Tschudi). Babunco; Rudderfish.

Four specimens, 56.2 to 66.8 mm S. L., and another 119 mm, were taken from tide pools at Lobos de Afuera Islands. Apparently known only from Peru, between Lobos de Afueras to the north and Mollendo to the south.

Family Chaetodontidae

69. *Chaetodon humeralis* (Günther). Butterflyfish.

A single individual 24.4 mm S. L. was seined at Lobos de Afuera Islands. Recorded only once before from Peru; known to occur from northern Peru to Gulf of California and Galapagos Islands.

Family Pomacentridae

70. *Chromis atrilobatus* Gill. Demoiselle, Reef-fish.

A single small specimen, 24.8 mm S. L., was taken with light and dip-net at Cabo Blanco. Known from Baja California to Peru, the earlier Peruvian records consisting of one specimen from Cabo Blanco and three from Lobos de Afueras (Hildebrand, 1946).

71. *Chromis crusma* (Valenciennes). Chavelita; Demoiselle.

Two specimens, 19 mm S. L., were taken under a light at Cabo Blanco. Ranges along coasts of Peru and Chile.

72. *Pomacentrus rectifraenum* Gill. Demoiselle.

The collection includes 53 specimens taken in tide pools at Lobos de Afuera Islands, their standard lengths ranging between 28 and 100 mm. Reported only once before from Peru, the species is known from Mexico to northern Peru. In life, the young exhibit a brilliant blue which darkens with increasing size to nearly black. The preserved specimens are all dark brown, the smaller ones generally darker than the larger.

73. *Abudefduf saxatilis* (Linnaeus). Sergeant Major.

This species was found only at Lobos de Afuera Islands, where 78 specimens were taken in tide pools and one in a seine. They vary in size between 35.5 and 70.3 mm S. L. Known from Cape Cod to Uruguay in the Atlantic, throughout the warmer parts of the Pacific Ocean, and from Baja California to Peru on the west coast of the Americas.

74. *Abudefduf analogus* (Gill). Sergeant Major.

Eighteen specimens from Lobos de Afuera Islands and Cabo Blanco. Known from the Caribbean, the Atlantic and Pacific coasts of Panama, and Galapagos Islands; now reported from Peru. Although this species and *A. saxatilis* resemble each other most closely, they may easily be distinguished by means of the following table:

A. analogus	*A. saxatilis*
Four scales between lateral line and origin of spiny dorsal.	Four and one half scales between lateral line and origin of spiny dorsal.
Dark bands on sides usually wider than light interspaces.	Dark bands on sides usually narrower than light interspaces.
Tips of vertical fins rounded.	Tips of vertical fins more or less acute.
Gill rakers 11 to 13.	Gill rakers 17 to 19.

75. *Nexilosus latifrons* (Tschudi). Castañeta; Demoiselle.

One specimen, 77.5 mm long, was obtained from a fisherman at Lobos de Afuera Islands. Known from Peru, northern Chile, and Galapagos Islands.

Family Labridae

76. *Bodianus eclancheri* (Valenciennes). Negra, Vieja Negra; Wrasse.

A specimen 224 mm S. L. was the gift of a fisherman at Lobos de Afuera Islands. Known from northern Peru and Galapagos Islands.

77. *Halichoeres dispilus* (Günther). Doncella, San Pedrano; Wrasse.

Twenty specimens of this pretty little fish were taken in a seine at Lobos de Afuera Islands. They range in size from 29.9 to 110.9 mm S. L. Known from Gulf of California to Peru and Galapagos Islands.

Family Uranoscopidae

78. *Astroscopus zephyreus* Gilbert and Starks. Star-gazer.

One specimen 28.0 mm long to base of caudal was taken with light and dip-net at Cabo Blanco. Known from Gulf of California and reported once before from northern Peru by Hildebrand (1946).

Family Blenniidae

79. *Ophioblennius mazorkae* Hildebrand. Blenny.

This species is represented in the Yale collection by a single specimen, 30.0 mm long to the base of the caudal, which was seined at Lobos de Afuera Islands. Previously known only from the type material from Mazorka Island, the present record extends the known range of the species by about 350 miles to the north.

80. *Rupiscartes atlanticus* (Valenciennes). Blenny.

Of this species the expedition secured nine individuals 61.9 to 123.0 mm long in tide pools at Lobos de Afuera Islands. Its previously recorded range on the Pacific coast of America extended from Mexico to Ecuador and Galapagos Islands; the range now includes Peru.

Body deep, compressed. Depth 3.5–4.00 in S. L. (25.0–28.5%). Head short, 4.3–4.8 (20.8–23.2%), anterior profile vertical. Snout short. Eye 3.6–4.3 in head (23.2–27.7%). Mouth inferior, horizontal, maxillary reaching middle to posterior margin of eye, 2.2–2.9 in head (34.5–45.4%). Gill membranes connected, free from isthmus. Teeth on margin of jaws small, close-set, movable, compressed. Lower jaw with two large canines placed well back. Lateral line high anteriorly, only slightly arched, interrupted under anterior rays of soft dorsal, reappearing lower down and in front of point of interruption. Anterior nostril with a fringed tentacle, upper margin of eyeball with a simple one, a fringe of nuchal tentacles on each side of nape. Sides of head with numerous scattered pores. No scales. Dorsal XII, 21; long, continuous, not indented, its origin over posterior margin of preopercle. Anal 23 or 24; similar to soft dorsal. Pectorals large, about equal to head. Ventrals small (Fig. 12). Caudal rounded to truncate.

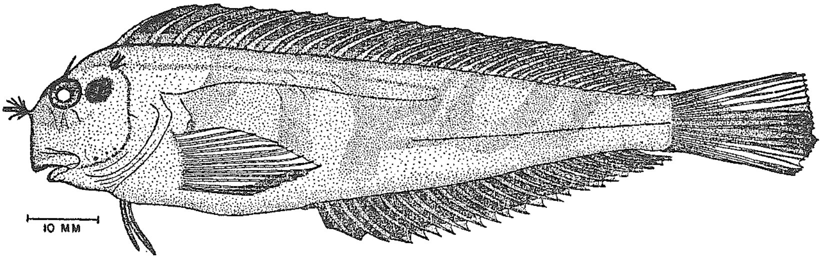

Fig. 12. *Rupiscartes atlanticus* (Valenciennes). Specimen 91 mm S. L., taken in a tide pool at Lobos de Afuera Islands.

Color in formalin nearly uniform brown, somewhat paler below. A prominent dark spot immediately behind eye and about as large as eye. Five or six dark cross-bars sometimes present on back; sometimes none or only one or two visible. Anal black, other fins dark or dusky. Upper and lower rays of caudal lighter; lower six rays of pectoral black.

81. *Scartichthys gigas* (Steindachner). Borracho; Blenny.

Fifty five specimens, 45.7 to 121.8 mm long, were taken from tide pools at Lobos de Afuera Islands and from seine hauls at Bahia Independencia and Sequion Bay. Known from Panama to Chile. A closely related form, *S. eques* (Steindachner), differs chiefly in color, being pale yellowish with a prominent dark longitudinal stripe. However, several of the Yale specimens are also more or less yellowish with either a dark stripe or a series of dark rectangular blotches. Although none of the *S. gigas* taken are as light as a specimen of *S. eques* with which they were compared, similarities are great enough to suggest that specific separation may not be warranted.

82. *Hypsoblennius piersoni* Gilbert and Starks. Blenny.

A single small specimen, 26.0 mm S. L., taken at Cabo Blanco, agrees closely with published descriptions and with specimens in the U. S. National Museum. Previously known only from Panama, this is a new record for the species.

The Yale specimen was at first identified as *H. minutus* Meek and Hildebrand. However, it was found that the type of this species in the U. S. National Museum bears the note "Identified as postlarva of *Hypsoblennius piersoni*. Carl L. Hubbs, III: 19: 1946." Comparison of the Yale specimen and the type of *H. minutus* with specimens of *H. piersoni* of similar size leads to the same conclusion.

Since the specimen is so young that it does not yet exhibit all adult characters, the following description is modified from Gilbert and Starks (1904).

Form elongate. Depth 5 (20%). Head 4 (25%). Snout very bluntly rounded. Mouth subinferior, small, transverse, reaching vertical through pupil. A slender nasal tentacle present. Orbital tentacle as long as eye; above basal stalk it is finely dissected, forming five or six slender filaments, some branched. Gill-opening extending to lower edge of pectoral base; gill membranes joined to isthmus. No posterior canines. Lateral line conspicuously developed in anterior portion only, ending under tenth or eleventh dorsal ray. Dorsal IX, 25; spines slender, increasing regularly posteriorly; no notch between spinous and soft dorsals. Anal II, 24. Pectoral 16. Ventral I, 3.

Color light olivaceous, with about six black blotches above and similar smaller blotches below each larger blotch; anterior blotches separated by a light streak corresponding in position to lateral line. Lower part of sides with a series of dark spots arranged in seven pairs, the anterior pairs developed as short vertical streaks. Few scattered smaller spots on head and sides of body. Narrow V-shaped bar on occiput, a broad bar downward from eye to angle of mouth, and a faint V-shaped mark on gular region. Dorsal translucent with irregular dusky markings and a black blotch at the front. A conspicuous black point at base of each anal ray. Anal translucent, with a dusky streak along base of its distal third. Pectorals and ventrals translucent with some dusky markings.

83. *Hypsoblennius robustus* Hildebrand.

One postlarva, 12.5 mm long, was taken in Talara Harbor and probably belongs to this specis. It has been compared with specimens in the U. S. National Museum, and while there are some differences, the Yale specimen is so much smaller that the observed discrepancies may be laid to size. Known from Talara, Chimbote, Callao and Bahia Independencia, Peru.

84. *Homesthes caulopus* Gilbert.

Another postlarval blenny from Talara seems to be identical with *H. lignus* Meek and Hildebrand. The U. S. National Museum specimens of *H. lignus*, with which the Yale material was compared, carry a note "Identified as *Homesthes caulopus* Gilbert by Carl L. Hubbs, III: 1946." Previously known only from Panama, it is now recorded from Peru. The following description of the adult is modified from Gilbert and Starks (1904).

Body robust, moderately compressed. Depth 4.0–4.6 (21.7–25.0%). Caudal peduncle's least depth 3 in head (3.33%). Head wide and heavy, 3.6–4.2 (23.8–27.7%). Snout short, about 4 (25%), bluntly rounded, anterior profile nearly vertical. Eye 4.0–4.2 (23.8–25.0%). Interorbital space deeply grooved, without median ridge, opening posteriorly into a deep transverse groove separating orbital region from occiput. Mouth wide, horizontal, maxillary reaching beyond center of eye, 3.0–3.2 in head (31.2–33.3%). Gill slit not reaching below pectoral base. Teeth more or less incisor-like; no enlarged posterior canines. A conspicuous fringed tentacle on anterior nostril, a similar but larger one on eye. Dorsal XII, 15 or 16; originating over preopercular margin; spinous dorsal low, nearly uniform in height; spines strong basally, with weak reflexed tips; soft dorsal much higher, membrane of last ray joined to base of rudimentary caudal rays. Anal II, 17, low, a short interval between its last ray and caudal. Pectoral 14. Ventral I, 4.

Lateral line strongly developed anteriorly, curving abruptly downward under posterior third of spinous dorsal, becoming only faintly visible and continuing to base of caudal. Anterior portion giving off numerous pairs of short transverse lines, each ending in a pore.

Color blackish, the sides with irregular light blotches, some subcircular in outline and containing black specks. Light markings near back, elongate and vertically placed, outlining dark bars of ground color. Lower parts lighter. A black spot behind eye; no distinct bars on head; tentacles whitish. Fins all blackish. Anal, ventrals, lower caudal and pectoral rays black; anal and caudal margined with white; some dorsal rays narrowly tipped with white.

Family Clinidae

85. *Labrisomus philippi* (Steindachner). Trambollo.

Four specimens, 38.5 to 76.5 mm long, were taken, the smallest being seined at Lobos de Afuera Islands, the others at Bahia Independencia and Paracas. Known from the coast of Peru, where it appears to be quite common, and once reported in 1901 from Coquimbo, Chile, by Delfin (cited by Hildebrand, 1946).

86. *Malacoctenus afuerae* (Hildebrand). Trambollo.

Six juveniles, 17.6 to 18.2 mm S. L., were taken with a seine in Sequion Bay, Bahia Paracas. Formerly known only from the type material from Lobos de Afuera Islands, the present record extends the range of the species by more than 500 miles to the southward.

Although this species was originally described as a member of the genus *Labrisomus*, the presence of only a single row of teeth in each jaw clearly places it in *Malacoctenus*.

Family Scombridae

87. *Pneumatophorus peruanus* Jordan and Hubbs. Caballa; Chub Mackerel.

Two specimens, 246 and 255 mm long to the base of the caudal, were taken with a dip-net under a light about 25 miles due west of Cabo Blanco. Ranges from southern Ecuador and Galapagos Islands along coast of Peru and Chile.

Family Cybiidae

88. *Scomberomorus maculatus* (Mitchill). Sierra; Spanish Mackerel. Several specimens were caught on hook and line; most of them were used for bait but one was prepared for exhibition. Known from Maine to Brazil in the Atlantic and from southern California to Galapagos Islands and Peru in the Pacific.

89. *Sarda chilensis* (Cuvier). Bonito; Skipjack.

One large specimen, 496 mm to base of caudal, was caught on hook and line a few miles off Talara. Others were purchased for bait. Ranges along Pacific coast of Americas from Chile northward. If Hildebrand (1946) is correct in assuming *S. chilensis* and *S. lineolatus* to be conspecific, then the range extends northward to Puget Sound.

Family Istiophoridae

90. *Istiophorus greyi* Jordan and Evermann. Vela; Sailfish.

Nine individuals were taken on hook and line in the vicinity of Cabo Blanco. Known from the west coast of North and South America but reportedly not common about Cabo Blanco, their presence there possibly being associated with El Niño. Work now in progress strongly suggests that the specific name, *greyi*, is not valid. However, it seems best to let it stand for the time being until the complete synonymy can be unravelled.

91. *Makaira mitsukurii* (Jordan and Snyder). Peje-aguja; Striped Marlin.

Fourteen rather small specimens, 118 to 205 pounds in weight, were caught on hook and line by the expedition. Local fishermen at Cabo Blanco claimed that these small Striped Marlin were not common there, the usual run of fish tending to average considerably heavier. It was suggested that these smaller ones represented either young or a small race which had come with El Niño from the north. Ranges throughout Pacific and Indian oceans in warm water.

91a. *Makaira ampla mazara* (Jordan and Snyder). Pacific Blue Marlin.

One specimen, 3020 mm S. L., was examined at Máncora in January 1955 (see Addendum). Not previously recorded from Peru; known from Pacific and Indian oceans.

92. *Makaira marlina* Jordan and Hill. Marlin Negro; Black Marlin.

Three specimens, the largest weighing 792 pounds, were taken by the expedition. One came from the Cope Bank, off Punta Montanita, Ecuador, approximately 1° 50′ S, 81° 00′ W, the others from the vicinity of Cabo Blanco. Distributed throughout warmer parts of Pacific Ocean; recorded also from East Africa (Morrow, 1954).

Family Xiphiidae

93. *Xiphias gladius* Linnaeus. Pez Espada, Albacora; Swordfish.

Three specimens were seen and photographed in the water north of Cabo Blanco. World-wide distribution.

Family Gobiidae

94. *Bathygobius soporator* (Valenciennes). Peje-gato; Goby.

This species was taken by treating tide pools with rotenone and by seining at Lobos de Afuera Islands, resulting in a total of 136 specimens from 10.6 to 120.5 mm long. Hildebrand (1946) stated, "This species evidently is not abundant on the coast of Peru," but the number of specimens taken by the expedition does not bear this out. No doubt the fact that these fish tend to hide in rocks and crannies close inshore, where they are difficult to catch, accounts for Hildebrand's impression. World-wide distribution in warm water.

Family Scorpaenidae

95. *Scorpaena plumieri mystes* Jordan and Starks. Peje-diablo; Scorpionfish.

Two small individuals, 30 and 37 mm S. L., were seined at Lobos de Afuera Islands. Known from Mexico to Panama and Colombia. Ginsburg (1953) has found that *S. tierrae* Hildebrand from Peru and Chile is identical with the present species.

Order Thunniformes

Family Thunnidae

96. *Parathunnus sibi* (Schlegel). Atún; Big-eyed Tuna.

Seven specimens weighing between 280 and 368 pounds were examined at Cabo Blanco in the latter part of March. One was prepared for exhibition. All were caught while still-fishing at various depths with from 20 to 100 fathoms of line out. In this respect, it is of interest to note Brock's (1949) remarks. "*Parathunnus*, aside from the occasional capture of small individuals, is rarely taken by surface fishing techniques such as trolling or fishing with live bait. This information would imply that *Parathunnus* is not a surface fish, but that, at least during daylight, it feeds in the layers below 20 fathoms."

Although this species has become well known to anglers in Peru in recent years, its presence there does not seem to have been recorded in scientific literature. Often difficult to distinguish from the Yellowfin Tuna, the two species may be separated as follows:

P. sibi	*N. macropterus*
Edge of liver striated on ventral surface.	Edge of liver not striated.
Gill rakers 7–9 + 17–19, total number 24–28.	Gill rakers 9–10 + 20–21, total number usually 30.
Dorsal and anal finlets with a broad black border; anal finlets often orange rather than yellow.	Dorsal and anal finlets bright yellow with only a narrow black border.

97. *Neothunnus macropterus* (Schlegel). Atún, Albacora; Yellowfin Tuna.

One small specimen was caught on a hand line off Cabo Blanco. Ranges through major portion of Pacific and Indian oceans. Possibly it is identical with the Yellowfin Tuna of the Atlantic.

The application of the two colloquial names, "Albacora" and "Atún," to this fish and the Big-eyed Tuna often results in confusion, which is not lessened by the fact that the swordfish, *Xiphias gladius*, may also be called "Albacora." However, it may help to clarify the nomenclature to note that, generally speaking, in northern Peru, "Albacora" means one or the other of the tunas, (although "Atún" is more commonly used), while the swordfish is "Pez Espada." In the central and southern parts, on the other hand, "Albacora" is the swordfish, while the tunas are called "Atún" or "Tuno."

98. *Kishinoella zacalles* Jordan and Evermann.

One small specimen, 504 mm fork length, is assigned somewhat doubtfully to this species. The specimen was in rather bad condition when examined, but apparently it did not possess an air bladder, which character immediately places it in the genus *Kishinoella.* Known from Hawaii. Nichols and LaMonte (1941) considered that the tuna reported as *Germo argentivittatus* by Nichols and Murphy (1922) from waters between Lobos de Tierra and Lobos de Afuera Island might possibly belong to the present species. However, they referred both that specimen and the species *K. zacalles* to the synonymy of their *Neothunnus rarus.* The last named species differs from the present one chiefly in having only 5–6 + 15–17 gill rakers, compared with 9 + 23 observed in the Yale specimen. The specimen is represented in the collection by a plaster cast as well as two Kodachrome photographs and detailed notes.

99. *Katsuwonus pelamys* (Linnaeus). Barrilete; Oceanic Bonito, Black Skipjack.

Although a number were taken on hand-lines and others were purchased for bait, only one specimen of this well known species was preserved. Cosmopolitan in warm seas.

Order Pleuronectiformes

Family Bothidae

100. *Paralichthys adspersus* (Steindachner). Lenguado; Fluke.

Two juveniles, 15.7 and 17.4 mm S. L., were taken in a seine at the mouth of La Laguna Grande in Bahia Independencia. Known only from Peru and Chile, where it is an important food fish.

Order Tetrodontiformes

Family Tetrodontidae

101. *Sphoeroides annulatus* (Jenyns). Tamborin; Puffer, Blowfish.

Twenty four specimens, 22.9 to 52.4 mm S. L., are in the collection. All were taken with a seine at Lobos de Afuera Islands. Known from Peru, Galapagos Islands, and Panama.

102. *Sphoeroides andersonianus* Morrow. Tamborin; Puffer.

The expedition secured 222 individuals of this species by seining at Lobos de Afuera Islands. The species, apparently new to science, is described on page 8. Known only from the type material.

Order Gobiesociformes

Family Gobiesocidae

103. *Arbaciosa pyrrhocincla* (Cope). Peje-sapo; Clingfish.

Six specimens were seined at Bahia Independencia and 29 at Lobos de Afuera Islands, with a size range for both lots of 18.5 to 43.2 mm. Apparently known only from Peru.

104. *Sicyogaster marmoratus* (Jenyns). Clingfish.

One specimen from Bahia Independencia is 14.5 mm long. Not common; known from Peru and Chile.

DISCUSSION

The ichthyofauna of the Peruvian coast is, generally speaking, of a subtropical to temperate nature. Although Peru lies wholly within the southern tropical zone, its shores are washed by the cold waters of the Peru Coastal Current which exert a strong modifying influence upon the climate and especially upon the marine environment. The salinity of the inshore portion of the Peru Current is normally about 35‰ and the temperatures are much colder than would be expected from this latitude. Indeed, they may be as much as 9° C lower than those of any other marine area of the world within the same zone of latitude. On the basis of surface temperatures, then, the ichthyofauna of the Peruvian littoral would be expected to show greater similarities to faunas in regions between 20 and 40 degrees of latitude than to faunas in regions between 0 and 20 degrees, although Peru lies wholly within the latter zone.

It is of particular interest, therefore, to note that each of the species recorded as new to Peru is a tropical species, well known previously from warmer seas to the north or west. There are at least two possible explanations for this phenomenon. It may be that these species are actually indigenous to northern Peru, but that, since the area has not been thoroughly worked by ichthyologists (cf. p. 10), these tropical species have heretofore escaped observation. On the other hand, it is also possible that they are not normally present in the Peruvian fauna but invade periodically when conditions of temperature permit.

At the time the collections were made (March through May, 1953), El Niño existed. According to results of this expedition as well as generally accepted theories, El Niño is a southward diversion of warm waters of the Equatorial Counter Current. Although its appearance in the north is an annual occurrence, El Niño does not normally exert its influence much further south than the Gulf of Guayaquil. However, during "El Niño Years" the warm water may be found much further to the south, sometimes even as far as Callao or Pisco. An El Niño year occurred in 1953 and was one of the more severe manifestations since 1925.

Being warmer and less saline, the water of El Niño tends to flow over the normal Peru Current water, blanketing the latter to a depth of about 25 meters with warmer surface layers. Of course this effect is more pronounced in the northern areas where the Equatorial Counter Current is strongest. At Cabo Blanco in 1953, surface temperatures up to 29.2°C were observed in March and April, whereas in the latter part of July 1931, Gunther (1936) reported surface temperatures of 18 to 22°C at Cabo Blanco and 17.38°C at Lobos de Afuera Islands. Normal surface temperatures in March, April and May are about 20 to 24°C at Cabo Blanco.

The elevated water temperatures of the upper layers during El Niño either drive out many fishes normal to the area or force them to lower depths where the effects of El Niño are not so pronounced. At the same time, the warm and less saline tropical waters in the upper layers permits an invasion of the area by species of fishes usually found only in tropical regions to the north. In addition, the southerly set of the current during El Niño undoubtedly assists in bringing tropical forms into the Peruvian coastal region.

Evidence to support this view is found in the known tropical distribution of the species recorded here as new to the Peruvian fauna. Each of these 20 species has been recorded from the warm waters to the north or west of the Peruvian Coast, from Galapogos Islands, Panama, Colombia, or Ecuador. Twenty new Peruvian records of species found previously to the north and west suggest that their presence off Peru was more than a mere coincidence.

The small size and relatively poor swimming ability of many of the species new to Peru also tend to support the hypothesis that they are not indigenous to the area. Thus, while such strongly-swimming, pelagic species as *Trachurops crumenophthalmus, Fodiator acutus,* and *Parathunnus sibi* are amongst the new records, 11 species, or 55% of the new records, dwell among reefs and in shallow protected waters. They are not strong swimmers and are not likely to have reached

Peru unless they were assisted by some agency such as the current of El Niño.

Although temporary invasions of some tropical species must have occurred sporadically for centuries, it appears highly unlikely that El Niño assists in making any great contribution to the permanent littoral fauna of Peru. The normal temperatures along the Peruvian coast are so much lower than those to which the invading species are accustomed as to make it virtually certain that these species would be unable to reproduce with any degree of success in the cold waters of the Peru Current. Much more likely is the probability that the majority of these species do not occur in Peruvian waters under normal conditions but must await El Niño before they again invade the area.

ADDENDUM

After the above report had been written, I was able to make a short visit to northern Peru in January of 1955. Although observations of the fish fauna were of necessity rather casual, nevertheless it was obvious that conditions were different from those which had obtained in 1953. Specifically, the following changes were apparent in the fish fauna:

An unidentified gray trigger fish (Balistidae) which was frequently seen in the commercial hand-line catch at Cabo Blanco in 1953 was completely absent in 1955. Fishermen reported that this fish had not been seen for some time. Unfortunately, we were not able to obtain an unmutilated specimen.

Halfbeaks (Hemiramphidae) were not observed in 1955. Two years earlier (p. 19) they could be seen at almost any time near the end of the mole at Cabo Blanco.

Mullets (*Mugil sp.*) appeared to be much more numerous at Cabo Blanco than they had been in 1953.

Pluma (*Cratinus agassizi*) were plentiful in 1955 whereas in 1953 only two were seen in the course of several months.

Cabrilla (*Paralabrax humeralis*) formed an important part of the commercial hand-line catch at Cabo Blanco and Paita in 1953. At the latter port, the catch was greater than the demand in the local market so that considerable numbers were frozen for shipment to other markets; in 1955 this species was extremely scarce and was not observed north of Lobos de Afuera Islands.

The Big-eyed Scad (*Trachurops crumenophthalmus*) appeared to be completely absent in 1955, but it is difficult to ascertain whether or not this is actually true, since local fishermen apparently do not recognize the species; they tend to group several species of Carangidae under the common name "Chumbo."

Dorado (*Coryphaena hippurus*) were reported to be scarce; in 1953 this species was reasonably common (see p. 33).

Sierra (*Scomberomorus maculatus*) were extremely numerous close to shore whereas two years earlier they were relatively scarce.

The same was true of the Skipjack, *Sarda chilensis*. In 1953 their scarcity worked considerable hardship on the commercial fleets fishing for them, but on January 11, 1955 I watched the "Conulsa" purse seine fleet at Máncora work all day within five miles of the anchorage and was told later that the day's catch had been greater than any in the previous history of the company.

Sailfish (*Istiophorus greyi*), of which the expedition took nine specimens in 1953, had disappeared in 1955. None had been taken for some months prior to my visit. Swordfish harpooners from the Máncora fleet reported that sailfish were rarely found on "The Bank," 3° 30′ S, 81° 10′ W.

Striped Marlin (*Makaira mitsukurii*) appeared to be much more plentiful in 1955 than they had been in 1953, and the same was true of the Black Marlin (*Makaira marlina*).

Swordfish (*Xiphias gladius*), virtually absent in 1953, were present in fair quantity in 1955. One to three fish per boat per day were being taken by harpooners at Paita during the second week in January.

The Big-eyed Tuna (*Parathunnus sibi*) was being taken in quantity off Máncora by long-line gear. It is difficult to assess its relative abundance in the two years, for the long-line gear was introduced into Peru only recently. However, in 1953 the expedition took seven fish in ten days and did not devote more than a few hours each day to fishing for this species. It is quite possible that the Big-eye, living generally at depths of 20 fathoms or more, remained unaffected by El Niño; our observations showed that the effect of El Niño was generally confined to approximately the upper 25 m (12–13 fathoms).

Summarizing, these observations, limited though they are, indicate an elimination of the more strictly tropical forms from the Cabo Blanco area and, at the same time, they suggest a reinvasion by species accustomed to more temperate waters. This is substantiated by comparison of surface water temperatures observed by the expedition with notes furnished by Mr. Donald Bates of Conulsa, Máncora. The highest temperature observed by Mr. Bates in January 1955 was 73°F. In 1953 the lowest temperature recorded by me in the Cabo Blanco area was 75°F., with temperatures ranging as high as 84.6°F. It would be strange indeed if a temperature difference of this magnitude were not accompanied by a corresponding change in the fauna.

ACKNOWLEDGEMENTS

While nearly every member of the expedition helped collect fishes at one time or another, the efforts of certain ones deserve special mention. Of the crew of the MARISE, Captain McLaughlin and Mr. Panciera were most enthusiastic. Among the scientists, a great deal of help was received from Miss Sarah Wheatland and Mr. Gerald Posner, as well as from LT CDR José F. Barandiarán, official observer for the Peruvian Navy.

For assistance in other directions, it is a pleasure to record the names of Mr. Tom Bates, International Petroleum Company, Talara; Dr. Felipe Ancieta, Dirección de Pesqueria y Caza, Lima; Sr. Enrique Avila, Companía Administradora del Guano, Lima; LT CDR Barandiarán; and CDR Esteban Zimic, Jefe del Servicio Hidrográfico y Faros, Lima. Without the ready assistance of these good friends and of many others, such success as the expedition achieved would have been impossible.

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Прибрежные и пелагические рыбы Перу с переписью новых уловов и описанием новаго вида *Sphoeroides*

Краткий обзор

Прибрежные и пелагические рыбы собранные вдоль берега Перу Йельской Южно-Американской Экспедицией 1953 года перечислены в систематическом списке снабженном примечаниями. Описан один вид, *Sphoeroides andersonianus.* Отмечены двадцать один новых для Перу видов и пределы распространения четырех видов, уже раньше указанных в Перуанской фауне, расширены на 600 миль. Обсуждена возможность соотношения между присутствием в этом районе тропических рыб и явлением называемым „El Niño". В заключение указано что появление их в такое время едва ли оказывает влияние на обогащение постоянной ихтиофауны Перу.

MID-DEPTH FISHES OF THE YALE SOUTH AMERICAN EXPEDITION

By

JAMES E. MORROW

ABSTRACT

Eighteen species of mid-depth fishes were taken in eleven tows of a pelagic otter trawl at depths of 51 to 183 fathoms. Sixteen species are considered new to Peru. *Vinciguerria lucetia* Garman is compared with *V. pacifici* Hildebrand. *Notosudis hamiltoni* Waite is redescribed, and it is shown that *N. argenteus* Maul is conspecific with *N. hamiltoni* Waite.

INTRODUCTION

Part of the collections of the Yale South American Expedition included the mid-depth fishes from the area off the coast of Peru. While it was not possible, because of a variety of circumstances, to pursue this phase of collecting as intensively as had originally been planned, nevertheless eleven tows at seven stations (Fig. 1) resulted in the capture of 125 specimens representing 18 species in 14 or 15 genera and at least nine families.

The gear used for this type of collecting was a small pelagic otter trawl, towed on a maximum of 400 fathoms of wire. The mouth of the net was 30 feet wide and the mesh was of one half inch bar measure throughout. Estimates of the depth of the net on each tow (see list of stations and species), made by simple trigonometry, are, of course, subject to the usual errors. Because of the short length of the wire, the gear was almost always operated during the hours of darkness, when the mid-depth fishes which were sought tend to approach nearer to the surface. Experimental tows made during the afternoon of March 18, 1953 with all wire out and with the net at an estimated depth of over 150 fathoms, yielded no specimens. However, other tows made later in the evening of the same day and at approximately the same place produced good results. Tows were usually of one half hour's duration. Although longer tows would doubtless have produced more specimens, it was felt that the shorter tows would bring the specimens up in better condition. This

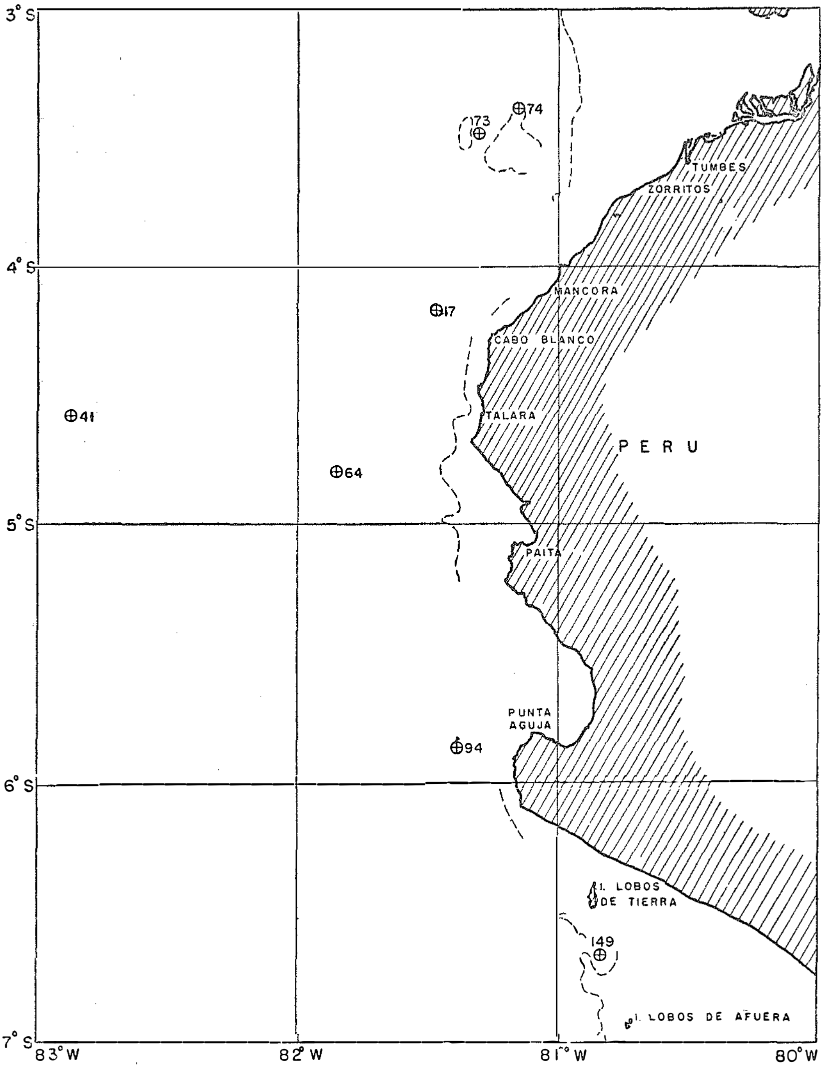

Figure 1. Map of the coastal waters of Peru, showing locations where mid-depth fishes were collected. The 100 fathom curve is indicated by the fine broken line.

proved to be true, particularly with such delicate fishes as the stomiatoids.

Although the present collection is rather small, it is of interest for several reasons. The deep waters close to the Peruvian shore are, ichthyologically speaking, totally unknown. The great oceanographic expeditions which explored the same general region have, without exception, made their collections much farther offshore. The fact that most of the species taken by us in our near-shore work may also be found far out at sea indicates that their habitat is limited in a shoreward direction by the depth of the water rather than by the distance from the beach.

One of the species reported here, *Myctophum affine*, has already been recorded from Peru. It is possible that *Vinciguerria pacifici*, described from Peru by Hildebrand (1946), is identical with *V. lucetia* of this report, for they are certainly similar (see p. 61). With these two exceptions, all species included here appear to be new to the Peruvian fauna.

Of special interest is the capture of a juvenile specimen of *Notosudis hamiltoni* Waite. This species, quite rare according to our present knowledge, appears to be of more or less world-wide distribution. As the individual grows, its appearance changes to such a degree that two of the four known specimens have been described as a separate species. This matter is discussed later (p. 63). Critical remarks on several other species are also included where appropriate.

LIST OF STATIONS AND SPECIES

In the following list, time is given as local time (Eastern Standard Time) on a 24 hour clock and indicates the hours during which the net was actually at the depths given. Positions were determined by dead reckoning. The depth of the water at each position was determined from U. S. Hydrographic Office charts of the area.

Station 17. March 18, 1953. 4° 10′ S, 81° 28′ W, drifting westward.

First haul. 1600–1630 hours; estimated fishing depth of net, 51 fathoms; depth of water 930 fathoms.

Leptocephalus, specimen A.

Second haul. 1645–1715 hours; estimated fishing depth of net, 152 fathoms; depth of water 1300 fathoms.

Manducus argenteolus (Garman)
Vinciguerria lucetia (Garman)
Argyropelecus olfersii (Cuvier)
Hoplostethus pacificus (Garman)
Monolene maculipinna Garman

Third haul. 2000–2045 hours; estimated fishing depth of net, 142 fathoms; depth of water over 1500 fathoms.

Vinciguerria lucetia (Garman)
Argyropelecus olfersii (Cuvier)
Stomias colubrinus (Garman)
Notosudis hamiltoni (Waite)
Myctophum affine (Lütken)
Lampanyctus mexicanus (Gilbert)
Leptocephalus, specimen B
Melamphaes mizolepis (Günther)

Station 41. April 3, 1953. 4° 35′ S, 82° 52′ W.

First haul. 2226–2305 hours; estimated fishing depth of net, 183 fathoms; depth of water 1860 fathoms.

Argyropelecus olfersii (Cuvier)
Melamphaes macrocephalus Parr
Melamphaes mizolepis (Günther)

Second haul. 2344–2414 hours; estimated fishing depth of net, 136 fathoms; depth of water 1860 fathoms.

Argyropelecus olfersii (Cuvier)
Bathophilus filifer (Garman)
Idiacanthus panamensis Regan and Trewavas
Myctophum affine (Lütken)
Leptocephalus, specimen C
Hoplostethus pacificus (Garman)
Melamphaes typhlops (Lowe)
Melamphaes mizolepis (Günther)

Station 64. April 7, 1953. 4° 48′ S, 81° 51′ W.

One haul. 2257–2327 hours; estimated fishing depth of net, 73 fathoms; depth of water 1900 fathoms.

Argyropelecus olfersii (Cuvier)
Stomias colubrinus (Garman)
Melamphaes bispinosus (Gilbert)

Station 73. April 13, 1953. 3° 29′ S, 81° 18′ W.

One haul. 1935–2005 hours; estimated fishing depth of net, 77 fathoms; depth of water 500 fathoms.

Stomias colubrinus (Garman)

Station 74. April 13, 1953. 3° 23′ S, 81° 09′ W.

One haul. 2253–2323 hours; estimated fishing depth of net, 67 fathoms; depth of water about 100 fathoms.

Stomias colubrinus (Garman)
Myctophum affine (Lütken)
Melamphaes mizolepis (Günther)

Station 94. April 20, 1953. 5° 58′ S, 81° 23′ W.

One haul. 0120–0150 hours; estimated fishing depth of net, 170 fathoms; depth of water 1000 fathoms.

Lampanyctus mexicanus (Gilbert)
Hoplostethus pacificus (Garman)

Station 149. May 20, 1953. 6° 40′ S, 80° 50′ W.

First haul. 2135–2205 hours; estimated fishing depth of net, 156 fathoms; depth of water about 650 fathoms.

Manducus argenteolus (Garman)
Hoplostethus pacificus (Garman)

Second haul. 2240–2310 hours; estimated fishing depth of net, 72 fathoms; depth of water about 650 fathoms.

Manducus argenteolus (Garman)
Hoplostethus pacificus (Garman)

LIST OF SPECIES COLLECTED

Order Clupeiformes

Family Gonostomidae

1. *Manducus argenteolus* (Garman)

18 specimens, 25.4 to 88.0 mm, St. 17 (2nd haul).
13 specimens, 51.7 to 114.5 mm, St. 149 (1st and 2nd hauls).

The skin of nearly all specimens has disintegrated, apparently an effect of the preservative. However, the photophores, fin rays, etc., are all reasonably intact.

2. *Vinciguerria lucetia* (Garman)

1 specimen, 20.1 mm, St. 17 (2nd haul).
1 specimen, 27.4 mm, St. 17 (3rd haul).

Hildebrand (1946) erected a new species, *V. pacifici,* on the basis of seven specimens taken from the stomach of a skipjack caught in Peruvian waters. Because of the close similarity of *V. pacifici* and *V. lucetia* the matter of identity was investigated more thoroughly. Accordingly, 20 individuals in the Bingham Oceanographic Collection (BOC 2638) from 16° 14′ N, 99° 36′ 30″ W (about 50 miles SSE of Acapulco, Mexico) were used for comparison. The present Peruvian specimens differ from the Mexican ones only in that the ventral fins are located farther forward than those in the Mexican material. The distance from snout to ventrals is 1.88 to 2.05 in standard length in the Mexican material, 2.19 in the Peruvian.

Judging from Hildebrand's description, *V. lucetia* and *V. pacifici* may be separated only on the basis of body depth. *V. pacifici* is said to be slimmer, the depth contained 6.5 to 7.2 times in the standard length. On the other hand, in our specimens of *V. lucetia,* the depth is 5.3 to 6.2 times. Although Hildebrand stressed the points that in *V. pacifici* ". . . the head is longer, the eye smaller, the dorsal is farther back on the body, the ventrals are farther forward . . .", the present material shows that these are not good characters for separating the two species. The positions of the dorsal and ventral fins in our *V. lucetia* are the same as those given by Hildebrand for *V. pacifici.* The head of *V. lucetia* tends to be a little longer than that of *V. pacifici,* which is diametrically opposite to Hildebrand's statement; for *V. lucetia* this measurement is 3.5 to 4.0, for *V. pacifici* 3.7 to 4.0. The eye is generally smaller in *V. pacifici,* 3.5 to 4.2 in head, as compared with 2.9 to 3.8 in *V. lucetia,* but there is sufficient overlap between the two to render this characteristic less useful. The only single character, then, that will effectively separate the two species is the depth of body.

Family Sternoptychidae

3. *Argyropelecus olfersii* (Cuvier)

25 specimens, 19.0 to 35.1 mm, St. 17 (2nd haul).
9 specimens, 19.3 to 34.0 mm, St. 17 (3rd haul).
1 specimen, 21.2 mm, St. 41 (1st haul).
9 specimens, 15.0 to 51.1 mm, St. 41 (2nd haul).
5 specimens, 12.2 to 23.4 mm, St. 64.

The identity of the Pacific ocean forms with *A. olfersii* is a matter which may still be open to question. Garman (1899) described *A. lychnus* from specimens taken off Mexico, Panama, Colombia and the Galapagos Islands. However, many subsequent authors (e.g., Brauer, 1906; Norman, 1930; Shultz, 1938) considered this species a synonym of *A. olfersii*. Thus, Schultz stated, ". . . since *lychnus* appears to have a higher dorsal blade and the upper preopercular spine is shorter, it is tentatively placed in the synonymy of *olfersii*." Schultz characterized *A. olfersii* as follows: "Lower preopercular spine pointing downward, curved slightly forward and outward, the upper very small or absent, its tip not extending past rear margin of preopercle in adults; . . . height of dorsal blade 1 to 1.4 times in length of its base." Parr (1931, 1937), on the other hand, while noting many similarities, felt that the two species might be distinguished by the curvature of the lower preopercular and posterior

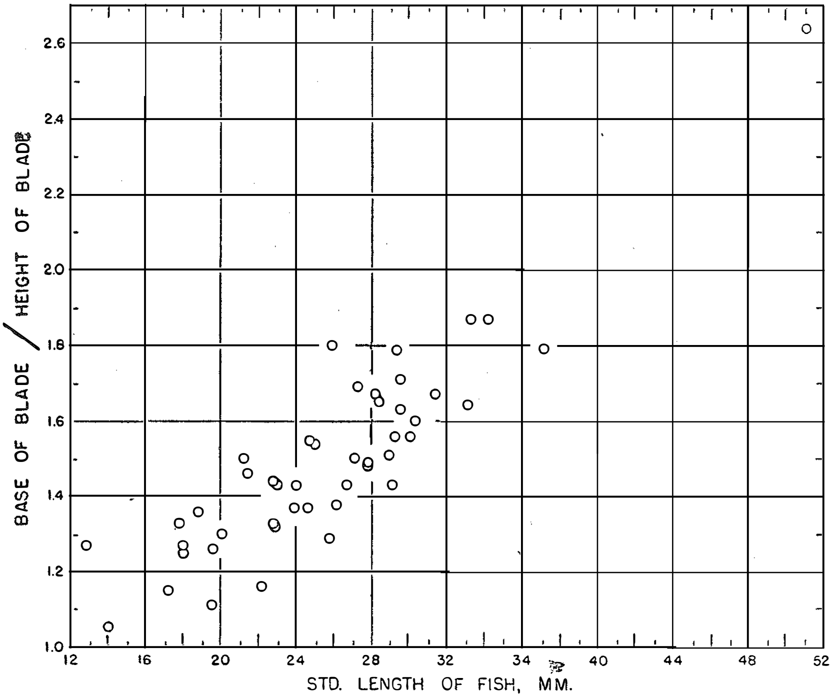

Figure 2. Relationship of the ratio base of dorsal blade/height of dorsal blade to standard length in *Argyropelecus olfersii*.

abdominal spines and by the relative length of the space between the caudal and supra-anal series of photophores. The last two factors used by Parr appear to be the result of the sketchiness of Norman's (1930) figure, whence Parr, with obvious misgivings, derived them.

Our Peruvian material indicates that the curvature of the lower preopercular spine varies considerably; in some it is curved slightly backwards, in others it is straight, and in the majority it is curved forward as in *A. olfersii.* In seven specimens this spine is straight on one side and curved forward on the other. The upper preopercular spine, although short, is always present and well developed, usually directed more or less outward. In this respect, the Peruvian material suggests *A. sladeni.* The height of the dorsal blade with respect to the length of its base appears to be related to the size of the individual (Fig. 2), varying, in the Peruvian material, from 1.05 in a 15 mm fish to 2.64 in one—51.1 mm long. In all other respects, however, the Peruvian specimens agree well with *A. olfersii.*

Family Stomiatidae

4. *Stomias colubrinus* Garman

3 specimens, 121, 123 and 114.5 mm, St. 17 (3rd haul).
1 specimen, 51.3 mm, St. 64.
1 specimen, 97.0 mm, St. 73.
2 specimens, 124 and 141 mm, St. 74.

5. *Bathophilus filifer* (Garman)

1 specimen, 49.6 mm, St. 41 (2nd haul).

Family Idiacanthidae

6. *Idiacanthus panamensis* Regan and Trewavas

1 specimen, 161.8 mm, St. 41 (2nd haul).

Order Scopeliformes

Family Notosudidae

7. *Notosudis hamiltoni* Waite

1 specimen, 52.5 mm, St. 17 (3rd haul).

This specimen is the fourth of this genus and species to be recorded in scientific literature. The distribution of the species is probably world-wide in cool waters. The type specimen (Waite, 1916) was found on a beach at Macquarie Island, 54° 45′ S, 159° 05′ W, two others from the Madeira Islands in the Atlantic (33° N, 17° W) have been described by Maul (1954) as a new species, *Notosudis argenteus*, and our specimen came from the northern waters of Peru, 4° 10′ S, 81° 28′ W. All three of these locations are in areas washed by cool currents. Macquarie Island lies in the West Wind Drift of the southern Pacific-Antarctic oceans; the Madeiras lie in the cool Canaries Current; and the coast of Peru, although in the tropical belt, is washed by the cold Peru Current.

In his introductory remarks on *Notosudis argenteus*, Maul said, "The fish under discussion belongs undoubtedly to the same genus [as *N. hamiltoni*] and is indeed quite close to the species. Several numerical values, however, differ strongly enough to make it quite clear that it cannot be conspecific with it." However, both of Maul's specimens are much smaller than the type, and these, together with the Yale specimen, which is even smaller, make it possible to show that all the differences between the type and the newer material can be ascribed to changes in proportion with growth of the individual or that they fall within a reasonable range of variation. The various counts and measurements for each of the four specimens are shown in Table I.

The only difference shown in Table I that is at all striking is the short base and low number of rays in the anal fin of the type specimen of *N. hamiltoni* as compared with the same characters in the other three specimens. However, Waite remarked that the specimen was rather badly damaged and "has the appearance of having been considerably digested." Dr. H. M. Hale, director of the South Australian Museum, kindly re-examined the type and sent a photograph of it. About 14 anal rays can be distinguished in the photograph, which also shows clearly that the ventral portion of the caudal peduncle is missing. One gains the impression from this photograph that, were the missing flesh present, the anal fin would be considerably longer. In his letter, dated 30th June 1955, Dr. Hale remarks ". . . it would appear that this area was bitten out by some creature. It is surprising, therefore, that Waite so confidently placed the number of anal rays at 15." Dr. Hale also observes that pseudobranchiae are present in the type specimen although Waite had described them as lacking.

TABLE I. Counts and Proportions of the Four Known Specimens of *Notosudis hamiltoni* Waite. Data on the Type Specimen Have Been Taken from Waite's Text or from the Figures Accompanying the Original Description; Those of *N. argenteus* Are from Maul. Actual Measurements in mm of the Yale Specimen Are Given in Parentheses.

	Yale specimen	*N. argenteus* paratype	*N. argenteus* type	*N. hamiltoni* type
Standard length, mm	52.5	69	214	505
Dorsal	11	13	14	12
Anal	18	19	19	15*
Pectoral	12	14	14	12
Ventral	9	9	9	—
Caudal	20 + 19	—	11 + 16 + 10	19 + 22
Gill rakers	2 + 17	2 + 15	1 + 11 + 6†	—
	As percentage of standard length			
Head	29.4 (15.4)	26.5	25.3	22.7
Depth	8.5 (4.5)	10.5	11.2	12.2
Snout	9.9 (5.2)	8.0	5.4	6.9
Premaxillary	11.1 (5.8)	13.0	13.6	13.0
Eye (horizontal)	6.9 (3.6)	8.3	7.0	4.0
Eye (vertical)	5.5 (2.9)	6.5	5.1	3.1
Interorbital	4.4 (2.3)	4.2	5.1	5.5
Depth of head	8.2 (4.3)	10.1	10.6	11.1
Caudal peduncle	4.4 (2.3)	5.3	5.4	4.6
Snout to ventrals	45.3 (23.8)	41.7	45.3	—
Snout to pectorals	29.5 (15.5)	27.6	26.8	25.9
Snout to dorsal	51.8 (27.4)	53.6	51.4	50.1
Snout to anal	76.8 (40.3)	79.7	78.1	77.9
Snout to adipose	85.1 (44.7)	86.0	85.6	85.0
Base of dorsal	7.6 (4.0)	6.5	9.4	7.6
Base of anal	12.2 (6.4)	10.9	11.2	6.1*

*Last few rays probably missing.
†One raker on upper arch, 11 rakers and 6 rudiments on lower arch.

Description: Proportional dimensions in per cent of standard length. Redescription based on the Yale specimen and on the published descriptions and figures of the other three specimens noted above.

Standard length: 52.5–505 mm.
Body: depth 8.6–12.2%.
Caudal peduncle: least depth 4.4–5.4%.
Lateral line: 55–57.
Vertebrae: 54.

Head: length 22.7–29.4%; depth 8.2–11.1%.
Snout: length 5.4–9.9%.
Eye: horizontal diameter 4.0–8.3%.
Interorbital space: 4.2–5.5%.
Gills: 4; rakers 0–2 + 15–20, including rudiments; longest about 20% of horizontal diameter of eye.
Nostrils: small, before orbit.
Mouth: premaxillary 11.1–13.6%.
Dorsal fin: rays 11–14; snout to origin 50.1–53.6%; length of base 6.5–9.4%; longest ray 10% in small specimens.
Pectoral fin: rays 12–14; snout to origin 25.9–29.5%.
Ventral fin: rays 9; snout to origin 41.7–45.3%.
Anal fin: rays (15?) 18 or 19; snout to origin 76.8–79.7%; length of base (6.1?) 10.9–12.2%.
Adipose fin: snout to origin 85.0–86.0%.
Caudal fin: rays 37–41, including small procurrent rays.

Body almost cylindrical, slightly compressed, deepest in large specimens.

Scales cycloid, deciduous, those of lateral line with a low keel.

Head long, flat above, longest in young specimens, deepest in large individuals. Snout acute, rounded at tip, generally longest in young. Eye large, generally largest in young, upper border of orbit entering dorsal profile. Pupil oval. Orbit more or less pear-shaped, greatest diameter horizontal. Interorbital increasing with age, in small specimens marked with longitudinal ridges which disappear in adults. Gills four, a slit behind the fourth; rakers moderate, lanceolate; gill membranes not united. Pseudobranchiae present, largely concealed by a fold of black membrane. Nostrils small, in advance of orbit, front one round, hind one a slit. Mouth large; rictus beneath eye in juveniles but well behind eye in adults. Premaxillary bordering entire length of gape, free of maxilla. Supramaxillaries present, consisting of two bones. Lower jaw projecting, concealed by maxillary for most of its length when mouth is closed, the symphysis fitting into a toothless notch at tip of upper jaw.

Teeth small, conical, rather blunt; one row in upper jaw, two distinct and well separated rows in lower jaw (outer row lost in adults?). A single row of teeth on each palatine. Vomer toothed, the number of teeth apparently increasing with age. Tongue smooth.

Dorsal origin about in middle of S. L. Pectorals immediately behind head, about midway up on sides, not reaching ventrals, longest in juveniles. Ventral bases not contiguous, in advance of vent; fins extending past dorsal origin. Anal origin well behind dorsal. Adipose fin well developed, its base above last few rays of anal.

Color: Fresh specimens dark above, silvery with bluish tints on sides; larger individuals more or less uniform bluish gray. Fins pale. Iris, inside of mouth, branchial cavity and peritoneum black.

Family Scopelidae

8. *Myctophum affine* (Lütken)

4 specimens, 39.2 to 49.6 mm, St. 17 (3rd haul).
1 specimen, 28.5 mm, St. 41 (2nd haul).
1 specimen, 44.6 mm, St. 74.

These six specimens key out to *M. affine*, but they also exhibit several differences from Atlantic specimens of that species. They seem to be identical with the third group described by Bolin (1939) under *M. affine;* he stated: "The third species . . . from the coast of Peru, shows striking differences when compared directly with *M. affine* of similar size. In these specimens the snout descends gradually to a bluntly rounded point instead of being abruptly declivous, the mouth is slightly inferior instead of strictly terminal, the eye is definitely smaller (8.5–9.1 instead of 10.1–11.5 [% of standard length]), and the body is less heavy anteriorly. It is possible that these specimens belong to *M. nitidulum* Garman. . ."

9. *Lampanyctus mexicanus* (Gilbert)

1 specimen, 58.1 mm, St. 17 (3rd haul).
1 specimen, 40.6 mm, St. 94.

Order Anguilliformes

Three leptocephali were taken during the cruise. Up to the present time it has not been possible to identify any of them, even so far as family. Without attempting to put a name to any of the specimens, the following notes are provided.

10. Specimen A

1 specimen, 165 mm, St. 17 (1st haul).

Preanal myomeres 125, post anal 43, total 168. Preanal length 86.8% of total length. Dorsal-anal distance 38 myomeres. Depth of body 7.46% of total length. Head long, narrow, pointed, 5.8% of total length; depth of head 41.7% of its length. A row of six brownish spots along midline on left side of body, only two such spots posteriorly on right side.

11. Specimen B
    1 specimen, 151 mm, St. 17 (3rd haul).

Preanal myomeres 223, postanal about 77 (last estimated 50 too small to count accurately), total about 300 myomeres. Preanal length 84.2% of total length. Depth of body 4.17% of total length. Head rather short, narrow, pointed, 3.1% of total length; depth of head 49% of its length.

12. Specimen C
    1 specimen, 90 mm, St. 41 (2nd haul).

Preanal myomeres 124, postanal 46, total 170. Preanal length 86.7% of total length. Dorsal-anal distance 80 myomeres. Depth of body 11% of total length. Head moderate, 5.11% of total length, dorsal profile bluntly rounded; depth of head 69.6% of its length. A single row of small brown ocellated spots on each side of body just below vertebral column, the spots occurring on almost every myomere. A row of pigment spots on each side of intestine.

Order Beryciformes

Family Trachichthyidae

13. *Hoplostethus pacificus* (Garman)
    3 specimens, 15.0 to 19.1 mm, St. 17 (2nd haul).
    1 specimen, 9.0 mm, St. 41 (2nd haul).
    1 specimen, 16.3 mm, St. 94.
    8 specimens, 12.8 to 21.3 mm, St. 149 (1st and 2nd hauls).

The specimens included under this species are all juveniles, rendering their identification with the species somewhat less certain than might be desired. However, through the kindness of Dr. L. P. Schultz, U. S. National Museum, it has been possible to examine a small specimen of *H. pacificus* and to compare it with the present material. The only difference seems to be that in the Peruvian material the anal origin lies under the 2nd or 3rd dorsal ray while in the somewhat larger specimen from the USNM the anal origin is under the 4th dorsal ray. In the Peruvian specimens there is a slit behind the fourth gill arch which may, however, be a characteristic of juveniles. In the U.S.N.M. specimen this slit appears to be either closed or greatly reduced.

Family Melamphaidae

14. *Melamphaes typhlops* (Lowe)

1 specimen, 33 mm, St. 41 (2nd haul).

The specimen at hand agrees almost perfectly with Norman's (1929) description of a 90 mm specimen, differing only in the size of the eye and the number of gill rakers. The present specimen has 11 gill rakers rather than eight or nine, and the eye is contained 7.2 times in the length of the head rather than "about 6."

This is a rather remarkable new record for this species, which up to now seems to have been found only in the eastern Atlantic ocean.

15. *Melamphaes macrocephalus* Parr

1 specimen, 26.6 mm, St. 41 (1st haul).

The specimen has been compared with the type and several paratypes in the Bingham Oceanographic Collection. There can be no doubt that all belong to the same species. Known from the west coast of Mexico and probably all along the Pacific coast of Central and South America, at least as far south as 4° 35′ S.

16. *Melamphaes bispinosus* Gilbert

1 specimen, 18.6 mm, St. 64.

This small specimen, which has been compared with the specimens in the Bingham Oceanographic Collection on which Parr (1931) resurrected the species, appears to be identical with them.

17. *Melamphaes mizolepis* (Günther)

1 specimen, 43.7 mm, St. 17 (3rd haul).
2 specimens, 48.8 and 62.2 mm, St. 41 (1st haul).
1 specimen, 51.5 mm, St. 41 (2nd haul).
1 specimen, 46.4 mm, St. 74.

Order Perciformes

Family Bothidae

18. *Monolene maculipinna* Garman

1 specimen, 65 mm, St. 17 (2nd haul).

This single specimen, a larva, is perfectly symmetrical; when caught it was almost totally transparent. It exhibits the characteristics of the Bothidae and is assigned to the above genus and species on the basis of counts of the dorsal and anal rays and vertebrae. According to Norman's (1934) monograph, this species is the only one among the Bothidae with the combination of 98 dorsal rays, 79 anal rays, and 43 vertebrae. Adults have been recorded from deep water off the coasts of Colombia and Panama.

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Джемс Е. Морро (в)

Средне-глубинные рыбы Йельской Южно-Американской Экспедиции

Краткий обзор

Восемнадцать видов средне-глубинных рыб были собраны с помощью пелагических рыболовных снастей в одиннадцать приемов на глубинах от 51 до 183 саженей. Шестнадцать видов оказались новыми для Перу. *Vinciguerria lucetia Gorman* описана по сравнению с *V. pacifici* Hildebrand, *Notosudis hamiltoni* Waite заново описан с указанием на то что *N. argenteus* Maul и *N. hamiltoni* Waite принадлежат к одному и тому же виду.

RACES OF THE STRIPED MARLIN, *MAKAIRA MITSUKURII*, IN THE PACIFIC

By

James E. Morrow

ABSTRACT

Statistical analyses of certain morphometric measurements and meristic characters have shown that striped marlin (*Makaira mitsukurii*) from Peru and from northern New Zealand represent separate populations. About 7 out of 10 in a mixed sample from the two localities can be properly assigned to their home area by the application of a character index. Evidence is presented which indicates that the pelvic fin stops growth after reaching a certain length and that its length is therefore not related to the length of the adult fish.

INTRODUCTION

The striped marlin, *Makaira mitsukurii* (Jordan and Snyder), is found in varying degrees of abundance throughout the warmer waters of the Pacific and Indian oceans. While this species does occur in the open ocean as well, more or less definitely circumscribed centers of abundance appear to be located fairly close to shore, as along the East African coast, around Ceylon, in the coastal waters of Japan, Formosa, the Philippines, eastern Australia and New Zealand, Chile, Peru, Panama, Mexico, southern California, and the Hawaiian Islands. For a long time it has been completely unknown whether these centers represent separate populations, more or less separated from each other both geographically and genetically, or whether the seasonal abundance of these marlin at each locality is an expression of the migratory pattern of a more or less homogeneous population ranging over the whole of the Indo-Pacific area.

The discontinuity between these numerous centers is probably brought about by at least two factors. The first is food supply and suitable conditions of the sea which would make the area attractive to the fish, leading them to congregate there. The other is the discontinuous distribution of the fishermen who catch these large fish. Thus, marlin are known to be plentiful off northern Chile and northern Peru, but it is not known whether or not they occur in numbers along the central and southern Peruvian coasts. Similarly, marlin are to be found along the coast of Ecuador, but there is no fishery, either sport or commercial, for marlin in these locations. We simply do not know whether there are enough fish present in these unfished areas to support a fishery. As recently as 1946, Hildebrand (1946), discussing the fishes of Peru, stated that "Two genera [of Istiophoridae] no doubt occur from time to time on the coast of Peru." Since then, modern methods have led to the development of extensive sport and commercial fisheries for marlin in the region between Paita and Máncora, an area which is now known to maintain a large population of these fishes. As fisheries technology advances in different parts of the world, it is probable that new centers of abundance of marlins (and of other species as well) will be discovered in previously unsuspected areas. It is also probable that the development of new areas will tend to fill the gaps between the currently known centers, leading to the impression that the distribution is much more nearly continuous than it now appears from available data.

For the present, however, there remains the problem of whether or not the striped marlin of the Pacific constitute a single, widely-ranging, more or less homogeneous population or a number of fairly discreet local populations with little or no intermixing. There is much to be said on both sides of the question. For example, marlin occur far out in the Pacific where they are regularly taken by long-line tuna fishermen. This might indicate that a single population covers the whole Pacific ocean. On the other hand, recent studies on tuna have shown that different parts of the open ocean support apparently quite discreet tuna populations. The concentration of marlin in certain areas, added to what appears superficially to be a migration of a single population along the Pacific coast of Central and North America, also suggests the presence of geographically localized populations. The data and conclusions presented here are a preliminary tentative step in the attempt to solve this broad question.

METHODS

This paper is based on morphometric measurements and meristic counts of striped marlin from New Zealand and Australia and from the northern coast of Peru. Gregory and Conrad (1939) published detailed measurements of 30 fish from New Zealand and Australia;

TABLE I. MEASUREMENTS AND COUNTS OF STRIPED MARLIN FROM NEW ZEALAND. MEASUREMENTS IN MILLIMETERS. TWO DAMAGED SPECIMENS NOT MEASURED HAD ANAL COUNTS OF 12 AND 14.

S. L.	*Depth*	*Anal*	*S. L.*	*Depth*	*Anal*	*S. L.*	*Depth*	*Anal*
2019	321	14	2551	457	—	2631	444	16
2293	381	15	2552	375	—	2635	432	14
2309	425	—	2553	425	15	2655	432	13
2338	444	15	2562	435	15	2660	499	16
2372	444	15	2568	419	15	2667	422	15
2400	400	—	2572	387	—	2685	432	—
2415	429	14	2579	438	16	2700	448	13
2439	391	14	2588	425	14	2705	419	13
2476	438	13	2590	—	15	2724	457	—
2478	387	—	2610	442	13	2737	457	14
2493	457	14	2610	457	14	2751	486	14
2521	432	12	2613	400	—	2790	470	—
2534	419	12	2615	461	13	2813	514	12
2538	419	15	2623	454	—	2820	495	15
2550	457	12	2629	482	13	2839	489	14
			2630	441	14	2865	505	—

to these are added less complete data on 49 New Zealand fish measured by me on the Yale New Zealand Expedition of 1948 (Table I). For the Peruvian fish, 14 sets of measurements were made by me on the Yale South American Expedition of 1953, and 25 more fish were examined during a brief visit to northern Peru in January 1955 (Table II). Thus there are available data on 79 fish between 2019 and 2865 mm in standard length from Australia and New Zealand, and on 39 fish from Peru with standard lengths between 2115 and 2700 mm.

Thirty measurements or counts were made on each of the Peruvian specimens. Gregory and Conrad considered 40 characteristics, and the Yale New Zealand Expedition examined 15 points on each specimen. The number of individuals involved in each comparison, therefore, is not the same throughout this study. For example, all fish were measured for depth of body; hence 39 Peruvian and 79 New Zealand fish were included in this comparison. By contrast, the spines and rays in the anal fin were counted on all Peruvian specimens and on only 37 marlin taken on the Yale New Zealand Expedition; such counts were not obtained at all by Gregory and Conrad. Also, it was not possible to weigh the Peruvian specimens examined in 1955. However, except for occasional accidental omis-

TABLE II. MEASUREMENTS AND COUNTS OF STRIPED MARLIN FROM PERU. MEASUREMENTS IN MILLIMETERS

Standard length	*Depth*	*Length base 2d dorsal*	*Length base 1st anal*	*Length pelvic*	*Width base pectoral*	*Snout to 1st dorsal*	*Snout to 2nd dorsal*	*Snout to 1st anal*	*Snout to operculum*	*Snout to end of maxillary*	*Anal count*
2115	—	90	200	330	71	812	—	1600	879	670	15
2155	353	77	253	359	62	761	1920	1520	818	612	15
2170	361	81	279	413	—	710	1830	1535	814	606	15
2238	352	84	252	412	69	841	1985	1621	872	665	15
2255	357	—	274	258	59	813	1990	1560	867	677	15
2263	390	81	283	351	75	781	2016	1623	861	658	14
2268	336	91	270	432	68	779	2010	1605	853	654	15
2270	348	87	256	322	64	810	2050	1630	880	676	15
2280	335	91	259	405	65	834	2035	1630	893	692	15
2282	376	83	284	484	73	813	2040	1638	863	655	15
2285	382	89	291	406	71	808	2052	1618	882	679	16
2295	371	83	247	411	73	785	2042	1625	878	675	15
2305	367	89	297	430	—	822	2060	1632	908	672	17
2306	387	89	280	333	70	847	2049	1653	894	678	15
2334	359	83	268	378	72	826	2069	1616	891	677	14
2350	379	83	288	355	73	827	2090	1630	891	682	14
2356	396	101	295	454	70	819	2071	1672	884	671	15
2370	388	92	279	371	68	833	2122	1664	926	698	15
2386	370	87	327	401	70	851	2151	1694	900	684	15
2394	378	85	296	378	72	809	2121	1687	893	676	16
2395	369	93	297	412	76	827	2110	1710	910	698	14
2440	390	102	294	384	72	838	2150	1720	926	712	16
2459	398	86	273	372	76	827	2178	1752	910	691	15
2460	363	82	297	381	71	887	2230	1725	945	741	16
2495	380	98	245	379	72	870	2200	1780	928	726	15
2517	375	81	259	398	72	885	2260	1825	957	745	14
2521	396	96	257	404	79	914	2238	1783	967	732	15
2527	412	102	290	402	73	901	2232	1794	980	757	15
2539	379	107	341	456	69	894	2241	1783	983	759	16
2555	394	101	322	311	75	865	2378	1795	968	749	15
2573	385	86	319	379	71	886	2278	1785	918	687	15
2575	439	95	347	390	81	905	2309	1810	968	731	15
2582	420	93	291	362	80	896	2320	1850	1003	764	16
2590	400	104	304	348	75	890	2315	1830	980	752	16
2620	397	97	320	410	77	895	2340	1860	1000	783	14
2626	382	102	287	373	73	869	2311	1855	966	719	14
2660	398	91	252	574	72	832	2128	1639	941	718	15
2690	410	99	330	—	82	933	2375	1875	987	755	15
2700	424	113	319	364	81	937	2312	1782	1010	784	14

sions, minimum samples of 39 Peruvian and 30 New Zealand fish are available for comparison with respect to each of the following characteristics: Standard length (Standard length as used here is the straight-line distance from tip of snout to minimum depth of caudal peduncle.); greatest depth of body; length of dorsal fluke of caudal fin (from anterior edge of corresponding caudal keel to tip of longest ray); length of ventral fluke of caudal fin; length of base of first dorsal fin[1]; height of longest dorsal spine; length of base of second dorsal fin; height of first ray of second dorsal fin; length of base of first anal fin; height of longest anal spine; length of pelvic fin; width of base of pectoral fin; length of pectoral fin; snout tip to base of pectoral fin[1]; snout tip to base of pelvic fin[1]; snout tip to origin of first dorsal fin[1]; snout tip to origin of second dorsal fin[1]; snout tip to origin of first anal fin[1]; snout tip to posterior edge of operculum[1]; snout tip to anterior margin of eye[1]; snout tip to posterior end of maxillary; anterior-posterior diameter of eye; number of spines and rays in first dorsal fin; number of rays in second dorsal fin; number of spines and rays in first anal fin; number of rays in second anal fin.

In examining the samples, regression equations have been utilized wherever appropriate, with the standard length of the fish as the independent variable. The various measurements of the two New Zealand samples were compared, and the same was done with the two samples from Peru. No significant differences were found between samples from the same area, hence it appeared justifiable to combine the two samples from each area and to compare the areas on the basis of the combined samples. Equations were fitted to the combined samples by the method of least squares. Each regression from each sample was compared with the corresponding regression from the other sample by standard statistical methods (Quenouille, 1950; Snedecor, 1948) with respect to variance ratio, slope, and distance between lines. A significant difference ($P < 0.05$) in any of these factors was considered an indication of a real difference between the samples. The regression equation used throughout the study is the classical allometry equation, $Y = bX^k$, expressed as its logarithmic transformation, $\log Y = \log b + k \log X$. The comparisons and tests of significance thus refer only to the logarithmic form. The use of the allometry equation has permitted further analysis and comparison of those characteristics in which growth is isometric ($k = 1$). Here Ginsburg's (1938, 1954) index of intergradation has been used, as well as the graphic method of comparison described by Hubbs and Hubbs (1953). In these two presentations, the dependent variable has been expressed as a percentage of the independent variable ($100\ Y/X$), and the mean percentage, together with its standard error and the standard deviation, is shown graphically. It should be

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[1] Projected to midline of body.

noted that, in determining M, σ_m and σ, calculations were carried to the first decimal. However, in determining the index of intergradation, it was usually necessary to classify the data in order to achieve a continuous distribution. This has resulted in some small discrepancies in the graphs.

The data available for this study are far removed, graphically, from the origin. Plots of the data, as well as calculated regressions, show little choice so far as fit of the regression to the data is concerned, between the allometry equation and a straight line. The biological implications of the two equations are somewhat different, however, particularly if the regression is extrapolated beyond the lower limits of the data; for this reason the allometry equation was chosen. But it must be emphasized that such extrapolation is completely and utterly unjustified. It is well known that the growth patterns of animals may undergo radical changes at different stages in their life histories. To assume that the growth pattern observed in adult animals has remained constant throughout the younger stages of life is thus totally indefensible. Lacking data on the younger stages, then, the validity of the equations for the various growth patterns is obviously limited to the observed range of the data.

DISCUSSION

Significant differences were observed in 11 of the characteristics listed: greatest depth of body; length of base of second dorsal fin; length of base of first anal fin; length of pelvic fin; width of base of pelvic fin; snout tip to origin of first dorsal fin; snout tip to origin of second dorsal fin; snout tip to origin of first anal fin; snout tip to posterior edge of operculum; snout tip to posterior end of maxillary; number of spines and rays in first anal fin. Each of these 11 characteristics and the differences found between samples is considered separately.

Greatest depth of body. The equations for this character exhibit a significant difference between the slopes of the two logarithmic regressions (values of k). For the Peruvian sample, the regression is expressed by $\text{Log } Y = 0.182 + 0.709 \log X$; for the New Zealand sample, the equation is $\text{Log } Y = \bar{2}.777 + 1.133 \log X$. The difference is significant at $P < 0.01$, indicating a probability of less than 1 in 100 that the two samples would show such diverse slopes by pure chance if drawn from the same population. The inference is, then, that the two samples represent different populations.

The Peruvian sample shows distinct negative allometry ($k < 1$) in depth of body, which is significant at $P < 0.02$. This indicates that as the fish grow longer they become relatively slimmer. By contrast, the New Zealand sample exhibits a slight degree of positive allometry. However, this is not significant, hence it is probable that these fish maintain the same relative rates of growth in both depth and length, at least within the size range considered here.

Length of base of second dorsal fin. This length maintains an isometric relationship to the standard length in both Peruvian and New Zealand samples. The variance ratio is of doubtful significance ($P = 0.05$) and the slopes of the two regressions are not significantly different. However, the distance between the lines is marked and is highly significant, with $P < 0.001$. This indicates a real difference between the two populations, the second dorsal fin of the Peruvian

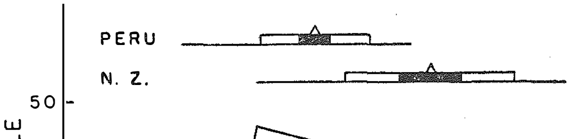

Figure 1. Distribution of the length of the base of the second dorsal fin, expressed as a percentage of the standard length. Solid line = Peruvian sample, broken line = New Zealand sample. Index of intergradation = 26.0.

fish being somewhat shorter than that of the New Zealand specimens. The equation for the Peruvian sample is $\text{Log } Y = \bar{2}.908 + 0.902 \log X$; for the New Zealand sample, $\text{Log } Y = \bar{3}.417 + 1.358\ X$. Despite the large value of k in the equation for the New Zealand sample, its standard error is such that it does not represent a significant departure from isometry, P being greater than 0.1.

The index of intergradation (Fig. 1) is 26.0, slightly above the upper limit of subspecific distinction but well below the lower limit given by Ginsburg (1938) for racial differences. On the basis of this measurement alone it is possible to separate about 26% of the New Zealand fish from the Peruvian fish but only 2.5% of the Peruvian fish from those of New Zealand. This gives a mean separation of a little more than 14%. Comparing the means for this measurement, it will be observed that they and their standard errors are well apart, indicating a real difference. However, the standard deviations overlap to some extent, suggesting that the difference is of less-than-subspecific degree. Nevertheless, the base of the second dorsal fin tends to be slightly but distinctly shorter in the Peruvian specimens.

Length of base of first anal fin. For this characteristic, the equation of the Peruvian sample is $\text{Log } Y = \bar{1}.566 + 0.853 \log X$; for the New Zealand sample, $\text{Log } Y = 0.192 + 0.684 \log X$. Again, despite the rather large departures from isometry indicated by the low values of k, the standard errors are also large and the degree of allometry is not significant. In the Peruvian sample, $P > 0.5$, and in the New Zealand sample $P > 0.4$.

The variance ratio of the two regressions is not significant nor is the difference between the slopes of the two equations. By contrast, the distance between the regression lines is significant at $P < 0.001$, with the anal base of the Peruvian specimens distinctly shorter than that of the New Zealand fish. A difference of this magnitude would occur less than once in a thousand times by pure chance if the two samples were drawn from the same population. There is thus a strong indication of a real difference between the two groups.

This conclusion is borne out by the graphic representation of the percentage proportions (Fig. 2). The index of intergradation is 22.0, equivalent to subspecific differentiation. However, the distributions about the means are such that this characteristic alone will

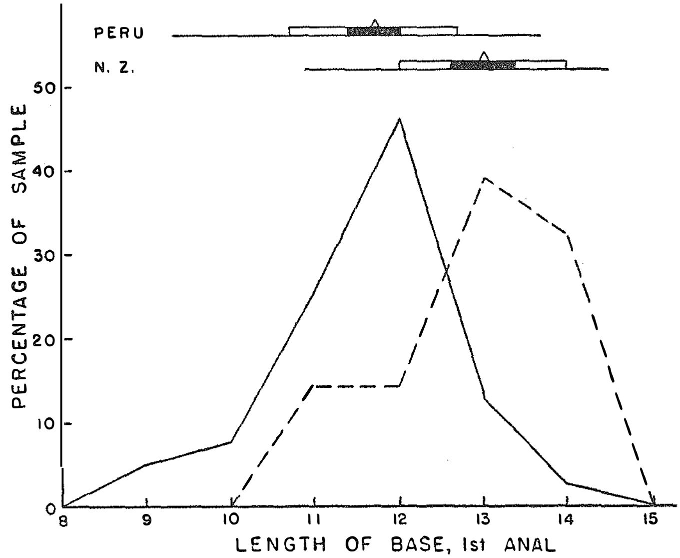

Figure 2. Distribution of the length of the base of the first anal fin, expressed as a percentage of the standard length. Solid line = Peruvian sample, broken line = New Zealand sample. Index of intergradation = 22.0.

not separate any of the New Zealand specimens from those of Peru and will separate only about 8% of the Peruvian fish from those of New Zealand. Examination of the standard errors and standard deviations shows that while the means are well spaced and must be considered significantly different, there is so great an overlap in the standard deviations as to indicate only a rather low degree of differentiation between the two samples.

Length of pelvic fin. This length does not appear to bear any particular relationship to the length of the fish among adult specimens. Careful examination of the data and plotting of the length of the fin against the length of the fish (Fig. 3) leads to the conclusion that after the fin reaches a certain size (within rather wide limits) it ceases to grow and thereafter maintains the same absolute length. Comparison of the length of the pelvic fin in the two samples is therefore based upon the absolute length of the fin without regard to the length of the fish.

The mean length of the pelvic fin in the Peruvian fish is 391.6 ± 7.8 mm; in the New Zealand sample, 319.6 ± 5.8 mm. The difference

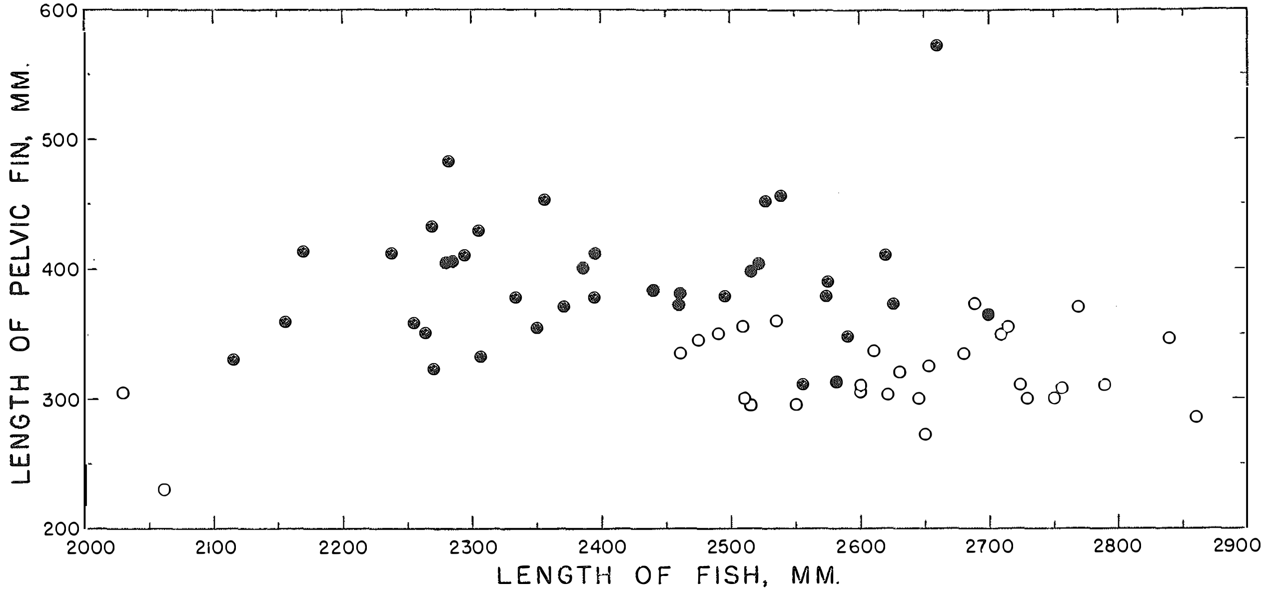

Figure 3. Length of the pelvic fin plotted against the standard length of the fish. Solid circles = Peruvian specimens, open circles = New Zealand specimens.

between the means, 72.0 mm, is significant at $P < 0.001$. Again it must be concluded that the two samples were not drawn from the same population.

Width of base of pectoral fin. The regressions of this measurement on the standard length are: for the Peruvian sample, $\text{Log } Y = \bar{1}.408 + 0.724 \log X$; for the New Zealand sample, $\text{Log } Y = \bar{3}.274 + 1.372 \log X$. The slopes of the two regressions suggest negative allometry in the Peruvian sample and positive allometry in the New Zealand fish. Neither one, however, is statistically significant, P being greater than 0.05 for each regression. The variance ratio is on the borderline of significance, with $P = 0.05$. Continuing the analysis, the slopes of the two regressions are distinctly different. Here $P < 0.01$ for the difference between the slopes. The width of the base of the pectoral fin thus increases much more rapidly relative to the standard length in the New Zealand fish than it does in the Peruvian fish.

Snout tip to origin of first dorsal. The equations representing the regression of this distance on the standard length are: for the Peruvian sample, $\text{Log } Y = 0.396 + 0.748 \log X$; for the New Zealand sample, $\text{Log } Y = \bar{1}.610 + 0.983 \log X$. The variance ratio of the two regressions is not significant. The difference between slopes approaches the 5% level of significance, with $P = 0.06$. The greatest difference was found in the distance between the regression lines, which is significant at $P < 0.01$. The origin of the first dorsal fin is slightly but distinctly nearer the snout in the Peruvian fish than it is in the New Zealand specimens.

Snout tip to origin of second dorsal. The two regression equations indicate but little difference between the two samples, although the distance between the lines may be of importance. The equation for the Peruvian sample is $\text{Log } Y = 0.191 + 0.928 \log X$; the New Zealand sample, $\text{Log } Y = \bar{1}.965 + 0.996 \log X$. The variance ratio is highly significant. The residual mean square of the regression for the Peruvian sample is nearly four times that for the New Zealand sample. Thus, although the form of the growth patterns of the two groups appears to be the same, the Peruvian fish show a much greater degree of variation.

There is no significant allometry in either regression, hence it is permissible to make a comparison of proportions. Expressed as percentage of the standard length, the mean snout to second dorsal fin distance is 88.5 in the Peruvian fish, 89.4 in the New Zealand fish. Although the difference is small, only 0.9%, it is significant at $P < 0.05$. The index of intergradation is about 22, within the range of subspecific distinction. However, the distribution of the observations is such that some doubt is cast upon the validity of this index here. Nevertheless, it appears that a difference in this characteristic does exist between the two samples.

Snout tip to origin of first anal. Here again, the variance ratio is highly significant, with the residual mean square of the Peruvian sample more than five times as great as the residual mean square of the New Zealand sample. The two regression equations are: for the Peruvian fish, $\text{Log } Y = 0.568 + 0.787 \log X$; and for New Zealand, $\text{Log } Y = \bar{1}.911 + 0.983 \log X$. It is probable that the slopes of the two regression lines are significantly different, but because of the significant variance ratio, this could not be tested. However, testing the degree of allometry shown by each equation indicates that the New Zealand fish must be considered as growing isometrically in this characteristic. On the other hand, the negative allometry indicated by $k = 0.787$ in the Peruvian sample is significant at $P < 0.01$.

Snout tip to posterior end of maxillary. This measurement, which might also be termed the total length of the upper jaw, produces regression equations in which the variance ratio and the difference between slopes are not significant. However, there is a significant distance between the lines. The equations are: for Peru, $\text{Log } Y = \bar{1}.906 + 0.822 \log X$; and for New Zealand, $\text{Log } Y = \bar{1}.536 + 0.982 \log X$. The total length of the upper jaw is thus slightly greater in the New Zealand fish than in those from Peru, and the difference is significant at $P < 0.01$.

Snout tip to posterior edge of operculum. The equations for the regressions of this characteristic on the standard length are; for Peru, $\text{Log } Y = 0.344 + 0.774 \log X$; and for New Zealand, $\text{Log } Y = \bar{1}.491 + 0.970 \log X$. The variance ratio is not significant. The difference between the slopes of the two equations, however, is significant at $P < 0.05$, indicating that in the Peruvian fish the head grows rather slowly relative to the length of the body. On the other hand, in the New Zealand fish, the growth rates of these two measurements are approximately equal. Thus there is a notable difference in the growth patterns of the two samples.

Anal count. The average number of spines and rays in the first anal fin differs in the two samples by approximately one element. In the Peruvian sample, the anal count varied between 14 and 17, with the mean at 15.03. The New Zealand fish had a range from 12 to 16, with the mean at 13.97. The difference, 1.06, is significant at $P < 0.001$. Even if the five New Zealand specimens with anal counts of only 12 (which might conceivably be the result of overlooking the last ray) are omitted, the mean count for the New Zealand fish is still only 14.28, and the difference between means is still significant at $P < 0.001$.

The distributions of the anal counts (Fig. 4) is such that while 32.4% of the New Zealand specimens can be distinguished as such on the basis of the anal count alone, only 2.6% of the Peruvian fish can be so set apart on the same basis, a mean separation of 17.5%. The

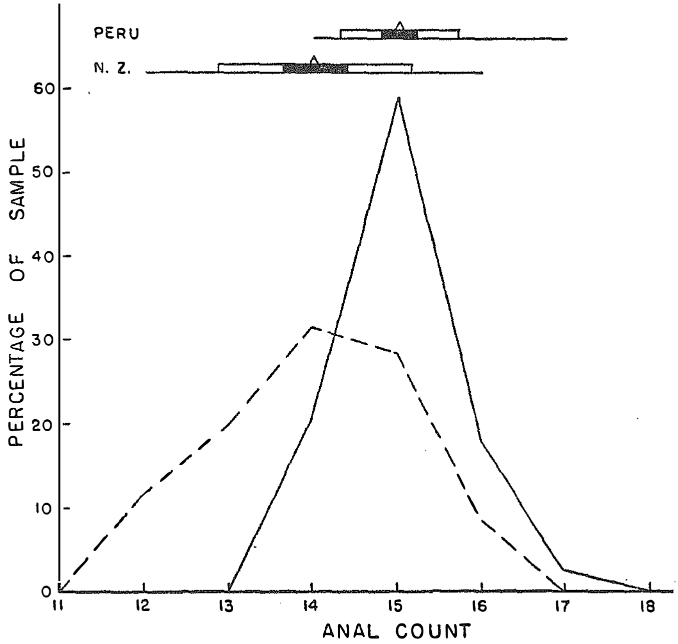

Figure 4. Distribution of the number of spines and rays in the first anal fin. Solid line = Peruvian fish, broken line = New Zealand fish. Index of intergradation = 26.9.

index of intergradation is 26.9, suggesting differentiation at about the racial level. It is quite certain, then, that the two samples represent separate populations with respect to the number of elements in the first anal fin.

Character Index. It is often convenient to have some means of distinguishing individuals with regard to the race or population to which they belong. Because of the relatively minute nature of racial differences, it is seldom that any single characteristic can provide such a distinction with any degree of reliability. However, character indices, essentially a summation of the small differences observed in several characteristics which result in a single larger difference, can sometimes provide a reasonably reliable indication of the group to which an individual specimen belongs. In an attempt to determine whether the Peruvian and New Zealand marlins could be separated in this manner, a number of character indices were constructed. The index producing the greatest degree of separation was composed of the following items:

$$\mathrm{CI} = \frac{\text{Pelvic length}}{10} - \frac{100}{\mathrm{SL}}\,[\text{Depth} + \text{Length of anal base} + \text{Width of pectoral base}].$$

A frequency distribution of the values of the character index for the two samples (30 fish from New Zealand and Australia, 39 from Peru) is given in Table III. There is a strong tendency for the New Zealand specimens to have character indices of considerably lower numerical value than do those specimens from Peru. All told, about 72.5%

TABLE III. FREQUENCY DISTRIBUTIONS OF THE CHARACTER INDEX FOR 30 FISH FROM NEW ZEALAND AND FOR 39 FISH FROM PERU

	Below −5.9	−5.0 to −5.9	−4.0 to −4.9	−3.0 to −3.9	−2.0 to −2.9	−1.0 to −1.9	0.0 to −0.9
Peru	0	0	0	0	0	0	0
N. Z.	1	2	4	4	4	4	3

	0.1 to 1.0	1.1 to 2.0	2.1 to 3.0	3.1 to 4.0	4.1 to 5.0	5.1 to 6.0	6.1 to 7.0
Peru	1	1	2	1	3	3	3
N. Z.	1	2	3	0	1	1	0

	7.1 to 8.0	8.1 to 9.0	9.1 to 10.0	10.1 to 11.0	11.1 to 12.0	12.1 to 13.0	Over 13.0
Peru	4	4	2	2	6	2	5
N. Z.	0	0	0	0	0	0	0

of the individual specimens can be designated as having come from one region or the other, with only 27.5% that cannot be placed in their proper group. Stated differently, if the two samples were mixed and the individuals were sorted by means of this character index, about seven out of ten specimens would be correctly placed. (Choosing different mid-points for the class intervals results in a slightly different distribution, but this does not have any pronounced effect on the conclusions.)

It must be pointed out, however, that the validity of this character index depends upon the limitation of its application to specimens falling within the size limits on which the index was constructed (2030 to 2860 mm standard length). The presence of allometric growth in the depth of the body of the specimens in the Peruvian sample would render the index useless if it were extended too far beyond these limits towards the smaller individuals.

SUMMARY

Measurements and fin ray counts of 39 fish from Peru and 79 from New Zealand and Australia have been compared to determine whether or not racial differences could be detected. Statistically significant differences were found between samples in the regressions of the following measurements on standard length: Greatest depth of body; length of base of second dorsal fin; length of base of first anal fin; width of base of pectoral fin; snout tip to origin of first dorsal fin; snout tip to origin of second dorsal fin; snout tip to origin of first anal fin; snout tip to posterior edge of operculum; tip to posterior end of maxillary.

Evidence indicates that the length of the pelvic fin is not related to the length of the fish in adults and that the pelvic stops growing after reaching a certain length. The average length of the pelvic is significantly different in the two samples.

The average count of the spines and rays in the first anal fin was 15.03 for the Peruvian fish, 13.97 for the New Zealand specimens. The difference is highly significant.

A character index constructed from the sum and difference of four characteristics resulted in a mean separation of 72.5% of all specimens into their respective geographical groupings.

Small but significant differences having been found in 11 separate characters, and a better than 70% separation having been obtained

by the use of a character index, it is concluded on the basis of these data that the two samples represent separate and distinct populations of the species.

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Джемс Е. Морро (в)

Рассы *Makaira mitsukurii* в Тихом Океане

Краткий обзор

Статистический анализ некоторых морфометрических измерений и сегментных признаков показал что *Makaira mitsukurii* из Перу и из северной Новой Зеландии представляют особые населения. Приблизительно 7 из 10-ти экземпляров в перемешанном образце из этих двух местностей могут быть правильно отнесены к их местонахождению по указателям их признаков. Дано доказательство тому что брюшные плавники, достигнув определенной длины, больше не растут и что поэтому их длина не имеет соотношения с длиной взрослой рыбы.

ON THE MORPHOLOGY OF THE PECTORAL GIRDLE IN THE GENUS *MAKAIRA*

By

JAMES E. MORROW

ABSTRACT

The pectoral girdles of two Atlantic and four Pacific species of *Makaira* are described in detail and compared. The pectoral fin of *M. m. marlina* and *M. m. tahitiensis* is supported by a rigid three point suspension which prevents the fin from being folded. In the remaining four species, the articulation is such that the fin can be folded and rotated freely. The rigid pectoral fin is a valid diagnostic characteristic for *M. m. marlina* and *M. m. tahitiensis*, separating them from all forms with folding pectorals. Although *M. a. mazara* and *M. a. ampla* cannot be distinguished on the basis of external features, their pectoral girdles show such differences as to indicate that these forms are at least subspecifically distinct. The recent specific taxonomy of the six species is discussed briefly.

INTRODUCTION

A study of fishes in the genus *Makaira* is made difficult not only because it is impossible to preserve specimens of such size in the ordinary manner, in alcohol or formalin, but also because they are generally rather difficult to obtain for study. In most parts of the world where they are found they are not the objects of large comcomercial fisheries. While there are numerous localities where sport fisheries bring in marlin, even here it is often difficult to obtain specimens for detailed examination. Therefore we know little about the internal anatomy of the members of this group. So scanty is our knowledge of the marlins that, even today, over 150 years following the first description and with the benefit of LaMonte's (1955) recent revision, there is no agreement as to the number of species to be recognized nor on the characteristics on which such recognition can be based.

One of the characteristics around which controversy has centered is the rigid or nonrigid nature of the joint of the pectoral fin. In at least one species, the Black Marlin of English-speaking sport fishermen, the pectoral fin is held rigid at right angles to the body and cannot be folded flat without breaking the joint. In most if not all of the other species, the pectoral fin folds flat against the body in the normal manner characteristic of most fishes. This matter was noted by Gregory and Conrad (1939), was mentioned briefly in passing by LaMonte and Marcy (1941), and was subsequently ignored in the literature until LaMonte's (1955) recent monograph was published. In her publication the question of the utility of this characteristic has been reopened with the statement, "This character, it will be noted, is a movement, not an anatomical structure. It may be proved, however, that the whole pectoral complex of bones, tendons, and muscles in some way prevents the fin from being brought flat against the body. In this case, the rigid pectoral will be the chief diagnostic character for this species . . ." The present work was begun some time before publication of LaMonte's paper; nevertheless, as a result of discussions with her, it was with this idea in mind that the present study was conceived and carried out.

MATERIALS

The following material has been available for dissection and examination:

Makaira marlina marlina Jordan and Hill. Black Marlin

One girdle from a fish taken in the central Pacific Ocean; 2635 mm S. L., 291 lbs.

One girdle from a small fish taken off Sydney, Australia; no data.

Two girdles from fish taken at Cabo Blanco, Peru; one 3268 mm S. L., 648 lbs, ♀; the other 1860 mm S. L., 108 lbs, immature ♀.

Makaira marlina tahitiensis (Nichols and LaMonte) ? Silver Marlin (?); Shirokajiki

Three girdles sent from Misaki and Tokyo, Japan; no data.

Makaira mitsukurii (Jordan and Snyder). Striped Marlin

Two girdles from specimens taken at the Bay of Islands, New Zealand (girdles and other parts preserved in formalin); one 2415 mm S. L., 186 lbs, ♂; the other 2550 mm S. L., 216 lbs, ♀.

Four fresh specimens from Cabo Blanco, Peru, examined in the field; 2306 to 2660 mm S. L., 2♂♂, 2♀♀.

Makaira ampla mazara (Jordan and Snyder). Pacific Blue Marlin

One girdle from a fish taken at Máncora, Peru; 3020 mm S. L., ♀.

One girdle from a fish taken in the central Pacific; 2858 mm S. L., 376 lbs, ♀.

One girdle from a fish landed at Misaki, Japan; dressed weight 140.6 kg; no other data.

One girdle sent from Tokyo, Japan; no data.

Makaira ampla ampla (Poey). Atlantic Blue Marlin

Two girdles from specimens taken near Miami, Florida; both adults; no other data.

Makaira albida (Poey). White Marlin

Two girdles from fish taken off Montauk Point, L. I., N. Y.; both adults; no other data.

Although it is apparent that there is considerable variation in the absolute size of the specimens examined and that size data are not available for some of the material, it is known that all except the two smallest *M. m. marlina* were adults. The smallest *M. m. marlina* was an immature female and there is no data on the other. The Japanese material, judging by its size, was from young adults. The pectoral girdle of the smaller *M. a. ampla* is quite comparable in size to that of the smallest *M. m. marlina,* while that of the larger is about equal in size to the girdle of the largest *M. mitsukurii.* The white marlin, *M. albida,* being a much smaller fish than the others, has bones that are correspondingly smaller. Inasmuch as corresponding developmental stages are available in all species examined, it is felt that a direct morphological comparison of the several forms is valid and that differences in absolute size do not invalidate the observations.

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the assistance of those who helped to secure the material used in this study: Mr. and Mrs. Wendell W. Anderson, Detroit; Mr. and Mrs. Charles P. Sagar, Short Hills, N. J.; Capt. R. W. Fagen and Mr. Al Pflueger, Miami; Mr. Ralph Morrill, New Haven; Dr. William F. Royce, Juneau, Alaska; Miss Francesca LaMonte, New York; Messrs. D. Bates and C. Colmeier, Máncora, Peru; Mr. S. Kip Farrington, New York; Mr. T. Bates, Talara, Peru; Col. John K. Howard, Miami; Dr. N. Y. Kawamoto, Tsu, Japan; Mr. Susumu Sugano, Yokosuka, Japan; and Dr. T. Abe, Tokyo, Japan.

THE PECTORAL GIRDLE—GENERAL

In fishes of the genus *Makaira*, the gross appearance of the pectoral girdle does not differ significantly from the typical teleost condition (Starks, 1930). The complex of three bones—coracoid, cleithrum, and scapula—is roughly triangular, with the apex of the triangle forward at the junction of the coracoid and cleithrum. Posteriorly, both coracoid and cleithrum expand dorsoventrally, the space between them being filled by the scapula. The girdle lies at an angle of about 45° to a vertical plane through the midline of the body, with its dorsal edge outward.

The coracoid is narrow anteriorly and broadens posteriorly. Lying in the body at an angle of about 45° from the vertical, its anteroposterior length is roughly twice its height. The bone is generally triangular, with the base of the triangle towards the posterior end of the body. It articulates anteriorly with the cleithrum and posteriorly with the cleithrum and scapula. The posterior portion of its ventral edge is expanded into a flat and more or less triangular process. Above this process is a conspicuous ridge extending from the scapula downward and forward towards the ventral edge of the coracoid.

In its anterior and ventral portion, a cross-section of the cleithrum is shaped like an inverted V, with the medial leg of the V providing the articulations with the coracoid and scapula. Dorsal to the scapula, the cleithrum is expanded into a broad blade extending posteriorly; the shape of this blade varies notably with different species. Dorsal and anterior to the blade is a prominent process.

The scapula is much smaller than either of the other two bones and is generally triangular in shape when viewed from the medial aspect. On or beside its posterior edge on the lateral aspect are the articulating surfaces for the pectoral rays and actinosts. Near its center, on the medial side, the scapula is pierced by the scapular foramen, but the shape of the bone and the angle of the foramen are such that on the lateral aspect the foramen lies close to the anterior edge of the bone. In some species, the anterior edge of the foramen may be formed by the cleithrum rather than by the scapula.

THE CORACOID

The coracoid of *M. m. marlina* (Fig. 1A) and of *M. m. tahitiensis* is characterized by the shortness of the ridge on its posterior portion and by the more or less horizontal, almost upturned, posterior process.

The coracoid ridge is massive and heavy, curving downward and forward and disappearing at or near the posterior third of the ventral edge of the bone. It is broadly and shallowly undercut on its anterior side. The posterior process is smoothly rounded ventrally, abruptly so posteriorly. In its most posterior extension, it is traversed by a horizontal ridge which is conspicuous in large specimens but less so sometimes in small ones. The dorsal edge of the posterior process is more or less horizontal or even angled slightly upward. The space between the coracoid and cleithrum, forward of the scapula, is larger than that in any other species examined. There is a shallow notch on the middle third of the ventral edge of the coracoid. In *M. m. tahitiensis* this notch is deep posteriorly and becomes shallow at its anterior end.

In *M. mitsukurii* (Fig. 1B) the coracoid ridge is not as massive as in *M. m. marlina* and is noticeably longer, extending nearly to the anterior end of the bone. The undercut on its anterior side is broad and shallow but deeper than in *M. m. marlina.* The posterior process is abruptly terminated and is pointed downward rather than horizontally or upward. The ridge on the posterior process is inconspicuous. The space between the coracoid and cleithrum is not large. The notch on the ventral edge of the coracoid, while shallow, is distinctly demarcated and occupies somewhat more than the middle third of the edge of the bone.

The coracoid ridge of *M. a. mazara* (Fig. 1C) is much less massive than that in the two preceding species and is deeply undercut on its anterior side. It extends in a slight curve from the lower posterior corner of the scapula to the posterior third of the ventral edge of the coracoid. There is a small protuberance of the ventral edge at this point. A little more than halfway down the edge of the ridge there arises a smaller narrow ridge which reaches the ventral edge of the coracoid near the middle of the notch and then runs along the ventral edge of the bone to the anterior end of the notch. The posterior process is nearly straight on its ventral edge, is abruptly rounded posteriorly, and extends backward at approximately the same angle as in *M. m. marlina.* The ridge on the posterior process is narrow and conspicuous and forms the posterior part of the dorsal edge of the process. The space between the coracoid and the cleithrum is small but extends nearly the entire distance between these two bones. The notch on the ventral edge of the coracoid, deeper than that in either

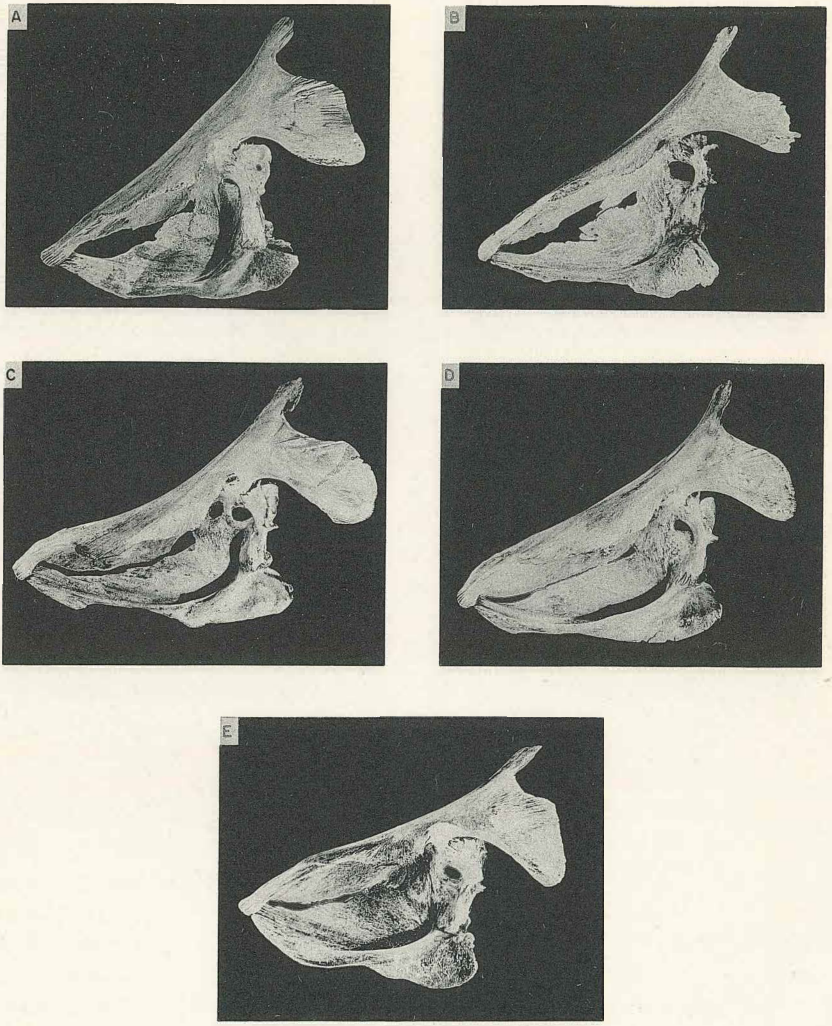

Figure 1. The pectoral girdles of five species of *Makaira* seen from the lateral aspect. A. — *M. m. marlina.* B. — *M. mitsukurii.* C. — *M. a. mazara.* D. — *M. a. ampla.* E. — *M. albida.*

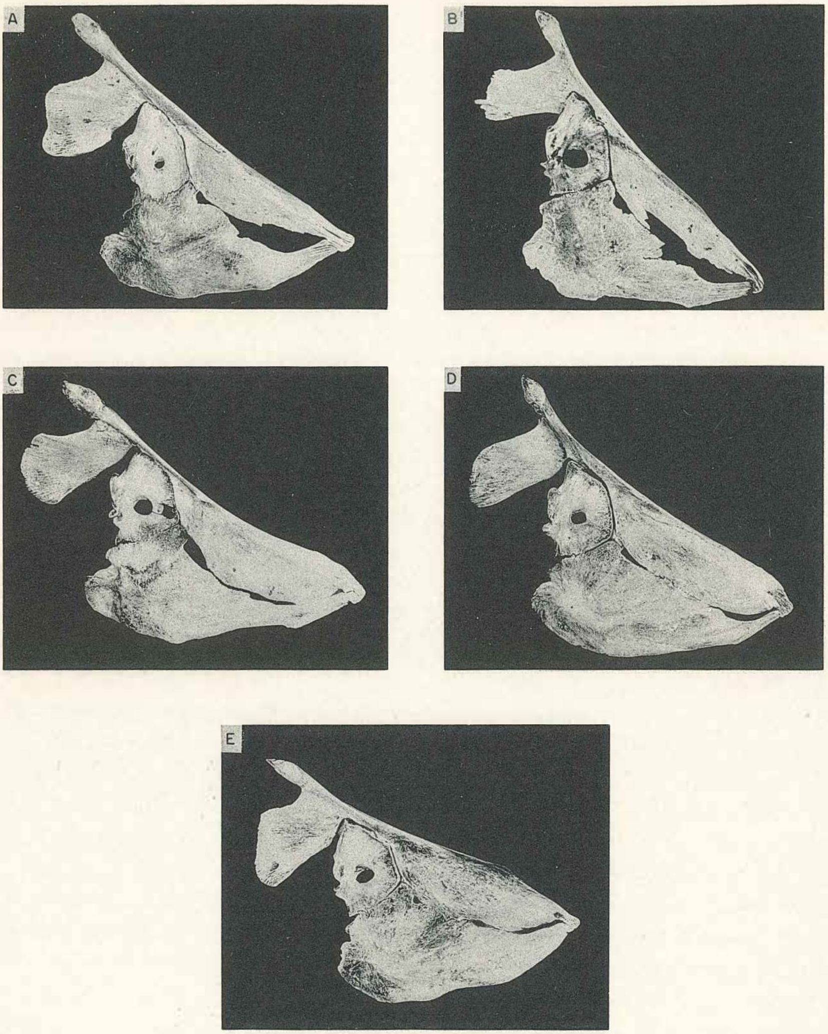

Figure 2. The pectoral girdles of five species of *Makaira* seen from the medial aspect. Lettering as in Fig. 1.

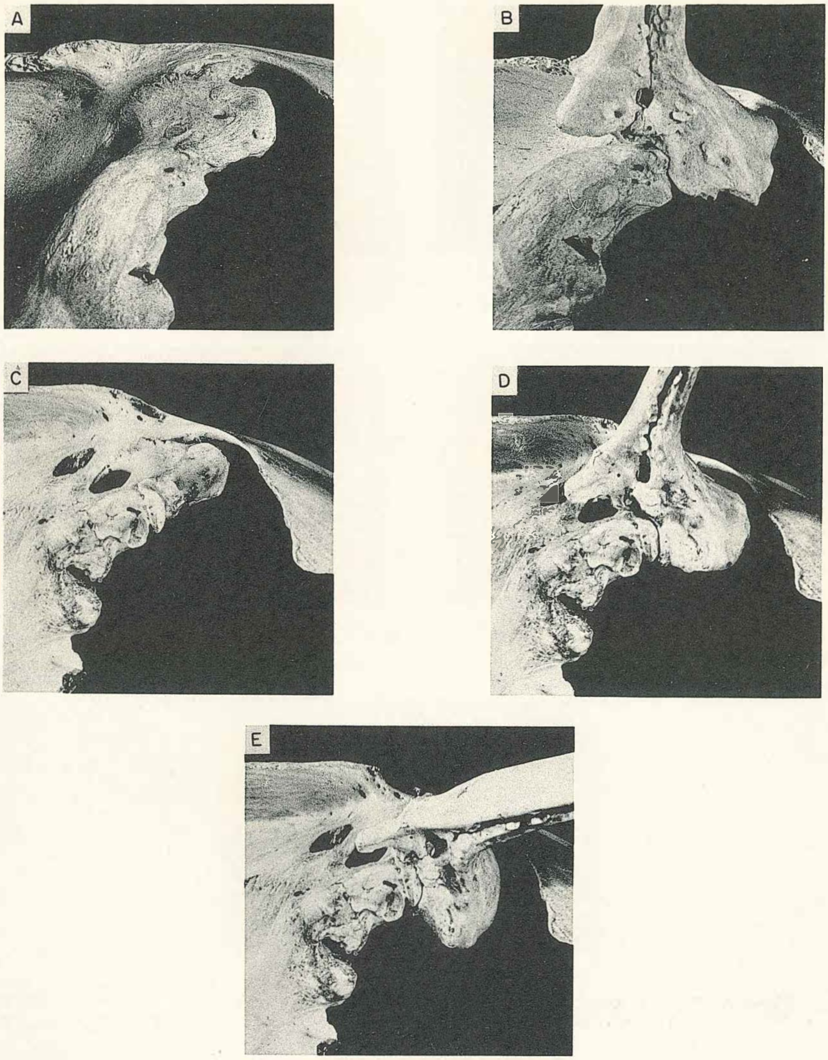

Figure 3. Articulation of the first pectoral ray with the pectoral girdle. A. — Scapula of *M. m. marlina* showing articular surfaces (see text). B. — Scapula and first pectoral ray of *M. m. marlina.* C. — Scapula of *M. a. mazara* showing articular surface. D. — Scapula and first pectoral ray of *M. a. mazara* with ray in erect position. E. — Same as D., with ray in folded position. See text for discussion.

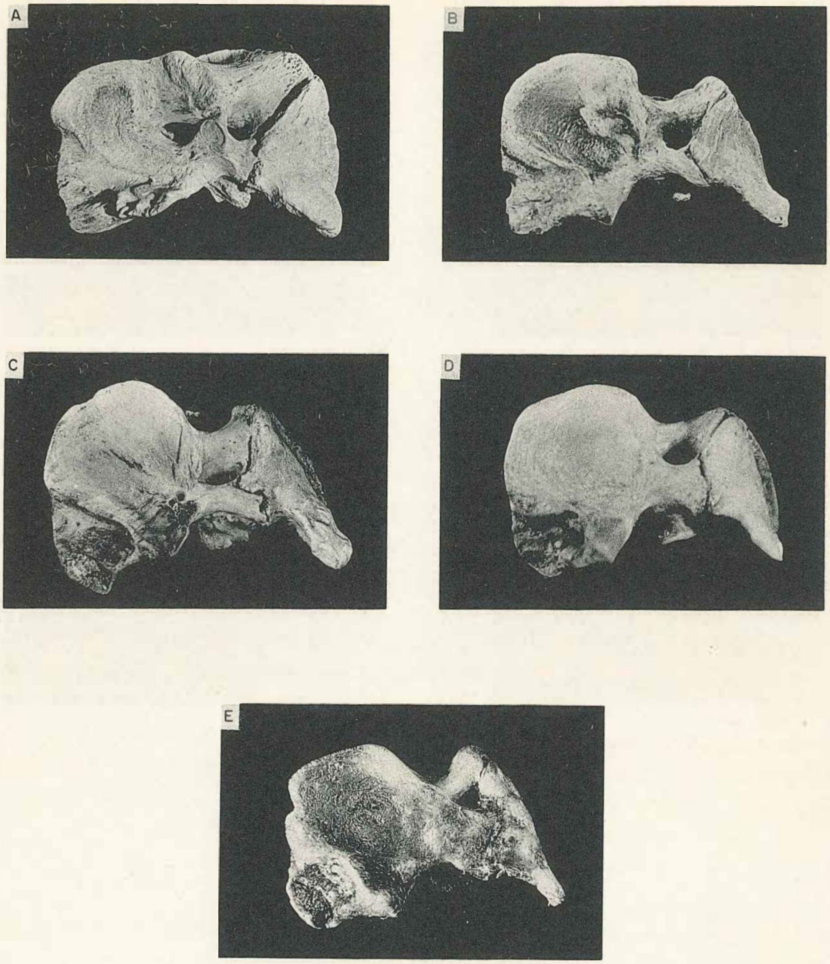

Figure 4. The basal ends of the first pectoral rays of five species of *Makaira*. The posterior side of each ray is toward the bottom of the page. Lettering as in Fig. 1. See text for discussion.

of the two preceding species, is sharply defined and occupies the middle and part of the anterior third of the ventral edge of the bone.

In *M. a. ampla*, the Blue Marlin of the Atlantic (Fig. 1D), the coracoid ridge is slender and deeply undercut on its anterior side. The heavier portion of the ridge does not reach the ventral edge of the bone. The upper edge of the ridge continues forward and downward, paralleling the ventral edge of the coracoid to its center or a little further forward, where the ridge disappears without reaching the ventral edge of the bone. The ventral edge of the posterior process is gently curved and abruptly rounded posteriorly; the process does not reach the horizontal in its backward extension. The ridge on the posterior process is low, broad and fan-shaped. The notch on the ventral edge of the bone is somewhat forward of the middle third and is but poorly defined. The space between the coracoid and cleithrum is reduced to a slit and is completely occluded for most of its length.

The coracoid ridge of the White Marlin, *M. albida* (Fig. 1E), most closely resembles that of *M. mitsukurii.* It is only moderately heavy and is moderately and broadly undercut on its anterior side; it curves downward and forward to disappear near the middle of the bone before reaching the ventral edge. The posterior process is slightly irregular on its ventral edge, abruptly curved posteriorly. It points distinctly downward. The ridge on the posterior process is low, rather broad, and inconspicuous. The notch on the ventral edge of the coracoid, approximately at the center, is more or less V-shaped and rather poorly defined. The space between the coracoid and cleithrum is small. The anterior end of the coracoid of *M. albida* is much broader than that in any other species examined.

THE CLEITHRUM

The anterior portion of the cleithrum, as mentioned previously, is V-shaped in cross-section. In *M. m. marlina* (Fig. 1A) and *M. m. tahitiensis*, the anterior edge (the apex of the V) is nearly straight throughout most of its length. The outer limb arises slightly posterior to the origin of the medial limb and curves smoothly backward and upward in a broad S-shaped curve. There is a distinct process near the posterior end, prominent and hooked in small specimens. The angle formed by the two limbs is between 80° and 90°; the inner aspect of this angle is broadly rounded. The lower margin of the blade of the cleithrum is a slight double curve and the ventral corner is quite sharp. The posterior margin is straight or slightly indented, the dorsal corner broadly rounded. The dorsal edge of the blade is nearly straight distally and curves smoothly upward to meet the dorsal process articulating with the supracleithrum. This process is but slightly expanded. On the medial side of the anterior edge of the cleithrum, distinctly forward of the anterior edge of the scapula, is a small blunt process (Fig. 2A).

In *M. mitsukurii*, the anterior edge of the cleithrum is slightly curved (Fig. 1B) and its lower portion is rounded rather than angular. The outer limb has a heavy thickened anterior portion with a slight projection anteriorly. The margin of the outer limb extends backward in a smooth curve. The angle between the two limbs is about 94°; its inner aspect is narrowly rounded. The lower margin of the blade, though nearly straight, curves slightly downward toward the ventral corner, which is abruptly rounded. The posterior margin of the blade is broadly rounded, as is the dorsal corner. The dorsal margin is also nearly straight and is not parallel to the ventral margin, the blade thus being slightly broader basally than distally. The dorsal edge of the blade near the base curves sharply to meet the dorsal process, which is slender and scarcely expanded. The small process on the medial side of the anterior edge of the cleithrum is moderately sharp and is located only slightly before the anterior edge of the scapula (Fig. 2B).

The anterior edge of the cleithrum of *M. a. mazara* (Fig. 1C) is distinctly curved throughout its length in sharp contrast to the condition in *M. m. marlina*. The lower portion bears a sharp, prominent crest. The distal limb of the cleithrum begins abruptly near the posterior end of this crest and is somewhat thickened and enlarged anteriorly. The margin of the distal limb is distinctly indented near its middle, smoothly rounded posteriorly. The angle formed by the two limbs is 69° to 74°; its inner aspect is acutely rounded. The blade of the cleithrum is distinctly narrower near its base than distally; both the dorsal and ventral margins curve outward. The posterior margin is broadly rounded throughout, so that it can hardly be said that there is a dorsal and a ventral corner. The dorsal process is heavy and is distinctly expanded on its posterior side. The process on the medial side of the anterior edge of the cleithrum is sharp and well defined and is placed well before the anterior edge of the scapula (Fig. 2C).

The anterior edge of the cleithrum of *M. a. ampla* (Figs. 1D and 2D) is curved, somewhat more so in the larger than in the smaller specimen. A sharp crest is present on the lower portion of the anterior edge. The anterior origin of the distal limb, near the anterior end of this crest, is not particularly abrupt; the anterior process is small and inconspicuous and the anterior portion of the limb is but slightly thickened. The margin of the distal limb is a single smooth curve without indentations. The angle between the two limbs is between 55° and 65° and its inner aspect is sharp. The ventral edge of the blade is nearly straight, the ventral corner quite sharply rounded. The posterior edge of the blade is scarcely curved, the dorsal corner broadly rounded. The dorsal margin is nearly straight and approximately parallel to the ventral margin. It curves rather abruptly into the dorsal process, which is slender and only slightly expanded. The process on the medial side of the cleithrum is sharp (Fig. 2D). There is a slight bulge in the anterior margin of the cleithrum at this point, which is distinctly before the anterior margin of the scapula.

The anterior margin of the cleithrum is bent downward more noticeably in *M. albida* than in any other species examined (Figs. 1E and 2E). The lower portion of the angle between the limbs of the cleithrum is rounded, becoming sharp and angular just before the process on the medial side. The sharp portion of this edge is slightly curved. There is no anterior process on the distal limb, but the anterior portion is markedly thickened. The margin of the distal limb is slightly indented near the middle, and there is a small broad posterior process on this limb. The angle between the limbs is 85° to 90°; its inner aspect is broadly rounded. The ventral edge of the blade is nearly straight, the ventral corner abruptly rounded. The posterior edge is nearly straight, the dorsal corner rather abruptly rounded; the dorsal margin curves quickly into the dorsal process, which is slender and not expanded. The process on the medial side of the anterior edge of the cleithrum is small and, as in *M. a. ampla,* it obtrudes slightly into the margin. It is placed only slightly forward of the anterior edge of the scapula (Fig. 2E).

THE SCAPULA

The medial surface of the scapula of all species is smooth and slightly concave, and from this aspect the bone is roughly triangular in outline, with each edge slightly convex (Fig. 2, A-E). From the lateral aspect, the scapula is elongated dorsoventrally and its outlines are extremely irregular. On its ventral portion lies a large heavy ridge, matching and joining the corresponding ridge of the coracoid.

In *M. m. marlina* and *M. m. tahitiensis* the scapular foramen is small, smaller in fact than in any other species examined, and it is located slightly below the center of the bone. It is longer than high, its anteroposterior diameter being 1.5 to 2.6 times its vertical diameter; this ratio appears to increase with the size of the individual. The greatest length of the foramen is 13 to 17% of the height of the scapula and the ratio appears to bear no relationship to gross size. The articular surface for the first pectoral ray lies on the upper portion of the lateral aspect of the scapula, at the posterior margin. It does not extend around to the posterior margin itself but is confined entirely to the lateral side of the bone. The main articular surface is broad above, narrowing sharply below. One or a group of several small foramina are found immediately in front of and behind the center of the articular surface. These were not observed in any other species examined. Near the lower end of the main articular surface are two small bony pads (cartilaginous in small specimens) which, combined with the flat main surface, support the first pectoral ray in a rigid three-point suspension and effectively prevent folding of the pectoral fin. Below and behind the main articular surface lie two small ridges in the same plane on the posterior edge of the scapula. These two ridges articulate dorsally with the median posterior process of the first pectoral ray and ventrally with the actinosts. In this position, the inner of the two ridges bears against the median posterior process of the base of the first pectoral ray in such a way as to prevent the fin from twisting. The whole articular complex is shown and compared with another species in Fig. 3.

Except for variations in size and shape of the scapular foramen, which appear to be specific, the scapulae of all remaining species of *Makaira* are so similar that a single description should suffice for all. As with *M. m. marlina* the scapular foramen is located slightly below the center of the bone. On the outer surface, the ridge is of the appropriate size and weight to meet and match the ridge of the coracoid (*vide supra*). Excepting *M. m. marlina* and *M. m. tahitiensis*, the scapular foramen is smallest in *M. a. ampla* and is largest in *M. mitsukurii*. The proportions are shown in Table I.

TABLE I. PROPORTIONAL RELATIONSHIPS OF THE SCAPULAR FORAMEN IN SIX SPECIES OF *Makaira*.

	$\frac{\text{length of foramen}}{\text{height of foramen}}$	$\frac{\text{length of foramen}}{\text{height of scapula}} \times 100$
M. m. marlina	1.50–2.59	13.4–16.0
M. m. tahitiensis	1.47–1.86	13.4–17.0
M. mitsukurii	1.47–1.60	22.1–24.0
M. a. mazara	1.22–1.53	(14.8) 19.5–22.5
M. a. ampla	1.28–1.64	15.9–18.1
M. albida	1.63–1.69	19.0–19.5

The scapular foramen of both *M. a. mazara* and *M. mitsukurii* lies close to the anterior edge of the scapula on the outer aspect; actually it lies so close that a portion of the anterior edge of the foramen is formed by the cleithrum. In *M. a. ampla* and *M. albida*, the foramen is not so close to the anterior edge of the scapula and the cleithrum does not enter the anterior edge of the foramen.

The articular surface for the first pectoral ray lies at the upper posterior margin of the scapula. In all species except *M. m. marlina* and *M. m. tahitiensis* (*vide supra*), this surface occupies part of the lateral surface of the bone and is continued on to the posterior edge. Bony secondary pads are absent, as are the foramina described under *M. m. marlina.* At the lower edge of the articular surface, the two small ridges are not in the same plane, the inner one being below the outer. This forms a groove in which the median posterior process of the first pectoral ray can move and permits free folding and rotation of the fin (see Fig. 3).

THE FIRST PECTORAL RAY

The basal end of the first pectoral ray of *M. m. marlina* and *M. m. tahitiensis* is roughly rectangular (Fig. 4A). The main portion of the articular surface lies on the upper third and corresponds in shape to the articular surface of the scapula. At the lower end of this surface are two bony or cartilaginous pads which articulate with the corresponding pads on the scapula. Above and below these pads are two rather large foramina. The median posterior process is broad. The ventral portion of the end of the ray, which is the area of attachment for several large muscles, is triangular, and its lateral and ventral corner is produced into a heavy blunt process.

As with the scapula, the basal ends of the pectoral rays of the remaining species are so similar that individual discussion is not necessary (Fig. 4, B-E). The dorsal portion, which includes the main articular surface, is nearly circular. The articular surface itself occupies nearly the whole of this area. Cartilaginous or bony pads are absent. There is a single large foramen. In *M. a. mazara* there is also a small foramen slightly anterior and dorsal to the large one. In all except *M. albida,* the large foramen is contained entirely within the dorsal portion of the ray, but in *M. albida* this foramen is placed further ventrad so that the lower third of its margin is formed by the ventral portion of the ray. The median posterior process is narrow and pointed. The lower portion of the end of the ray is triangular, but its ventral corner is more slender and attenuated than in *M. m. marlina.*

DISCUSSION AND CONCLUSIONS

The articulation of the pectoral fin of *M. m. marlina* and *M. m. tahitiensis* is supported by a rigid suspension that effectively prevents the fin from being twisted or folded flat against the body. This is a matter of anatomy and not merely of movement. Hence the rigidity of the pectoral fin at once sets off *M. m. marlina* and *M. m. tahitiensis* from all other species examined and may be used as the chief diagnostic character for the species group. It is hoped that this will serve to clarify the uncertainties on this point that have recently appeared in the literature (LaMonte, 1955; Smith, 1956).

Although it is beyond the scope of this paper to go deeply into matters of taxonomic synonymy, it may be advantageous to explain briefly the reasons for the use of several of the specific names of marlins employed here. *M. mitsukurii* is clearly identified as the Striped Marlin of the Pacific. Although there is no doubt that the name *M. audax* (Philippi) actually has priority in point of time, LaMonte (1955) has given cogent reasons, with which we concur, for retaining at least temporarily the specific name *mitsukurii.*

The species here designated as *M. m. marlina* was described by Jordan and Hill (1926; 59–60) in such general terms that the identification of specimens with their description is well nigh impossible. However, they included a photograph which is clearly that of a Black Marlin and which shows not only the pectoral fins held stiffly away from the sides of the body but certain other pertinent characters as well. Since the rigid pectoral fin is now shown to be a valid diagnostic characteristic for this species, the Black Marlin must take the specific name *marlina.*

A point which merits further discussion is the identity of the fish known in Japan as Shirokajiki, designated in this paper as *M. m. tahitiensis.* Nakamura (1938) described the Shirokajiki as *Makaira marlina* Jordan and Hill. His illustration of the pectoral girdle of the Shirokajiki cannot be distinguished from our Black Marlin material, although slight differences between the two have been described in the present paper. LaMonte (1955), quoting a communication from Dr. T. P. Koh in Formosa, notes that the Shirokajiki is whitish in color whereas the Black Marlin is normally deep bronze to slatey blue-black. The same information was sent to us by Dr. T. Abe from Tokyo. The white skin is said to be characteristic also of the Tahitian Silver Marlin described by Nichols and LaMonte (1935). Consequently, LaMonte (1955) considered the Shirokajiki and the Tahitian Silver Marlin to be identical, and she tentatively included both in the subspecies *tahitiensis.* She also suggested that the white skin might be caused by hormonal imbalance in an ordinary Black Marlin. The differences between the Shirokajiki and the Black Marlin, as observed in the bones of the pectoral girdle, are rather minute, so that if LaMonte's suggestion as to the cause of the white color should prove correct, there would be no reason to separate the two forms. However, pending results of further investigations, it seems best to retain them provisionally as subspecies. In accordance with the specific nomenclature used here, then, the names for the Black and Silver marlins should be, respectively, *Makaira marlina marlina* Jordan and Hill and *Makaira marlina tahitiensis* (Nichols and LaMonte).

The Pacific Blue Marlin, *M. a. mazara,* was described by Jordan and Snyder (1901). As with the black marlin, the description was in such general terms as to make it difficult to identify specimens with the original description. Fortunately it was stated that the species was known to the Japanese as "Kurokajiki." Our Japanese material is identical with that from the central Pacific and Peru and identical also with the description and illustration of the pectoral girdle of the Kurokajiki given by Nakamura (1938).

Rivas (1956) has pointed out that Blue Marlins of the Atlantic and Pacific oceans cannot be distinguished on the basis of any of the external characteristics examined by him; he has therefore synonymized the two forms. However, in the light of the new evidence presented here, this view is no longer tenable. The morphological differences observed in the pectoral girdles show conclusively that Blue marlins of both oceans are at least subspecifically distinct. The proper names for the two forms are therefore *Makaira ampla ampla* (Poey) for the Atlantic form and *Makaira ampla mazara* (Jordan and Snyder) for the Pacific.

In the past there has been considerable uncertainty as to whether or not the Black Marlin, *M. m. marlina,* and the Blue Marlin, *M. a. mazara,* were actually separate species. Except for the rigid pectoral fin and one or two other less sharply defined characters, these two species are not at all dissimilar in their external appearance. Further, the descriptions by Jordan and his co-workers are so poor that the two species can hardly be separated on that basis. LaMonte (1955) discussed this matter in considerable detail but wisely left definite conclusions to the results of further investigation. By contrast, Smith (1956) states, "In my view, in the Indo-Pacific these two forms are not yet acceptable at full specific rank . . ." With this we must emphatically disagree. The evidence which has been presented here shows without a question of doubt that *M. a. mazara* and *M. m. marlina* cannot possibly be considered as conspecific.

In conclusion, it is pointed out that there are a number of specific names which, in point of time, have priority over those used here. However, many of the older descriptions are so inadequate and inaccurate that it has not been possible to identify them with any degree of certainty. Despite this fact, publications have appeared recently in which these old names are assigned to currently known species, even though at least one author admitted that he had never seen most of the forms he was naming. For the present it is far better practice to employ those names which can definitely be assigned to recognized forms and to leave the question of priority to the results of investigations planned for the future.

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Джемс Е. Морро (в)

К морфологии плечевого пояса у *Makaira.*

Краткий обзор

Плечевой пояс двух Атлантических и четырех Тихоокеанских видов *Makaira* описан подробно и подвергнут сравнению. Грудной плавник *M. m. marlina* и *M. m. tahitiensis* прикреплен к неподвижной подвеске в трех пунктах делающих сгибание плавника невозможным. Неподвижный грудной плавник важный диагностический признак отделяющий их от всех видов с подвижными плавниками. Хотя *M. a. mazara* и *M. a. ampla* не могут быть отличены по внешним признакам, их плечевой пояс представляет такие отличия какие указывают на их принадлежность к другому подвиду. Дано краткое обозрение таксономии шести видов.

THE PERU CURRENT[1]

BY

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CONTENTS

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[1] Part of a thesis presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Yale University.

ABSTRACT

This study of the oceanography and related meteorology of the Peru Current and of the phenomenon commonly called El Niño is based primarily on results of the Yale South American Expedition to Peruvian waters between March 10 and May 21, 1953. Sea water observations included temperature, salinity, oxygen, phosphate, nitrate, plant pigments, phytoplankton, and zooplankton. Additional observations which have been of value in this study but which are not reported here are available at the Bingham Oceanographic Laboratory; these included water transparency, air temperature, atmospheric pressure, wind force and direction, humidity, cloud cover, and visibility. The rate of photosynthesis and the effect of added nutrients on growth were ascertained experimentally.

In mid-March and again in early April El Niño occurred along the Peruvian Coast north of 6° S as a wedge of water which advanced southward over the northbound Peru Current. This tongue of water, advancing and retreating twice during the Expedition, was accompanied in its southerly advance by occasional rain, north winds, a southerly current, water temperatures exceeding 24° C, and salinities of less than 34‰. When typical northerly flowing, low temperature, and high salinity Peru Current water was present, the winds were southerly and there was no precipitation.

These conditions, together with faunal observations, indicate a southerly transport of water from more northerly regions, no doubt from the Equatorial Countercurrent and also probably from the region off Central America. It is not clear whether the water from these two northern regions formed separate layers of the wedge, one over the other, or became mixed as they moved down over the Peru Current.

Analysis of air pressure data obtained from the U. S. Weather Bureau for the period 1899 through 1939 indicates that El Niño is associated with periodic localized reductions in the seasonal shift of atmospheric circulation over the eastern Pacific; these reductions in turn appear to be associated with a slowing down of the seasonal atmospheric shift over the western Pacific. In a strict mathematical sense these periodic occurrences are not cyclical, being merely fluctuations.

In the Peru Current, maximum phosphate, nitrate, phytoplankton, and zooplankton quantities were essentially of the same order of magnitude as those known for highly productive temperate waters of the northern hemisphere, whereas in the warm low-salinity water of El Niño they were generally lower. Nitrate was the principal limiting factor and the photosynthetic rate was about the same as that for north temperate waters of the Atlantic.

Upwelling, found at two locations previously reported by earlier investigators, averaged between one and two meters per day. During the Yale Expedition the littoral was apparently never normal in all respects; nevertheless, tentative estimates of the vertical transport of phosphate in the Peru Current as a whole showed that about 4.0×10^5 metric tons of phosphorous were brought to the surface in a year by upwelling and a roughly equal amount by eddy diffusion. Within limited areas of intense upwelling, where the rate of supply is much greater than the diffusion effect, the rate of plankton production may be an order of magnitude higher than the largest values obtained in temperate waters.

An independent estimate of productivity was achieved by calculating the amount of phytoplankton required to produce the known population of anchovies as indicated by guano production and commercial fish catches. By this method the calculated phosphorous requirement of the phytoplankton was 4.95×10^4 metric tons, which is an order of magnitude lower than the estimated phosphates supplied by vertical transport. It is not known whether the difference in total phosphate obtained by the two methods is due to error in the transport estimate or to utilization of a considerable quantity of phytoplankton by other organisms not included in the calculations.

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INTRODUCTION

The Peru Current flows northward along the west coast of South America for 1,500 miles from Valparaiso, Chile to the Gulf of Guayaquil in Ecuador. Forming the eastern arm of the South Pacific gyral, it swings to the west just south of the Equator and becomes part of the South Equatorial Current. Despite its extensive course within the tropics, this water mass, which has frequently but less aptly been called the Humboldt Current, is nevertheless cool and rich in nutrients. It has long been known to support large quantities of plant and animal life. For a detailed discussion of the Peru Current, see Gunther (1936).

Some idea of the impressive productivity of this Current can be obtained from the vast guano deposits produced by the millions of birds feeding from its waters. It has been estimated that this deposit, one of the most valuable natural resources of Peru and Chile, averages 150,000 metric tons of dry guano annually. For the production of such an amount it is estimated further that the yearly consumption of fish by guano birds about equals the total annual commercial fisheries catch for the whole United States.

Such great fertility is unusual in the tropics, where marine productivity, despite its apparent prodigality of species, is generally considered to be inferior to temperate areas of high output. Thus the hydrographic and other pertinent features of the Peru Current as they relate to the organisms that develop in it are matters of scientific and practical interest.

Several related meteorological and geographical features are doubtless involved in this abundance, but upwelling of deep water in coastal areas is generally supposed to be its immediate source. Steemann Nielsen (1954), in his work on the Benguela Current, has reported the only quantitative studies on the basic productivity of a tropical *coastal* upwelling area while the Pacific Oceanic Fishery Investigations have been studying tropical *oceanic* upwelling regions. Such research is of considerable ecological and oceanographic interest, not only in its own right but in its value for comparison with comparable research of temperate waters which are classically far more productive than their tropical counterparts. In addition, such studies could add important information relevant to the general problem of productivity of the sea.

Furthermore, there is considerable oceanographic interest in El Niño, an anomalous recurrent phenomenon which apparently involves a warm water incursion from the north which is superimposed along the Peru littoral. At least once in this century and several times before, El Niño was so intense and extensive that vast numbers of marine organisms and birds were killed. In its wake it brought misery to the coastal population, a large percentage of which relies on marine fishing for food and income.

However, the Peru Current has never been adequately studied, many of its critical parameters having been either neglected or superficially treated. The present investigation was undertaken to provide, insofar as data permit, a general study of the productivity and food chains of the Peru Current. To obtain basic data, this project was made an integral part of the Yale South American Expedition (Merriman, 1955). Operations were conducted in the field from March 10 to May 21, 1953 aboard a 63-foot converted southern New England commercial fishing vessel, the MARISE.

The initial stations at sea showed at once that abnormal conditions with a well developed El Niño prevailed. Consequently, the original plan to study the Peru Current as such was radically reorganized so as to observe more effectively this important, traditionally periodic, modification of the normal oceanography of this area. As a result, the information obtained relates almost entirely to El Niño, a fact hardly avoidable in any case since normal conditions in the Peru littoral had not been entirely restored when the expedition was terminated.

HISTORY

EXPEDITIONS

Studies of the Peru Current have been undertaken on several occasions, but for the most part they were secondary to other more vital tasks. Of the subsurface studies, the most comprehensive one was that of the WILLIAM SCORESBY (Gunther, 1936); while this expedition made many stations in the Peru Current, the biological studies were treated only casually. Mary Sears (1954), concentrating on two small areas—Cabo Blanco and Pisco Bay, made intensive subsurface observations in the Peru littoral, including limited quantitative plankton studies. The CARNEGIE Expedition (Fleming, *et al.*, 1945) was in the Peru Current briefly. Funder (1916) studied only the southernmost end of the Peru Current whereas Agassiz (1891) examined only its northernmost end. Barreda's (1954) studies of Pisco Bay included temperature, salinity (by hydrometer), transparency, and limited plankton analyses. The Shellback Expedition (Wooster, 1952) will doubtless add much valuable information when its results are published.

A number of studies have been based solely on surface observations, the most notable of these being the excellent work of Schott (1931) who had only the salinity and temperature observations taken by steamers as source data; Coker (1918), Murphy (1923, 1926), and Zorell (1928) also employed surface data. Schweigger, who has resided in Peru for over a quarter of a century, has published many papers on the Peru Current (1931, 1940, 1942, 1943, 1945, 1947, 1949, 1951, 1953, and 1954), basing his analyses mostly on surface temperatures and rarely on surface salinities (determined by hydrometer); his subsurface observations were even sparser.

Several writers have discussed the Peru Current in the course of reporting a fisheries survey (Bini, 1952; Coker, 1908; Fiedler, *et al.*, 1943; Landa, 1953; and Rojas, 1953), but except for the work of Coker and Landa, these papers have offered little new information on the Peru Current.

The Yale South American Expedition has obtained in greater detail than ever before simultaneous hydrographic, chemical, and biological (including plankton and fish) observations of the Peru littoral at both surface and subsurface levels. While the expedition did not achieve entirely an integrated ecological picture of the Peru Current, in a strict sense, largely because of the concatenation of events, it was possible, for the first time, to investigate El Niño fairly intensively.

PHYSICAL OCEANOGRAPHY

The Peru Current. In the surface waters off the northernmost region of Peru, near Cabo Blanco, the normal temperature in February is slightly less than 24° C, the salinity slightly less than 35‰, and the current northerly. During this month the isotherms are longitudinal and roughly parallel to the coast. By way of comparison, surface temperatures off New Guinea and eastern South America at the same latitude and in the same month are approximately 28° and 27° C respectively. The presence of the relatively cool water at the surface off Peru is due to upwelling; as the wind, generally from the south and southeast, drives the surface water offshore, cool and nutrient-rich subsurface water rises to the surface to replace it. Although several zones of upwelling have been discovered along the coasts of Peru and Chile by Gunther and by Schott (1931), others doubtless exist and will be located eventually. According to Gunther as well as Sverdrup (1931), upwelling is a shallow phenomenon that occurs from about 50 to 300 m with a mean depth of 130 m. Schott has suggested that the rate of upwelling in the Peru Current is about 0.5 m per day, and although Gunther has taken exception to this figure, he offers no alternative value.

El Niño. El Niño may be defined as a tongue of surface water with high temperatures and low salinity that extends southward over the northbound Peru Current along the coast. During El Niño, isotherms are latitudinal and the current flows southward. Meteorologically, it is accompanied by north winds and heavy rains; normally the Peruvian coastal area suffers from drought which is eased only during the southern summer by a perpetual haze (garua) and no precipitation. At Trujillo (8° S), for example, during El Niño in 1925, 395 mm of rain fell during March alone; in the same month during the six previous years, total precipitation was only about 10 mm. Although Schweigger has considered the "true" El Niño Current (La Legitima Corriente del Niño) to be an annual phenomenon in which there is apparently a leakage of water on a small scale from the Gulf of Guayaquil onto the northernmost Peru littoral, Schott (1951) and his followers refer to it as the larger and much more extensive phenomenon that occasionally moves much deeper southward. Sverdrup, *et al.* (1942) used El Niño to describe both the lesser annual shifts of the Equatorial Countercurrent southward as well as less frequent but more extensive southerly shifts. In this paper El Niño is used in the sense of Schott. Considering the cause of El Niño, Schott (1931) worked with some rather fragmentary air pressure data for 1891 and showed that the equatorial trough in that year, when a severe and catastrophic El Niño occurred, shifted much farther south than normal. Beyond this, little else has actually been done.

The subject of periodicity in El Niño has been a controversial one. Many workers have felt that abnormally high rainfall records provide the most satisfactory means for explaining El Niño's periodicity. Frijlinck (1925) observed from rainfall records that heavy precipitation occurred in Peru in 1728, 1770, 1791, 1828, 1864, 1871, 1877/78, 1884, 1891, and 1925; and Eguiguren's (1894) analyses are in accordance with the observations of Frijlinck (through 1891) if we include only those years listed by Eguiguren as having extraordinary rainfall. Berlage (1927) has correlated Java droughts with the heavy rainfall in Peru as recorded by Frijlinck, the only exceptions being 1905, 1911/12, and 1918, when droughts prevailed in Java and when, according to Frijlinck, no abnormal precipitation occurred in Peru. High temperatures alone cannot be used as proof of El Niño because they might be due to several other factors, such as: *in situ* warming (Sears, 1954) and inshore swirls of oceanic water (Gunther, 1936). Others have postulated that bird deaths are an indication of the presence or absence of El Niño since their deaths are commonly attributed to the absence of anchovies when El Niño is present. However, such a hypothesis would have to be modified by a consideration of bird deaths due to other factors such as an epizootic infection. Hutchinson (1950), in his extensive studies of guano deposits, concluded that El Niño probably occurred in 1891, 1911, 1918, 1925, 1932, and 1939. Garbell (1947), though subscribing to the meteorological phenomenon (the shift in the equatorial trough) as well as the supposed periodicity, offered no new evidence despite the fact that he supplied details as to the air masses involved.

Chemical and Biological Oceanography

Even less work has been done on the chemical and biological aspects of the Peru Current than on its physical oceanography. The Scoresby, Carnegie, and Shellback Expeditions studied the phosphate distributions and the latter two expeditions reported the silicate distribution. However, the results are sketchy and leave much to be desired. Gunther noted not only the association between upwelling and higher surface phosphates but the reduction of surface phosphate by phytoplankton metabolism as well. The only other work on phytoplankton is that of Hendey (1937), who prepared a species list from the Scoresby collections. Studies of zooplankton are limited to the Carnegie group's list of copepods (Wilson, 1942) and to Gunther's brief preliminary remarks on zooplankton abundance.

Some interesting if varied production estimates have been obtained from studies of the guano birds and their deposits. Schweigger (Schott, 1935: 394) estimated and reported without explanation that the ratio of fish consumption to guano production is 35.7:1. Gamarra Dulanto (1941), by starving and quantitatively feeding birds, arrived at a ratio of 16:1. Since the birds, when starved, probably converted some of their body substance to guano, it is questionable whether his results are wholly valid. From phosphorus analyses of *Engraulis encrasicholus* and Peruvian guano, Hutchinson obtained ratios ranging from 9.5:1 to 15.3:1. Recent unpublished phosphorous analyses of fresh *Engraulis ringens* (the Peruvian anchovy) by Mrs. Mary Townsley on material supplied to Professor G. E. Hutchinson by Sr. Enrique Avila have indicated that the ratio should be 13.1:1.

With Mrs. Townley's biochemical estimate (undoubtedly more reliable than the results of force-feeding experiments) and with an average annual guano production of about 227,000 metric tons (Murphy, 1954: 234), the fish consumption (principally anchovy) required for that amount of guano would be 2.97×10^6 metric tons. This figure exceeds the annual catch of the U. S. and Alaska Fisheries combined (2×10^6 metric tons) for the year 1951 (Anderson and Peterson, 1954), and at that the estimate of the total fish consumption by the bird population in Peru is minimal.

The unsubstantiated view of Gamarra Dulanto that the loss of guano more or less equals the amount successfully deposited was disputed by Hutchinson. The disagreement is based on the huge food consumption that this correction would imply. Actually guano production may be a poor basis for estimating the amount of fish consumed by birds. Their phosphate requirement for growth, reproduction, etc., is not included in estimates based on guano production; furthermore, there are several ways in which guano may be "lost" in that it does not become or remain as part of the cumulative deposits; rain and heavy surf wash away some guano from the deposits, according to Mary Sears (personal communication), some sticks to the birds' feathers and is washed off during feeding, and there is undoubtedly some defecation at sea. However, Murphy (1936, 1954) believed that the birds defecate almost exclusively on land, and Hutchinson suggested that, since these birds build their nests of guano, there would be a selective advantage in their retaining as much of their droppings as possible. Nevertheless, positive evidence on this point is lacking.

OBSERVATIONS AND METHODS

Sea temperature, wind speed and direction, air temperature and pressure, cloud types and quantity, humidity, and visibility were determined at all stations occupied, a total of 154. Bathythermograph (BT) lowerings were made at 70 stations; salinities as well as occasional zooplankton collections were obtained at 66 stations; and at 18 stations the following data were acquired: BT, salinity, zooplankton, phytoplankton, dissolved oxygen, phosphate, nitrate, plant pigments, and a Secchi disc reading. The water column was sampled at 5 or 6 intervals to a depth of 100 m, where depth permitted. Zooplankton was collected by oblique tows of #2 and #10 nets, the water column (maximally 100 m deep) being equally divided into an upper layer and a lower layer. A bucket thermometer was employed for surface temperatures.

In addition to the routine observations, two types of biological experiments were carried out as supplements to the productivity studies. 1. In the enrichment experiments, phosphate, nitrate, iron, and manganese were added in various combinations to different bottles of sea water containing natural phytoplankton populations; the change in the dissolved oxygen content was then measured after a suitable period of time. 2. In experiments to determine the rate of photosynthesis, the light and dark bottle method was employed.

Chemical determinations were obtained by the following methods: Knudsen for salinity, Winkler for oxygen, Atkins-Deniges for phosphate and Zwicker and Robinson for nitrate. A Klett photoelectric colorimeter was used in the phosphate, nitrate, and plant pigment analyses and a salt correction factor of 1.35 was applied to all phosphates. Plant pigments were analyzed by filtering 375 ml of sea water through #42 Whatman paper, extracting the residue with 90% acetone and then comparing the extractant colorimetrically with a chlorophyll standard and the Harvey plant pigment standard. Details of the chlorophyll calibration are given by Riley and Conover (1956). For phytoplankton counts, six ounces of sea water were drawn off from a Nansen bottle. Aside from analyses of salinity and plant pigments, all determinations were carried out on shipboard within 24 hours of collection, frequently within four to eight hours.

To take full advantage of El Niño which had already developed when we arrived, Sts. 1–34 off northernmost Peru were occupied from March 10 until April 18 (Fig. 1). Sts. 35 through 46 followed a transect across the Current that reached nearly 100 miles offshore (to 82° 52′ W) while Sts. 47 through 67 lay on a rectangular route whose long axis paralleled the coast from 4° 33′ to 6° 24′ S; the rectangle was about 30 miles wide from the eastern edge to the western limit.

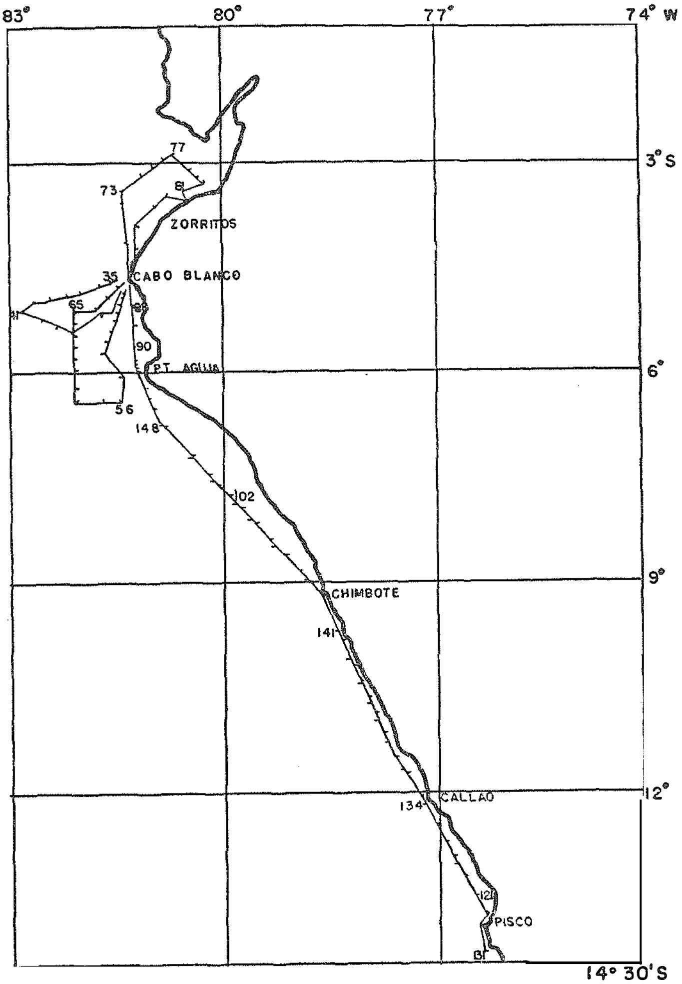

Figure 1. Track record. Stations before No. 35 were in the Cabo Blanco-Talara area and are not shown. Sts. 91 through 154 were not exactly along the same line but are so figured for clarity; southbound stations (#91–131) are indicated to the right of the line, northbound stations to the left.

Sts. 71–81 covered a sweep through the Gulf of Guayaquil, Sts. 88–115 the section from Talara to Callao (April 19 to 24), and Sts. 134–154 the return trip (May 16 to 21). Pisco Bay was surveyed at Sts. 123–129; St. 130 was situated between the Bay and St. 131, the southernmost point of the Expedition.

A complete station list including all data is in the possession of the Bingham Oceanographic Laboratory, Yale University, New Haven, Connecticut.

EL NIÑO

Observed Characteristics

While the Yale Expedition was off Peru, most of the surface water temperatures were relatively higher and the surface salinities relatively lower than those observed previously; the highest surface temperature, 29.12° C, was observed at Zorritos, the second highest, 28.91° C, just south of Cabo Blanco. Surface salinities at both of these stations were less than 30.85‰.

Inshore waters in the Cabo Blanco-Talara region exhibited four distinct series of temperature fluctuations (a fact commented upon by Barandiaran, 1954) (Fig. 2). In the first series from March 10–18 (Sts. 1–17), all surface temperatures were above 24° C, most of them being above 25° C; in the second series from March 21–31 (Sts. 18–32), they dropped below 24° C; in the third series from April 2–15 (Sts.

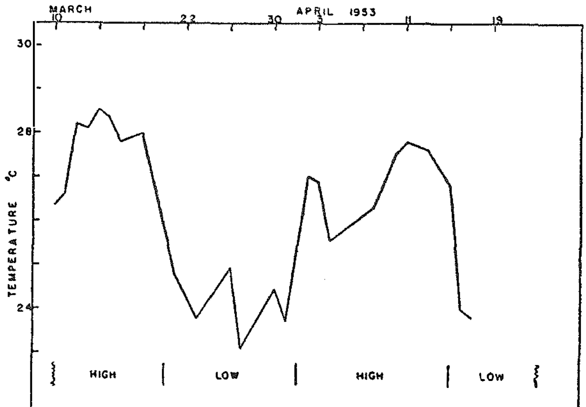

Figure 2. Surface temperatures in the Cabo Blanco-Talara region with separation into high and low temperature series indicated.

33–35, 66–84),[2] temperatures were high again; and in the fourth series after April 16 they again fell below 24° C.

With few exceptions, surface temperatures of 25° C and above were accompanied by surface salinities of less than 34‰ whereas temperatures below 25° C showed salinities greater than 34‰. Excepting Sts. 1–3, the surface data for the Cabo Blanco-Talara area (Fig. 3) in the form of a T-S diagram emphasize the distinction between the warm, low salinity water and the cooler, high salinity water; Sts. 1–3 displayed high surface temperatures as well as high surface salinities. At Sts. 1–4, which occupied a line WSW of Cabo Blanco, surface salinity decreased and surface temperature increased shoreward from St. 1. St. 4 alone showed a low surface salinity; this may have been due to brackish water in a narrow coastal belt or to rainfall that occurred immediately before St. 4 was occupied. In any event, the higher surface salinities at Sts. 1–3 were not found again off Cabo Blanco until temperatures decreased again later.

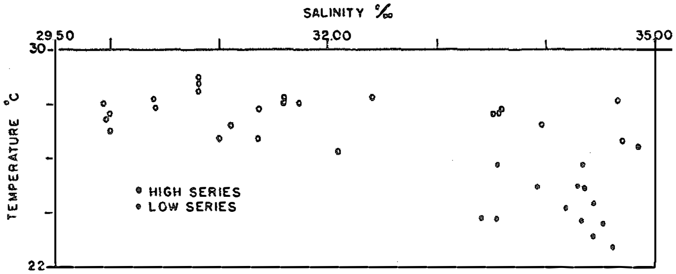

Figure 3. T-S diagram of surface water data in the Cabo Blanco-Talara region.

Meteorological conditions were also abnormal. In 1952 only 17 mm of rain fell at Talara during the entire 12 months whereas in the first four months of 1953 precipitation totaled 156.4 mm (E. Roldan, personal communication). Air temperatures fluctuated with sea temperatures, being high with the high sea temperature series and low with the low series. During the high temperature series the average air temperature was 3.2° F higher than that for the low series. The higher series was accompanied by abnormal rainfall and northerly winds were observed part of that time, particularly before the precipitation; northerly winds were never observed during the low series (Fig. 4). In short,

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[2] Sts. 36–65 excluded here because they were not in the inshore Cabo Blanco area.

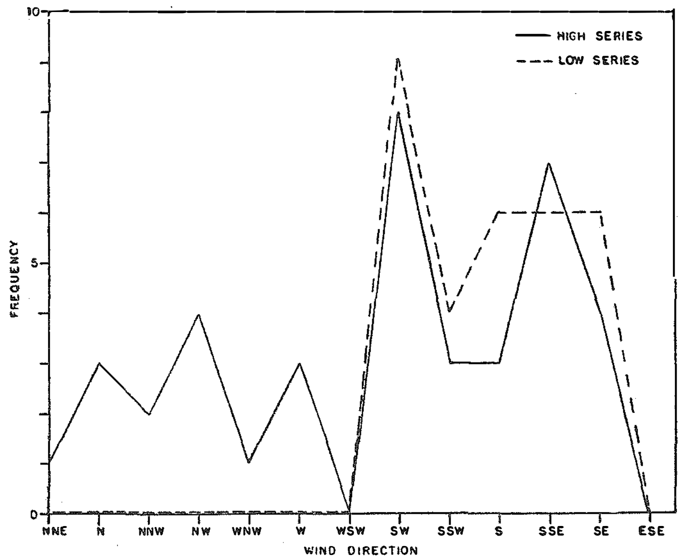

Figure 4. The frequency of different wind directions observed by the Yale Expedition in the Cabo Blanco-Talara region during the high and low temperature series.

two series of observations exhibited high surface water temperature, low salinity, and abnormal meteorology while two alternating series displayed low temperature, high salinity, and normal meteorology.

VERTICAL AND HORIZONTAL DISTRIBUTION

Below the surface, when the high surface temperatures and low salinities obtained, the following conditions prevailed: during the first series, temperatures and salinities were 24° C and 34‰ at 10 and 25 m; during the third series, the same temperatures and salinities were found only at shallower depths of 5 and 10 m.

Figs. 5 and 6 show temperature sections for the Current transect and Fig. 7 pictures the comparable salinity profile. The slope of the isohalines, verified from ship-drift data, indicates a southerly inshore current and a northerly offshore current, with the boundary line at about 82° 10′ W. The isotherms do not give as clear a picture as the isohalines, although the temperature profile of the out-bound trip, slightly north of the in-bound trip, suggests a similar sloping.

In Figs. 5–7 it is seen that there is a pronounced decrease in the depth of the abnormal El Niño water westward and a less abrupt de-

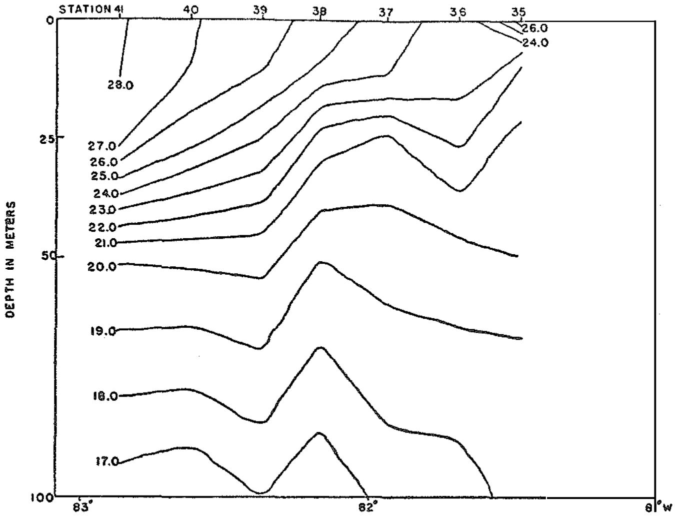

Figure 5. Vertical distribution of temperature westward from Cabo Blanco.

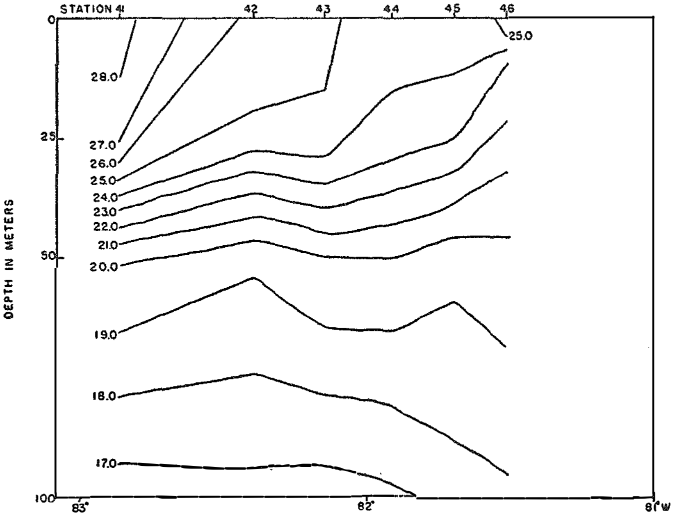

Figure 6. Vertical distribution of temperature eastward to Talara.

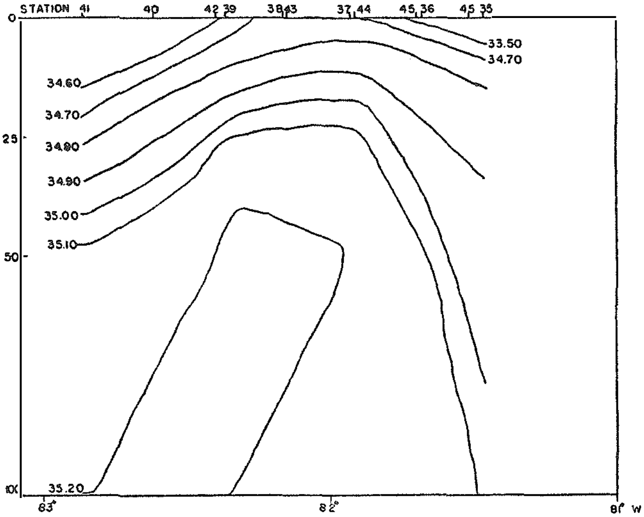

Figure 7. Vertical distribution of salinity cross-current off Cabo Blanco-Talara.

crease southward. Figs. 8–11 show the abnormal water at the surface between Talara and Punta Aguja, but Figs. 10 and 11 do not show it as clearly as Figs. 8 and 9. Fig. 12, showing temperatures during the fourth of the previously mentioned series when surface temperatures were low, reveals a bending of the shallow isotherms toward the surface at 5° S. As previously stated (Posner, 1954[3]), no southward current was observed south of Punta Aguja. Thus the abnormal water formed a wedge southward over the Peru Current with its base north of Cabo Blanco and its apex no further south than Punta Aguja.

At Sts. 2 and 3 an unexpected and possibly abnormal hydrographic feature was observed at depths of 100 and 200 m when samples gave a salinity of 36‰. One possible interpretation of this feature is given in the following Discussion (p. 127).

Colors of the sea water most commonly observed were a clear green and green-blue, the clear green almost matching that in Gunther's pl. 16, fig. 10, the green-blue that in his fig. 1. Blue water was observed principally offshore about 50 or more miles. Inshore, according to Lt. Cdr. José F. Barandiaran of the Peruvian Navy (personal communi-

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[3] In that paper the text is correct while the caption of Fig. 2 is in error, through editorial alteration.

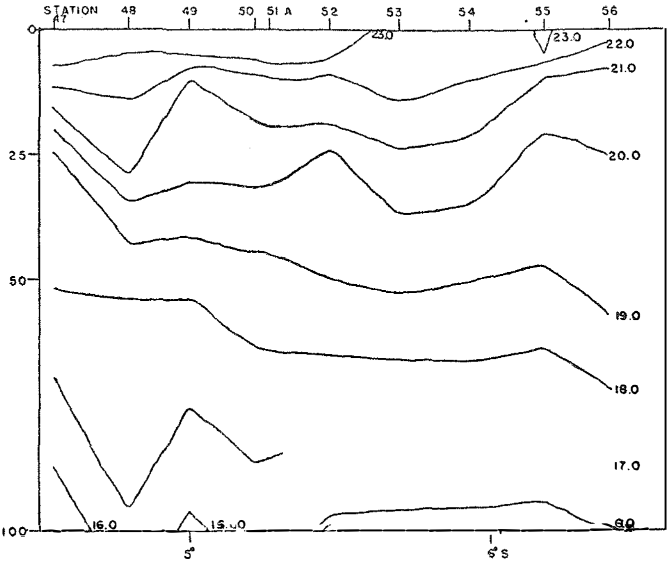

Figure 8. Vertical distribution of temperature from Talara to south of Punta Aguja.

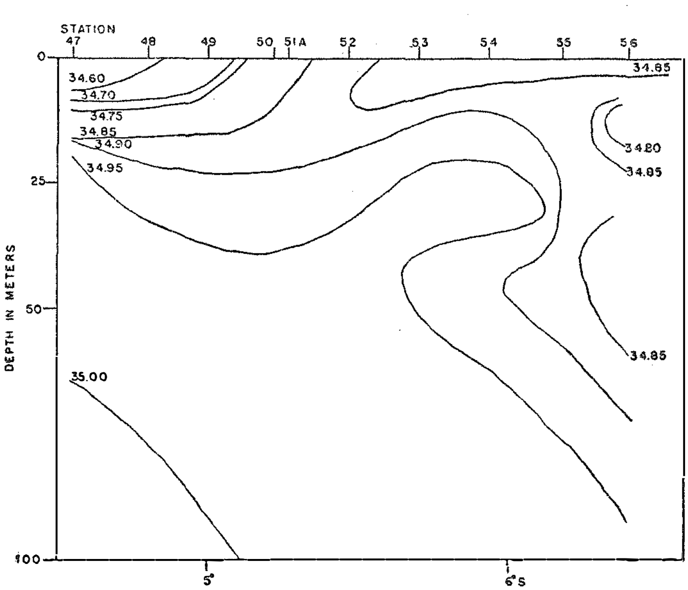

Figure 9. Vertical distribution of salinity from Talara to south of Punta Aguja.

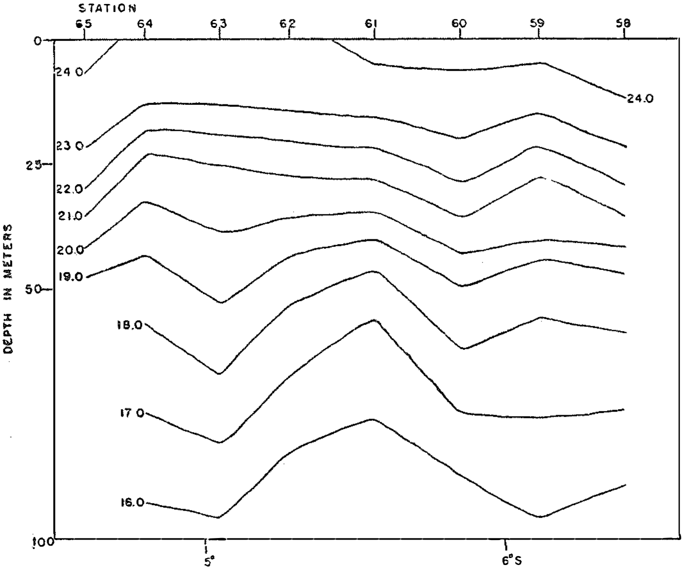

Figure 10. Vertical distribution of temperature along a line 30 miles west of that in Figs. 8 and 9.

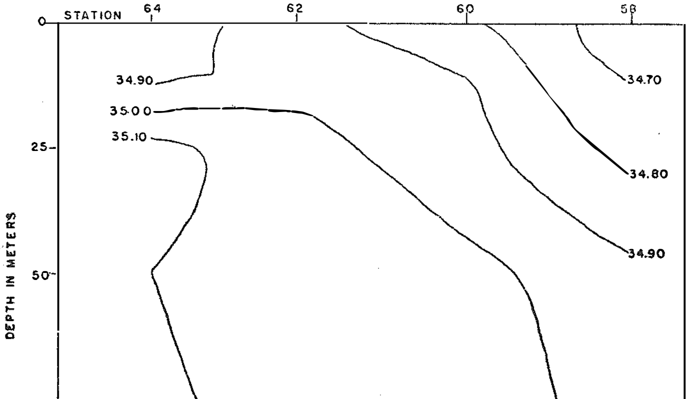

Figure 11. Vertical distribution of salinity along the same line as in Fig. 10.

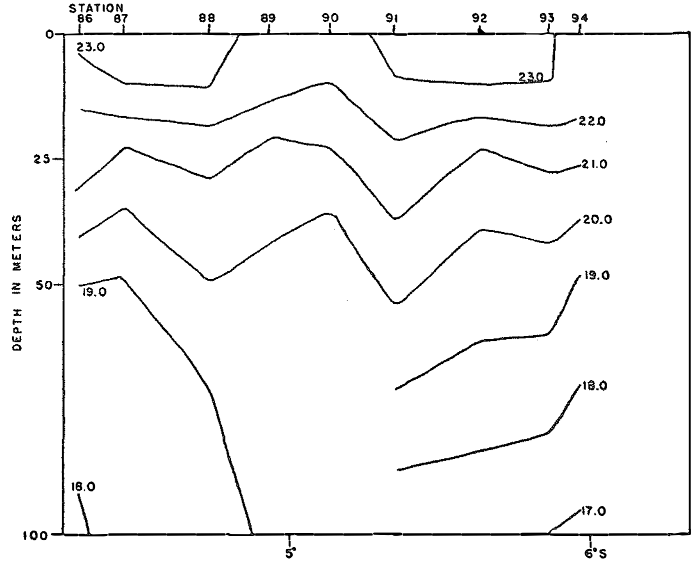

Figure 12. Vertical distribution of temperature along the same line as is Fig. 8, ten days later.

cation), who was with the Marise from first to last, the water is commonly olive-green, a color not seen during the Expedition. He also commented that never before in his experience had the water at the Lobos de Afuera Islands been greenish-blue, a condition which was observed as late as May 19. In such places as the Gulf of Guayaquil, Pisco Bay (inshore), Talara Harbor, and Cabo Blanco a dirty green predominated. The water on the inshore side of the Chincha Islands was green with a strong reddish tinge, a color which would approximate that of Gunther's pl. 16, fig. 11 if the latter contained more green. Red water, caused by an unidentified dinoflagellate, was observed at St. 51. This patch, about two square miles in area, was located at the southern rim of El Niño water (Figs. 8, 9).

Consideration of plankton distribution and chemical abnormalities are included in a later section devoted to the Peru Current.

Discussion

The first problem is to specify the source of El Niño water. As indicated already, the unusual hydrographic conditions during El Niño were accompanied by unusual weather conditions, with a shift in the wind to the north and a pronounced increase in rainfall. The wind shift, by reducing or stopping upwelling, would permit *in situ* warming of the upper water to a far greater degree than usual. The increased rainfall would tend to reduce the salinity, especially along inshore areas where the water is shallow and the influence of land run-off most pronounced. But these local modifiers, while probably contributing to El Niño, cannot explain the active transport that has been observed.

Consider first the available surface data as a means of identifying El Niño waters. Sverdrup, *et al.* (1942: fig. 197), with data from DANA St. 3556, have shown that this station is located in the region where the Equatorial Countercurrent begins to curve back on itself, the surface salinity there being 33.52‰ (Thomsen, 1937). These same authors (Sverdrup, *et al.*, 1942: chart VI) have also indicated that water of a salinity of less than 34‰ in the tropical eastern Pacific appears to emanate from the more southerly regions off Central America, with the lowest values (28‰) found in the Gulf of Panama. According to both Schott (1935: pl. 19) and Riehl (1954: fig. 3.2), there is a high rainfall in the general area of the Gulf of Panama, and Schott maintains that this high precipitation causes the reduced surface salinity in this region, where normally the surface salinity reaches 34.5‰ only in winter.

While Schott (1931) believes that the source of El Niño water off Peru in 1891 was the Equatorial Countercurrent, in his pl. 20, fig. 3 he suggested the possibility that some Gulf of Panama water was present also.

For the Gulf of Guayaquil, normal salinity data are difficult to locate, but Gunther, on the basis of observations just west of Punta Santa Elena, Ecuador, considered the observed salinities of about 33.8‰ to be an indication of Equatorial Countercurrent water. According to the U. S. Navy Hydrographic Office (1934), surface salinities between the Galapagos Islands and the Gulf of Guayaquil declined steadily from west to east, with the salinity at the Galapagos Islands on February 1, 1934 being 33.91‰ and that off the Gulf (3° 03′ S, 81° 01′ W) on February 7 being 32.95‰, a figure which they also found at 2° 44′ S, 82° 48′ W on February 2. Schweigger (1954) ascribed a salinity of less than 34‰ to the "true" El Niño Current, *i.e.*, the current which he believes derives from the Gulf of Guayaquil.

Morrow (1957), in his ichthyological studies during the Yale Expedition, reported 21 new fish records from the waters off Peru during El Niño; none of these fishes were previously reported for only the Gulf of Guayaquil. Most of the forms were previously known from waters along the west coast of Central America and Ecuador, thus indicating involvement of water from that area. Also, a few of the species collected off Peru were known earlier only from the Galapagos Islands, suggesting the inclusion of Equatorial Countercurrent water. From the foregoing observations and data, then, it is fairly clear that the source of the 1953 El Niño was the Equatorial Countercurrent and Central American waters.

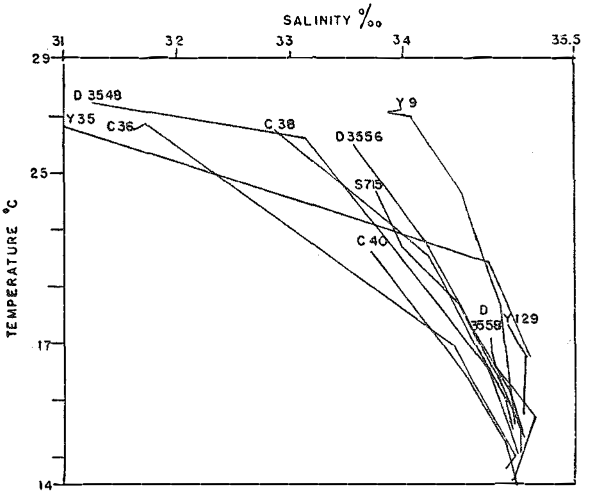

Figure 13. T-S diagram of CARNEGIE (C), DANA (D), WILLIAM SCORESBY (S), and Yale (Y), stations from the surface to a depth of about 100 m.

But what of the contributions of deeper waters to El Niño, if any? In an attempt to ascertain whether deeper water contributes to El Niño, some of the data from our expedition (Sts. 9 and 35, both El Niño stations, and St. 129, in the Peru Current) together with data from previous expeditions (DANA Sts. 3556–3558, 3548; SCORESBY St. 715; CARNEGIE Sts. 36, 38, 40) were plotted on a T-S diagram (Fig. 13); these stations were selected because they represent widely divergent regions of the eastern tropical Pacific (e.g., Gulf of Panama, Equatorial Countercurrent, and Galapagos Inslands). Though the stations were widely scattered (from 7° N to 2° S and from 80° to 99° W), the water between 50 and 100 m was quite similar and therefore provides no clue to a solution of the problem. The only suggestion of abnormal surface water movement was the presence of 36‰ water off the Peru coast. Water of similar high salinity has been reported either from 100–200 m or from 0–100 m in the central tropical Pacific by Austin (1954, 1954a), Bruneau, *et al.* (1953), Cromwell (1953, 1954), Fleming, *et al.* (1945), Montgomery (1954), Stroup (1954), Sverdrup, *et al.* (1942), and Thomsen (1937). On the other hand, no such high salinity was reported for Peru coastal waters by Gunther and by Sears,

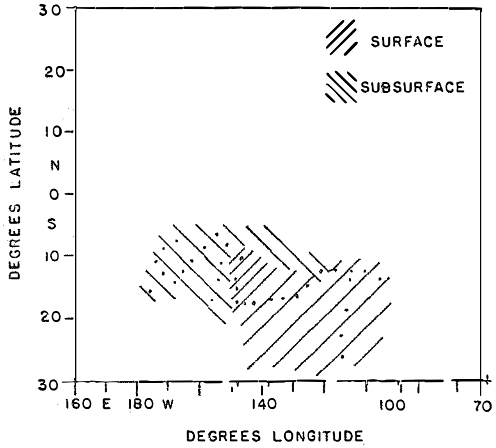

Figure 14. The horizontal and vertical distribution of 36‰ water in the central Pacific Ocean. Dots indicate station locations. Composite data from authors.

or by Funder who did not operate north of Callao or west of 90° W. Observations of 36‰ water by the above workers are plotted in Fig. 14, which shows that an area of high surface salinity lies roughly between 150°–100° W and 10°–25° S. This area of high salinity water is limited to a narrow subsurface stratum immediately northwest and west of the region where it extends to the surface, implying sinking and northerly movement of high salinity water or a modification of the upper layers by local factors such as precipitation. Since the high salinity water of that area has not been observed between that area and Peruvian waters, it is problematical whether or not it contributes to El Niño. However, Sette (1954) has reported that a subsurface countercurrent flows beneath the Equator at a depth of 100 to 200 m.

Thus, from the results above and the work of Wooster and Jennings (1955), it is clear that waters of the Equatorial Countercurrent and western Central America contribute to El Niño, but it is not clear whether these two water masses mix or stratify and whether at subsurface depths other water movements might not be involved.

Under OBSERVED CHARACTERISTICS (p. 117) it was pointed out that there were four distinct series of water temperature fluctuations, and it is pertinent to inquire whether or not these fluctuations were random or periodic. Gunther suggested the existence in the Peru Current of a seiche period of two months, based on only two observations, one month apart, off Callao. Schweigger (1954a) subjected a considerable mass of sea surface temperatures to harmonic analysis and concluded that these temperatures along the northern Peru coast varied in rhythmical fashion with an approximate periodicity of 41 days; regrettably he failed to employ more analytical procedures, such as those summarized by Whittle (1954). Scheigger (1954a: 18) implied that the seiche, perhaps involving a large section of the Pacific, might influence the invasion of the Peru Current by the Equatorial Countercurrent. While seiches are generally limited to areas that are more or less narrowly confined by land, they are not unknown along open sea coasts. In 1932, Patton and Marmer reported a seiche off Atlantic City, New Jersey that had a period of 15 minutes and was apparently produced by strong winds. Schweigger mentioned a seiche of 17–19 days in the Gulf of Bengal and one of 34 days in the Atlantic. At any rate, the seiche periods proposed for the Peru area by Schweigger and Gunther are highly improbable; in fact, some of Schweigger's remarks indicate that he was actually referring to internal waves. Considering the observations of the Yale Expedition, a period of about 25 days has been obtained, but it is not believed to represent a true seiche or to be even necessarily periodic.

Before leaving the subject of temperature fluctuations, it should be noted that, based upon our biological observations, the El Niño of 1953 was mild. It may be that the severity of El Niño is simply a reflection of the speed of invasion of El Niño water and its duration.

The supposed seven-year periodicity of El Niño would be far less questionable if it could be shown that it was associated with some natural periodic fluctuation. Since El Niño has strong meteorological involvements, a good place to search for such an association would be in meteorological data. Murphy and others have suggested that the northwest winds of El Niño derive from northeast trade winds of the northern hemisphere that swing down across the Equator, and Schott's (1931) work suggests the possibility that El Niño could result from an increase in the seasonal shift of the atmospheric circulation; in fact, Schott pointed out the shift in the equatorial trough during the El Niño of 1891. If this concept is broadened into the working hypothesis that El Niño is associated with or caused by an enhanced seasonal shift of the atmospheric circulation, as manifested by the movement of the equatorial trough, then the region just north of the Equator and only slightly west and east of 90° W Long. would be of prime importance.

With the above hypothesis, in the following pages a suitable meteorological parameter is selected, the months, years, and locations for study are determined, and finally the usefulness of the hypothesis is tested.

While various meteorological and climatic parameters (*e.g.*, air pressure, wind speed and direction, rainfall, etc.) might be used, the single parameter that best expresses the synoptic picture at a given location is generally the barometric pressure. And in the absence of sufficient long range barometric data for the southern hemisphere, it is necessary to use the more plentiful data from the northern hemisphere, which, according to Murphy and Schott, will serve well our present purpose. Furthermore, Garbell has also indicated that El Niño can be defined meteorologically in terms of northern hemisphere data.

Since charts of "Monthly Mean Pressure at Sea Level for the Northern Hemisphere" (U. S. Weather Bureau) at 10° N give data for only January 1899 through June 1939, present consideration will be limited to only those years. According to Hutchinson, El Niño occurred in 1911, 1918, 1925, 1932 and 1939. Although there is no evidence that 1904 was an El Niño year, it also is included here in order to obtain as much data for the 20th century as possible. The variance of the monthly abnormal values for that year did not exceed the mean normal values; no obvious discrepancies appear by considering 1904 abnormal.

In view of the fact that the region just north of the Equator and only slightly east and west of 90° W Long. is of primary importance, first consideration will be given to the region between 120°–70° W at 10° N.

Since El Niño generally appears shortly after Christmas and rarely lasts beyond March, the mean monthly air pressure values at sea level for the specified north equatorial areas were determined from data for the consecutive months of August through March. Because much of the region subjected to analysis is open ocean, probably few, if any, direct barometric measurements are available in the charts; the values given were probably obtained by interpolation of isobars constructed from observed data, but they are undoubtedly precise enough for this study. After the data were tabulated according to month and location, means were determined. Air pressures were coded; by adding 1000, the real values in millibars can be obtained. The means for El Niño years were always based on six values, while the means for normal years, since the available data ceased with June 1939, were based on 35 and 34 values, depending on whether the months followed or preceded the New Year.

By using the "t" test, means for each of the analyzed months of El Niño years (1904, 1911, 1918, 1925, 1932, 1939) were compared with corresponding months of "normal" years at intervals of 10° along 10° N Lat. Seven of the 48 comparisons showed differences, with P values ranging from 0.5–8.0%; the remaining 41 comparisons were greater than 20%. While only one difference was highly significant, that being for September at 120° W, 10° N, the fact that the observations fell into two clearly defined groups warranted further examination of the former group. Thus, at such locations where the P value was 8.0% or less, the analysis was extended northward at 10° intervals to 60° N.

Table I, which gives the results of the original analysis and of subsequent additions of values falling within the same range of probability, shows that the sign of the difference of the means is negative (with one exception) in months preceding December and positive in the months thereafter. It also shows that in the month of December there was no significant difference between abnormal and normal means. These results suggest that there is a localized reduction in the seasonal north-south shift of the atmospheric circulation. At first glance such a conclusion appears to be in disagreement with the idea of Garbell and others that El Niño is associated with an *increased* seasonal shift, such a shift being necessary to bring the NE trade winds across the Equator. However, the desired result can be achieved by increasing the north-south component of the NE trades. If the isobars are normally more or less symmetrical and if areas of reduced movement appear within regions of normal movement, then a twisting of the isobars would result in an increase of the north-south component. That is precisely what the present data and analysis indicate.

TABLE I. Analyses by month and location over the north Pacific up to 60° N where, between 1899 and 1939, the mean sea level air pressures during normal (non-El Niño) years differed significantly from those during abnormal (El Niño) years.

	Location		Mean		*Diff.*	*Standard*	*P Level*
Month	° W Long.	° N Lat.	Norm.	Abnorm.	(sign)	*error*	*%*
Aug.			No Significant Differences				
Sept.	120	10	10.09	12.00	—	.604	.5
	70	10	10.85	11.67	—	.452	8
Oct.	110	10	10.53	11.50	—	.548	8
		30	12.29	13.17	—	.454	7
		60	13.38	10.83	+	1.375	8
Nov.	110	10	10.59	11.67	—	.607	8
Dec.			No Significant Differences				
Jan.	110	10	10.94	10.17	+	.339	3
		50	19.23	17.00	+	1.105	5
Feb.	100	10	11.49	10.5	+	.413	2.5
		30	18.91	17.5	+	.762	7
		40	20.66	18.3	+	1.187	6
	90	10	12.26	11.5	+	.414	6
Mar.			No Significant Differences				

In view of the fact that the El Niño phenomenon is apparently associated with fluctuations in the shift of the equatorial trough over a restricted area of the Pacific and since the meteorological situation in Peru during El Niño resembles monsoonal conditions, with sharp wind reversal and increased rainfall, it is of particular interest to determine whether there is a relationship of El Niño to more extended meteorological conditions. Such a course would then follow in the wake of Berlage's suggestion that El Niño may be connected with droughts in Java (see p. 113).

Air presures for September of the years 1899–1938 were determined along Lat. 10° N from Long. 140° W to 50° E (Table II).

West of 140° E the normal mean pressure significantly exceeds the abnormal at some locations, whereas east of 140° E the abnormal exceeds the normal, suggesting a fundamental difference in the seasonal atmospheric shift east and west of that location. Riehl (1954: fig. 1.9) has indicated that east of 160° W the equatorial trough does not normally shift south of the Equator; in fact, from 80°–150° W he has pictured the trough as being located no farther south than 5° N. Thus, the situation east of the international date-line could result from a

TABLE II. ANALYSES FOR SEPTEMBER, 1899–1938, AT 10° N FROM LONG. 140° W–50° E WHERE THE MEAN SEA LEVEL AIR PRESSURE DURING NORMAL YEARS DIFFERED SIGNIFICANTLY FROM THAT DURING ABNORMAL YEARS.

Long. (°E)	80	110	160	180
Mean Normal	9.44	8.44	10.44	10.00
Mean Abnormal	8.67	7.67	11.83	12.67
P Level (%)	1.5	7	8	0.1
Long. (°W)	160	140	120	70
Mean Normal	10.18	11.03	10.09	10.85
Mean Abnormal	12.00	12.67	12.00	11.67
P Level (%)	1.4	1.0	0.5	8

slackening in the seasonal shift, as suggested above. On the other hand, Riehl's same figure has shown that the equatorial trough has a large seasonal variation in January in the region west of the international date-line, a variation which coincides roughly with the monsoon region of the western Pacific. According to Hare (1953: figs. 12, 13), the intertropical front's position during January and July is correlated with wind circulation and rainfall patterns over Africa, and monsoonal weather is apparently associated with regions of broad seasonal shifts in the position of the equatorial trough.

Since the monsoon-like conditions of the eastern Pacific are associated with a reduced seasonal shift in the position of the equatorial trough, there seems to be a contradiction. However, examination of air pressures for October for the regions studied above shows that the shift in circulation over the western Pacific is slower during abnormal years than during normal years. If, as indicated above, monsoons occur where the seasonal atmospheric shift is large, then a slower shift could cause a reduction in the rainfall over the western Pacific, thereby producing the droughts in Java discussed by Berlage.

It appears, therefore, that a reduced shift in the atmospheric circulation over the Pacific is correlated with a drought in the western Pacific whereas, in the eastern Pacific, where bending of isobars occurs, the reduced shift is associated with increased rainfall.

The question now arises as to whether or not this meteorological abnormality associated with El Niño is cyclical in the mathematical sense; *i.e.*, is each year progressively less normal until El Niño occurs and then progressively more normal? If the years just before and after El Niño are eliminated, one would expect an increase in the P value if there were a trend. While P values at some locations did increase, at other locations they either decreased or were unaffected. Similar results were obtained when the two years before and the two after El Niño were eliminated. Thus there is no satisfactory evidence of a tendency in the air pressure measurements toward a "build-up" of El Niño forces. While this analysis does not indicate what causes the periodicity of the air pressures, whatever it is, it seems to influence the air pressure only once in seven years.

Pursuing the periodicity problem further, the trends in air pressure were determined from the September data at 10° N and 120° W, a locality where the previous analysis had indicated a significant difference between normal and abnormal years. These air pressures, first subjected to periodogram analysis, indicated seven, ten, and fourteen-year cycles. But the curve calculated from a multiple regression equation derived from an harmonic analysis of these cycles gave a poor fit. Then a correlogram was prepared as an alternative, and it also indicated no trends . Additional air pressure data for April, May, June, and July at the same location were then worked up so that these, along with the previous tabulations, provided a continuous plot for every month of the year from January 1899 through June 1939 at 10° N, 120° W. The plot showed no visible evidence of a periodicity or pattern in the curve other than the expected fluctuations at seven-year intervals.

Throughout the above analysis, two types of statistical tests employing contradictory suppositions were used: the "t" test based on randomness; periodogram, correlogram, and harmonic analysis based on nonrandomness. In applying these different types of tests to the same data there is an inherent *non sequitur*. The three tests of randomness applied in this work (the number of turning points, the length of phase [Kendall, 1948], and serial correlation [Quenouille, 1952]) provided no significant evidence against the randomness of the series, hence they did not suggest any cyclical changes in the air pressure. This failure to indicate a build-up is in agreement with the attempt (noted above) to increase P values obtained in a "t" test by eliminating certain years from the analysis.

De Boer (1941), in his extension of Berlage's work, determined that the following air pressure cycles obtained over Batavia: 2.34, 3.36, 5.97, 7.32, 8.47, 11.12, and 15.87 years. Of these, only the 5.97 year cycle appeared to be well developed, since he felt he could trace it from 1888 to 1941. He then concluded that the basic cycles are 3.36, 7.32, 11.12, and 36 years, the other periods being combinations of two or more of these, and that the 7.32 year cycle probably originated in the northern part of the North Atlantic Ocean. However, in view of the fact that De Boer's work has not been tested sufficiently by modern statistical methods, the serial correlation technique was applied to his six-year cycle, the only one for which he supplies data, and the results were statistically insignificant. Thus the validity of the remainder of De Boer's analysis is placed in doubt. As shown by the above discussion, periodogram and harmonic analyses can be used only after prior statistical tests have shown the validity of applying them.

In conclusion, a relationship which is periodic but not necessarily cyclical in the mathematical sense apparently exists between Peruvian and Javanese weather.

"NORMAL" CONDITIONS

As late as May 21, when the MARISE sailed for home, the Peru littoral north of Punta Aguja was not quite normal, nor, judging by the water color, was the water southward to Pisco; still, conditions were returning to normal, especially south of Punta Aguja. In the following section these normal and quasinormal conditions will be discussed.

PHYSICAL OCEANOGRAPHY

On the journey southward from Talara to Callao, the isotherms were bent sharply upward at 8° and 9° S (Fig. 15) whereas on the return trip, three weeks later, the peaking was obvious farther to the south (Fig. 16), 8° and 10° S. While the pertinent isotherms were situated at depths greater than 75 m on the southbound trip, on the return trip they extended no deeper than 25 m; also there were four less obvious isotherm convexities on the return trip. In a plot of surface temperatures between 6° and 12° S (Fig. 17), convexities in the isotherms reported above correspond with depressions in surface temperatures. The salinity distribution (Fig. 18) was irregular and uninformative. The decrease in salinity between 25 and 50 m, only present at Sts. 104, 106, 108, and 110, implies less stability in the water column though not enough to cause a decrease in σ_t with depth; isotherms in this region showed a slight bending upward.

Between March 10 and May 21, 1953, one prominent area of upwelling was located in the Independencia Bay–Le Bocqueron (Pisco Bay) region. Less obvious but persistent upwelling was also observed at about 8° S, but between April 20, when it was first noticed, and May 20, when it was last traversed, it had become less clearly defined.

Current velocity was approximated from ship drift and similar observations, since special equipment for accurate hydrographic observation was not available.

TABLE III. CURRENT OBSERVATIONS

St.	Current speed (cm/sec)	Current direction
67	77	South
124	155	North
128	50	North
131	93	North

Table III lists observations on current velocity and direction that will be used in a later section. Note that St. 67 was taken in El Niño water and is included here for comparative purposes.

CHEMICAL AND BIOLOGICAL OCEANOGRAPHY

Phosphate and Nitrate. Total phosphate in the water column is given in Table IV. Surface phosphate varied between 0 and 2.32 mg-at/m^3, the two highest values, 2.15 and 2.32, being observed at Sts. 124 and 131 in regions of upwelling; the lowest surface oxygen values (1.90 and 2.92 ml/l), were also observed at these stations, indicating the presence of moderately deep subsurface water. While St. 85 had a fairly high surface phosphate value (1.04 mg-at/m^3), the regions surrounding it showed low values. St. 154 produced the highest surface nitrate, 34.7 mg-at/m^3, while several stations gave a value of 0. Generally the observations indicate that El Niño stations had lower surface phosphates and nitrates than normal Peru Current stations; compare, for example, St. 85 with St. 154, or St. 100 with St. 148.

Phytoplankton. The phytoplankton, as determined by measurements of plant pigment concentrations, displayed a patchy and irregular distribution (Table IV), due in large measure to the general disruption of the Peru Current. The highest concentration was found at St. 81; here the surface values were five times greater than those at

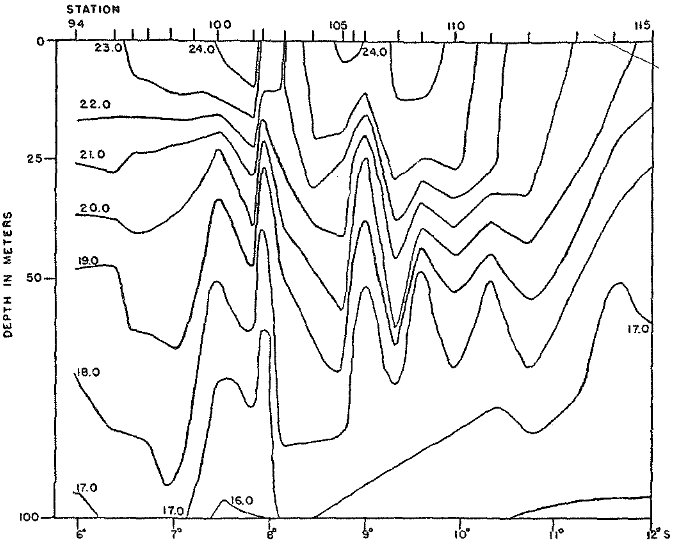

Figure 15. Vertical distribution of temperature south to Callao.

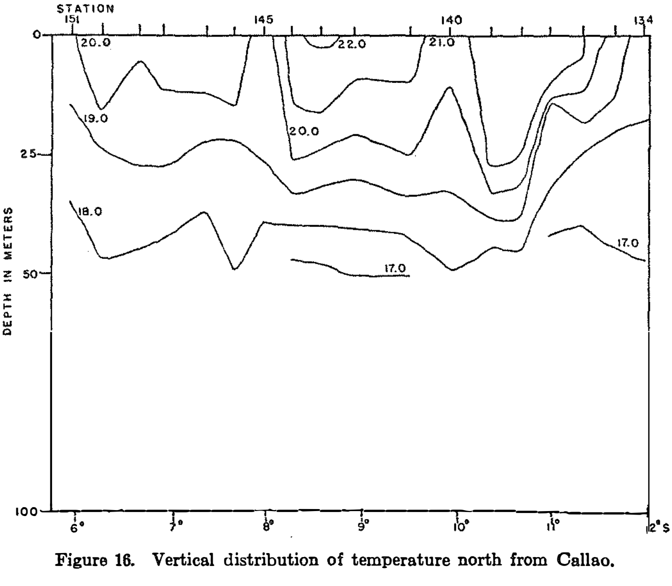

Figure 16. Vertical distribution of temperature north from Callao.

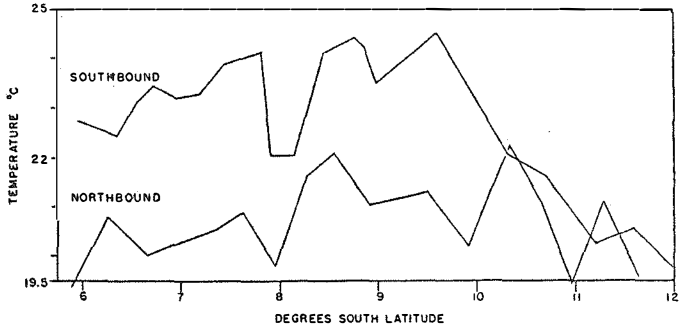

Figure 17. Surface temperatures between 6° and 12° S.

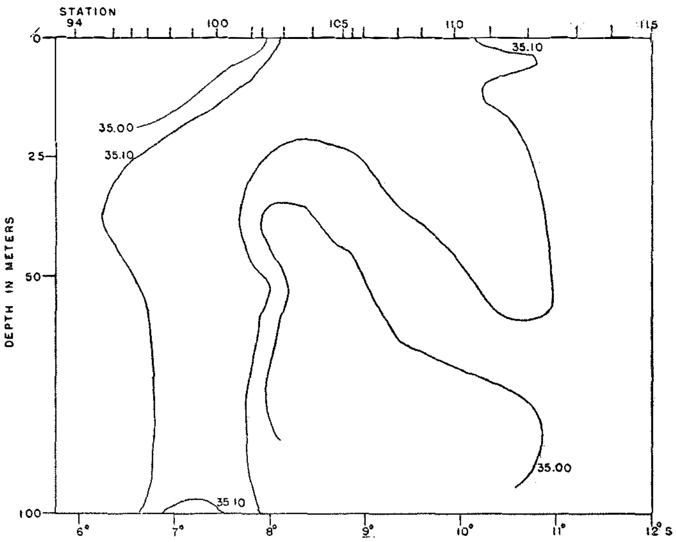

Figure 18. Vertical distribution of salinity south to Callao.

nearby stations in spite of the fact that the oxygen, nitrate, and zooplankton values and general water appearance were about the same as those of neighboring stations. Excepting St. 81, the highest plant pigment value was found at St. 142 (3900 × 10^3 Harvey units/m^2 sea surface); the lowest values were obtained at St. 71 (210 × 10^3).

In determining the effects of nutrients as limiting factors in phytoplankton growth, two enrichment experiments were performed, one

TABLE IV. DISTRIBUTION OF PHOSPHATE, NITRATE, PLANT PIGMENTS, AND ZOOPLANKTON. THE LATTER IS MEASURED TO A DEPTH OF 50 m. THE WATER COLUMN DEPTH FOR THE OTHER VARIABLES ARE AS INDICATED.

St.	Location		Depth of water column (m)	Phosphate (mg-at/m^2)	Nitrate (mg-at/m^2)	Plant pigment (10^3 H.U./m^2)	Zooplankton (ml displ. vol./m^2)	
	° S	° W					#2 Net	#10 Net
1	4° 18′	81° 23′	—	—	—	—	24.0	37.0
2	4 18	81 19	—	—	—	—	22.2	32.7
3	4 17	81 18	—	—	—	—	24.9	30.4
4	4 16	81 18	—	—	—	—	16.4	41.2
7	4 29	81 20	—	—	—	—	5.6	34.4
9	4 34	81 20	—	—	—	—	17.2	23.4
32	4 47	81 21	—	—	—	—	52.4	—
34	4 03	81 10	100	109	1475	—	—	14.2
67	4 18	81 20	100	168	1619	1106	22.2	10.9
70	4 42	81 22	50	46	492	592	34.5	56.5
71	3 57	81 16	100	120	1563	207	16.9	14.0
81	3 36	80 47	50	—	672	2033	36.0	66.0
85	4 15	81 15	50	66	616	684	—	—
87	4 27	81 23	50	59	892	570	11.3	80.1
91	5 21	81 24	100	84	1358	1529	15.3	35.7
100	7 26	80 22	100	98	1846	535	17.4	28.1
117	12 20	77 10	100	161	1453	1254	27.4	15.7
124	13 53	76 27	70	164	1396	314	12.8	15.6
128	13 39	76 24	50	82	591	1416	—	12.9
129	13 39	76 25	50	83	989	346	4.3	8.4
131	14 11	76 18	75	203	1369	1552	14.7	108.2
133	13 22	76 33	100	209	1731	952	5.0	12.1
135	11 38	77 32	75	131	2866	745	2.8	3.4
142	8 55	78 48	50	75	1707	—	19.5	12.7
148	6 55	80 44	50	70	1780	605	8.7	12.7
154	4 35	81 24	50	68	1847	283	5.4	15.6

at Callao and one at Pisco Bay. However, the results at Pisco Bay, which are generally in agreement with those at Callao, have been omitted from Table V because of errors in the original data. Both experiments disclosed that nitrogen was the most important limiting factor, since it was more effective than any other single element in stimulating oxygen production. Phosphate and nitrate together produced a greater effect than either alone, while iron and manganese produced negative or slightly positive results.

TABLE V. NUTRIENT ENRICHMENT EXPERIMENT AT CALLAO

Oxygen (mg-at/l)

	Content	Change
Control	.180	——
P	.178	−.002
N	.242	+.062
P+N	.248	+.066
Mn	.124	−.056
Fe	.128	−.052
P+N+Fe	.215	+.035
Fe+Mn	.140	−.040

An experiment on the rate of photosynthesis, performed at St. 85, gave erratic results. Surface oxygen production was about the same as the mean for highly productive waters such as those of Long Island Sound (Riley, 1941) and about three times greater than the value for tropical areas.

Zooplankton. Estimates of the amount of zooplankton were obtained by measuring the displacement volume of preserved zooplankton or by weighing if the sample was extremely small. Results were calculated in terms of the quantity in a column of water with a volume of one square meter by 50 m (Table IV). The #2 net tows ranged from 2.8 ml/m^2 at St. 135 to 52.4 at St. 32, the #10 tows from 3.4 ml/m^2 at St. 135 to 108.2 ml/m^2 at St. 131. At several stations where total depth did not greatly exceed 50 m, the zooplankton crops were of about the same magnitude as those given for productive north temperate waters; in New England coastal and offshore waters, the water column, of variable depth from top to bottom, contained between 20 and 113+ cc of zooplankton/m^2 (Riley, *et al.*, 1949: fig. 10).

Table IV shows the zooplankton concentrations for the northern region of Peru. While Sts. 1–4 and 67 were closely spaced and yielded similar amounts of zooplankton with a #2 net, St. 67 produced a smaller population than Sts. 1–4 when sampled with a #10 net. The sharp differences among stations in Table IV probably reflect the usual patchiness of zooplankton, since there are no obvious correlations of zooplankton with phytoplankton or with areas of upwelling.

DISCUSSION

Upwelling. In order to ascertain the relative importance of upwelling and eddy diffusivity to the high productivity of the Peru Current, a quantitative estimate of upwelling and diffusivity is essential. To obtain an estimate of upwelling, two methods proposed by Hidaka (1954) are used, since lack of complete seasonal water temperatures exclude other methods. Hidaka has shown that both of his methods are generally applicable to the California and Peru Currents in that they yield reasonable results, therefore both of his methods were employed in order to determine which method yielded the best results.

The following relationship of Hidaka's was tried first:

$$\text{Upwelling} = V\,(D_h/D_v)^{-1} = V\,(A_h/A_v)^{-1/2},$$

where V is the horizontal current velocity, D_h the frictional distance, D_v the depth of frictional influence, and A_h and A_v the coefficients of horizontal and vertical mixing. The result gave unreasonable figures for upwelling, probably because of the difficulty in properly estimating A_h and A_v. In this instance, values of A_v were obtained from Sverdrup, *et al.* (1942: table 64) and it was assumed that A_h varied between the reasonable extremes of 10^6 and 10^8.

Hidaka's other equation was then tried:

$$\text{Upwelling} = (2\pi\tau/\rho\omega \sin\phi)\ (\Delta\psi/\Delta x)\quad ,$$

using his reasonable assumption that $\Delta\psi = .033$ and $\Delta x = 0.14$.

TABLE VI. UPWELLING = $(2\pi\tau/\rho\omega \sin\phi)\ (\Delta\psi/\Delta x)$

St.	τ	D_v(m)	$10^5 D_h$ (cm)	Upwelling (m/day)
102	.08	30	30	.456
107	1.17	30	30	6.67
124	1.17	100	100	2.00
131	.08	100	100	.137
134	.08	100	100	.137
137	.03	100	100	.051
142	.36	30	30	2.05
				Mean 1.64

The results (Table VI) appear to offer reasonable estimates of upwelling but not absolute values; therefore these estimates will be used in subsequent calculations. Even though Hidaka's original restriction—that the wind blow along the coast—has only been partly met here, these values agree well with those derived for other areas; McEwen (1929) estimated upwelling off southern California to be 10 to 20 m/month and Saito (cited by Hidaka, 1954) obtained a figure of 2.25 m/day in the same area.

The stability of the water column for 11 stations where phosphate analyses were carried out was determined from the equation

$$E' = 10^{-3}\, d\sigma_t/dz \quad ,$$

where E' is the approximate stability and $d\sigma_t/dz$ the change in σ_t with depth. With but five exceptions, the stability was moderate to high, even at St. 124 where there was considerable active upwelling. St. 131 showed the least general subsurface stability. The coefficients of vertical eddy diffusivity were computed from Riley (1951: fig. 2) and the results are listed in Table VII.

TABLE VII. Coefficients of eddy diffusivity (A)

St.	A	St.	A	St.	A	St.	A
34	.25	41	.08	67	.61	70	.15
71	.20	81	.23	85	.18	87	.18
91	.19	100	.20	117	.35	124	2.19
128	.56	129	.79	131	2.08	133	.40
135	.28	142	.17	148	.19	154	.40

Phosphate and Nitrate. Since the Peru Current was in a state of flux during the Yale Expedition, it seems less than worthwhile to compare chemical observations from one station with another. Although it might be argued that data from areas of known upwelling might be satisfactory for comparison with those of other regions, since they might be normal, the duration of upwelling undoubtedly does affect the distribution of nutrients in the area. On the one hand, Schweigger (1953) offered evidence that steady normal temperatures existed in the region south of Punta Aguja in 1953. On the other hand, Barreda (1954) indicated great variation among surface temperatures occurring in the same month, even during normal periods; Barreda reported surface temperatures of 20.0, 25.0, 17.5, and 15.4° C just inside Le Bocqueron, Pisco Bay, for March 4, 7, 18, 23, and 31 respectively.

Granted that the use of data from upwelling areas for comparative purposes is a questionable procedure, it is of interest nevertheless to compare our data with those of other expeditions. The Dana Expedition (Thomsen, 1937) reported surface phosphates as high as 0.95 mg-at/m^3 at about 0°, 99° W and as low as zero at about 32° S, 176° W. The William Scoresby, operating in the Peru Current, found the highest surface phosphate, 2.83 mg-at/m^3, at about 36° S, 73° W, and the lowest, 0.13, at 27° S, 72° W; 16° S, 77° W; 9° S, 80° W; and 4° S, 82° W (Discovery Committee, 1949). East of the international dateline, the CARNEGIE obtained its highest surface phosphate, 1.46, at about 14° S, 78° W; its lowest figure was 0.13 at approximately 30° S, 109° W (Fleming, *et al.*, 1945).

Regarding nitrate values, Gunther provided none, and, although the DANA Expedition did provide some, the regions sampled were far from the Peru Current; however, they are the only values available for the eastern Pacific and will have to suffice. The DANA's highest surface nitrate was 10.71 at 0° N, 99° W, the lowest, zero, at 3° N, 88° W and at 32° S, 176° W.

Sverdrup, *et al.* (1942: fig. 48) reported phosphate values of 3 mg-at/m^3 at 1100 to 1800 m and at 2800 m in the Pacific; for nitrates, their figures (1942: fig. 49) were as high as 36 mg–at/m^3 at depths greater than 2000 m. When the above values are compared with the maximal surface values encountered on the Yale Expedition, it is apparent that there is a bunching of the nutrient isopleths toward the surface in the coastal area.

General Relations of Nutrients, Phytoplankton, and Zooplankton. In such areas as Le Bocqueron and Independencia Bay, the surface layers contained a large quantity of nitrate and phosphate but they showed little biological activity. Oxygen saturation in the surface waters of Le Bocqueron was 34.9%, with a surface phosphate of 2.15 mg-at P/m^3. In Independencia Bay (St. 131) the oxygen saturation at the surface was only 53%, whereas the surface phosphate was 2.32. The absence of biological activity in regions of high nutrient concentration is probably due to the recent ascent of such water to the surface layers where phytoplankton could develop. At St. 142, where upwelling was far less obvious, the water probably had been at the surface long enough for a large phytoplankton population to develop.

Nutrients and Plankton Associated with Upwelling. To obtain a picture of the change in oceanographic characteristics with time, a specific station can be analyzed at intervals or else several different stations can be studied at approximately the same time. The latter course has been followed here in a survey of Sts. 124, 128, and 129 (Table VIII) which are located in the vicinity of Pisco Bay. St. 124

TABLE VIII. DATA FOR STS. 124, 128, AND 129

Depth		Temp. (°C)			Salinity (‰)			Phosphate (mg-at/m³)			Nitrate (mg-at/m³)		
124	*128–9*	*124*	*128*	*129*	*124*	*128*	*129*	*124*	*128*	*129*	*124*	*128*	*129*
0	0	17.63	19.86	19.52	34.90	34.89	34.92	2.15	1.17	0.80	20.2	0.05	12.1
5	5	17.52	19.41	19.02	34.92	34.89	34.99	1.98	.93	.92	19.9	.4	15.9
	10	—	19.13	18.52	—	34.86	35.07	—	.89	1.32	—	1.2	19.8
20	25	16.58	17.30	16.97	34.89	34.95	35.05	2.41	1.98	1.88	19.9	17.6	20.7
45	50	16.02	16.41	16.41	34.89	34.93	35.05	2.43	2.04	2.04	20.0	17.9	21.5
TOTALS:									82.25	82.90		591.1	988.8

Depth		Oxygen (ml/l)			Chlorophyll (mg/m³)			*Net*	*Depth*	Zooplankton (ml. displ. vol./m³)		
124	*128–9*	*124*	*128*	*129*	*124*	*128*	*129*			*124*	*128*	*129*
0	0	1.90	4.91	5.80	3.4	9.4	—	2	50–25	.37	.07	.10
5	5	1.63	5.04	4.40	1.7	2.2	10.2	2	25–0	.07	.02	.04
	10	—	4.43	2.47	—	19.6	.1	10	50–25	.44	.32	.18
20	25	0.72	0.61	0.59	1.4	3.5	.03	10	25–0	.04	.10	.13
45	50	0.26	0.30	0.46	.6	1.7	.05	—	—	—	—	—
TOTALS:		—	97.55	78.90								

was in Le Bocqueron, the passage between San Gallan Island and the mainland; St. 128 was just off the northern end of North Chincha Island; and St. 129 was just west of North Chincha Island. The temperature profiles indicated upwelling at St. 124 and considerable surface warming at Sts. 128 and 129. The surface salinities at the three stations were virtually identical, although there was some oceanic water below ten meters at St. 129. Temperature and salinity demonstrated that the water at St. 124 had welled up recently whereas that at Sts. 128 and 129 had surfaced some time previously. St. 124 produced the highest phosphates and nitrates and the lowest dissolved oxygen and chlorophyll content. St. 129 showed higher nitrate, lower oxygen and a lower chlorophyll content than St. 128. In phosphate content, Sts. 128 and 129 were virtually equal.

Thus, the water at St. 129, with a slight decrease in nutrient and with a moderate increase in oxygen and chlorophyll content, was of intermediate "age" after upwelling; the water at St. 128, which showed the greatest reduction of nitrate and the greatest increase in oxygen and chorophyll, was of mature "age." In speaking of "age," the time scale of upwelling used here is biologically applicable solely to phytoplankton development; *i.e.,* the zooplankton had insufficient time to develop a population commensurate with the amount of food available.

Estimates of "Normal" Nutrient Enrichment and Productivity. Originally, it was intended that an estimate of the productivity of the Peru Current be included in the ecological studies, but with abnormal conditions prevailing, the initial plan could not be fulfilled. However, the area was beginning to recover from El Niño toward the end of the expedition. To be sure, upwelling was observed and its magnitude roughly estimated, but the picture obtained probably does not reflect a normal biological state, in spite of the fact that a few large phytoplankton concentrations were observed. Nevertheless it seems worthwhile to examine the most fundamental problem involved in the productivity of the region, namely the rate of supply of nutrient elements to the surface layer.

Previous information consists mainly of records of fish catches and of guano deposition from which an indirect estimate may be made of the amount of phytoplankton productivity required to support the fish populations on which the birds feed. The food chain in Peruvian waters is simple and short; according to Sears (1954) and Rojas (1953), the anchovy, which is the major forage fish for both birds and carnivorous fishes, is primarily a phytoplankton feeder.

The mean total annual catch of bonita and tuna in Peru for the years 1951–1953 was 51,594,554 kilograms (Ancieta, personal communication), and according to Avila (personal communication), these species annually consume 4.4 times their own weight per year. Thus they would consume 2.27×10^5 metric tons per year, principally anchovy. The birds, as noted earlier (p. 114), consume 2.97×10^6 metrice tons of anchovy per year. And finally, the commercial catch of anchovy per year in Peru is 2×10^4 metric tons. From these data, then, the total "yield" of anchovy equals 3.2×10^6 metric tons per year. Proceeding on the assumption that each anchovy consumes 9.5 times its own weight per year (Okul, 1941), the phytoplankton yield is about 3×10^7 metric tons (wet weight), which corresponds to about 3.67×10^6 metric tons of dry phytoplankton, assuming 12.2% of the wet phytoplankton weight (Harris and Riley, 1956). Since approximately half of the organic content is carbon, and assuming a normal C:P ratio of 41:1 (Sverdrup, *et al.*), the annual phosphorus requirement is estimated at about 4.95×10^4 metric tons. This figure represents merely the phosphorous requirement of that fraction of the phytoplankton which is directly converted to fish production recorded in a commercial harvest of one kind or another. Thus, it is a minimal estimate of phytoplankton utilization.

An independent estimate of productivity may be derived from previous calculations of rates of upwelling and eddy diffusivity. It is claimed that upwelling is fundamental to the high productivity of the Peru Current, but, since upwelling is of limited extent in the Peru Current while upward transport of nutrients by vertical eddy diffusivity occurs over a much larger area, it is reasonable to include both phenomena in an analysis of total nutrient supply.

The vertical flux, F_p, of phosphorus, P, through a square centimeter of horizontal surface at any depth, z, is given by the equation:

$$F_p = wP - (A/\rho)\frac{\partial P}{\partial z},$$

where w is the vertical velocity of the water in cm/sec, A the coefficient of vertical eddy diffiusivity, and ρ density of the water (Sverdrup, *et al.*). The vertical axis is directed positively downward. In the following pages, the terms are computed in the cgs system except that it will be convenient to designate P in μg-at P/cm^3. The first half of the equation, wP, will be applied to areas of known upwelling, while in the remainder of the Peru Current, w will be considered negligible (Table IX).

After the stability of the water column, E (p. 141), was determined for individual stations, it was combined with the current speed, V, and with the acceleration of gravity, g, in the empirical expression: $V(gE)^{-1/2}$. This value was used in obtaining the coefficients of eddy diffusivity, A (Riley, 1951: fig. 2). Since 25 and 50 m generally bracket the thermocline, they were selected as the depths for an estimation of P and $\partial P/\partial z$. The method can be illustrated by considering St. 34 in Table IX. $V(gE)^{-1/2} = 2.5 \times 10^2$; thus A in column 5 is 0.25 gm/cm/sec. In column 6 the difference in phosphate from 25 to 50 m is 0.11. Column 10 gives the daily increase in phosphorus in terms of μg-at P/cm^2/day (mean $= 2.36 \times 10^{-3}$) according to the formula at the top of column 10. Column 7 was taken in part from Table VI. In column 9 the increase in μg-at P/cm^2/day due to upwelling is given (mean $= 168.45 \times 10^{-3}$). These mean figures are the estimated amounts of phosphate carried through a square centimeter between 50 and 25 m by eddy diffusivity or upwelling. Neither of the above means is based on all stations, the values for the abnormal stations (34, 41, 67, 70, 71, and 81) being omitted. Stations considered as centers of upwelling are not included in the mean for eddy diffusivity, and similarly, nonupwelling stations were not included in the mean for upwelling. Some stations were not clearly of one type or another, therefore they are included in both means.

For water along the Peru coast, it is assumed that we need to consider only the upwelling areas off Arica, San Juan, and the Guanape Islands; that being the case, upwelling is limited to roughly $2.14 \times 10^{10}\text{m}^2$ (Gunther, 1936: figs. 30, 34, 66). Further, it is assumed that the Peru Current, along the Peru coast only, has a length of 1400 miles and a width of 300 miles[4] (CARNEGIE Sts. 71, 72, 73). The total area of the Peru Current is then estimated to be $1.44 \times 10^{12}\text{m}^2$. Upwelling is calculated to bring 4.1×10^5 metric tons of phosphorus to the upper layers per year, and similarly, eddy diffusivity brings 3.9×10^5 metric tons. The two distributing agents then are of about equal

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[4] Gunther has suggested 1000 miles as its width here, but this seems excessive.

TABLE IX. Daily increase in phosphorus due to upwelling and eddy diffusivity.

1. St.	2. $10^8 E$	3. V (cm/sec)	4. $V(gE)^{-1/2}$	5. A (gm/cm/sec)	6. P_{50}-P_{25} (10^3 μg-at/cm^3)	7. w (cm/day)	8. P_{25-50} (10^3 μg-at/cm^3)	9. Daily increase (10^3 μg-at P/cm^2) due to Upwelling (wP_{25-50})	10. Daily increase (10^3 μg-at P/cm^2) due to Eddy Diffusivity $\frac{[-A\ (P_{50}-P_{25})\ 86{,}400]}{(\rho \times 25 \times 10^2)}$
34	1100	25	250	.25	.11		1.075		.9266
41	9800	25	79.8	.08	—		—		—
67	1600	77	610	.61	.99		1.615		20.348
70	2800	25	150	.15	.52		1.28		2.253
71	1600	25	198	.20	—.19		1.325		—1.281
81	1200	25	228	.23	—		—		—
85	1900	25	180	.18	.16		1.48		1.079
87	2000	25	177	.18	.96		1.65		5.823
91	1800	25	186	.19	.49		.745		3.137
100	1500	25	204	.20	—.17	46	.965	44.36	—1.146
117	500	25	354	.35	1.02	46	1.38	63.49	12.030
124	500	155	2190	2.19	.02	200	2.42	484.01	1.476
128	800	50	559	.56	.06	5	2.01	10.05	.7571
129	400	50	791	.79	.16	5	1.96	9.79	4.259
131	200	93	2080	2.08	.06	14	2.68	37.50	4.205
133	400	25	396	.40	.01	14	2.295	32.14	.1346
135	800	25	280	.28	.21	5	1.915	9.56	1.982
142	2200	25	169	.17	—.20	205	1.51	309.56	—1.146
148	1800	25	186	.19	—.02	46	1.56	71.78	.1283
154	400	25	396	.40	.01	5	1.445	7.24	.1346

magnitude and account for 8.0×10^5 metric tons of phosphorus in the aggregate. For comparison with other regions, the vertical transport of P is given in g/m²/yr in Table X. Phosphorus data for other temperate waters of the southern hemisphere are not available, but in the northern hemisphere, Long Island Sound, which has approximately the same level of productivity as Block Island Sound and Georges Bank, may be regarded as typical of the most productive temperate regions. Thus areas of upwelling have a productivity potential that is an order of magnitude larger than the most productive temperate waters. By contrast, nonupwelling regions are comparatively poor.

TABLE X. VERTICAL TRANSPORT OF PHOSPHORUS IN THE PERU CURRENT AND LONG ISLAND SOUND

Peru Current	Vertical transport ($gP/m^2/yr$)	Total utilization of P
Upwelling area 21,000 km²	19.5	—
Nonupwelling area 1,436,000 km²	.27	—
Mean	.53	—
Long Island Sound	1.6	4.05

The total upward movement of phosphorus does not indicate the total utilization of P by the phytoplankton because some phosphate is regenerated and reused in the eutrophic zone. For example, Riley (1956) has estimated that in Long Island Sound the total utilization of phosphorus by the phytoplankton is 2.5 times the amount regenerated on the bottom and returned to the surface layer by upward transport, and Harvey's (1950) estimate for the English Channel is about 1.5. Thus the total phytoplankton utilization of phosphorus is about one to two million metric tons per year.

Fish production in Block Island Sound and in the English Channel is approximately 0.5% of net phytoplankton production. Assuming a Peruvian fish production of 3.22×10^6 metric tons[5] containing 1.13×10^4 metric tons of phosphorus (Hutchinson, personal communication) and assuming further a phytoplankton consumption of one to two million tons, the estimated efficiency of anchovy production is

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[5] Murphy (1954) has quoted Schweigger as saying that the peak anchoveta population off Peru is 2×10^7 metric tons, a figure which is almost ten times more than our minimal estimate.

0.6 to 1.1%. Because it is believed that anchovies feed directly on phytoplankton, they should have a much greater efficiency of production than the above value for zooplankton feeders or demersal forms. Possible explanations are: (a) the phytoplankton productivity has been overestimated; (b) a significant fraction of phytoplankton production is utilized by animals which are not recorded as part of the commercial statistics. The latter explanation appears to be more feasible, especially since the guano production has recently been markedly increased by enlarging the nesting area and thus far no food limitation has been apparent.

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Перувианское течение

Краткий обзор

Настоящее исследование океанографии и связанной с ней метеорологии Перувианскаго течения и явления обыкновенно называемаго „El Niño“ преимущественно основано на результатах Йельской Южно-Американской Экспедиции в Перувианских водах от 10-го Марта до 21-го Мая 1953 г. Исследование морской воды включало температуру, соленость, кислород, фосфат, нитрат, растительные пигменты, фитопланктон и зоопланктон. Дополнительные наблюдения имевшие значение в этом исследовании, но не упомянутые здесь, хранятся в Бингамской океанографической лаборатории. Они включают прозрачность воды, температуру воздуха, атмосферное давление, силу и направление ветра, влажность, облачный покров и видимость. Темп фотосинтеза и влияние добавочных питательных веществ на рост определялись опытным путем.

В средине Марта и опять в начале Апреля „El Niño“ наблюдался вдоль Перувианских берегов на север от 6° южной параллели ввиде водяного клина движущагося на юг над Перувианским течением движущемся на север. Этот клин воды, дважды наступавшей и отступавшей, в продолжение экспндиции, сопровождался в его южном движении случайными дождями, северным ветром, южным течением, температурой воды превышавшей 24° C. и соленостью меньше 34‰.

Когда течение было типично на север температура была низкая, присутствовала вода большой солености из Перувианскаго течения, ветер дул с юга и дождей не было.

Эти обстоятельства в связи с фаунистическими наблюдениями указывают на перемещение воды на юг из более северных районов, несомненно из экваториальнаго противотечения, а вероятно и из района прилежащаго к Центральной Америке. Не ясно образует ли вода из этих двух северных районов отдельные слои клина, один над другим, или перемешивается в своем течении над Перувианским течением.

Анализ атмосфернаго давления, основанный на данных сообщенных метеорологическим бюро Соединенных Штатов за период от 1899 до 1939 года показал что „El Niño“ связан с периодическими местными уменьшениями сезонной смены атмосферной циркуляции над восточным Тихим Океаном. Эти уменьшения в свою очердь повидимому связаны с замедлением сезонной атмосферной смены над западным Тихим Океаном. В строго математическом смысле эти периодические явления не циклические, а простые колебания.

В Перувианском течении максимальные количества фосфата, нитрата, фитопланктона и зоопланктона были сущесвенно того же порядка величины как в плодородных умеренных водах севернаго полушария, тогда как в теплой малосоленой воде „El Niño“ они значительно меньше. Нитрат был главным ограничительным фактором и фотосинтетический темп был приблизительно такой же как у северных умеренных вод Атлантическаго Океана.

Вертикальное передвижение воды вверх, наблюденное в двух местах и упомянутое прежними исследователями, колебалось от одного до двух метров в день. Во время Йельской экспедиции литоральная зона повидимому никогда не была нормальной во всех отношениях. Несмотря на это пробная оценка вертикальнаго переноса фосфата в Перувианском течении показала что около 4.0 × 10^5 метрических тонн фосфора были перенесены на поверхность в течении года вертикальным движением и почти столько же водоворотной диффузией. В ограниченных районах интенсивнаго движения вверх, в котором темп снабжения гораздо больший чем путем диффузии, темп наростания количества планктона может быть гораздо высшаго порядка чем быстрейший темп в умеренных водах.

Другая оценка была получена путем подсчета количества фитопланктона потребнаго для разведения определеннаго размера населения анчоусов как видно по выработке гуано и улову торговых рыб. Высчитанная этим методом потребность в фосфате для фитопланктона равнялась 4.95 × 10^4 метрических тонн, что представляет порядок гораздо меньшей величины чем для фосфатов перенесенных вертикальным движением. Не известно является ли разница в количестве фосфата, полученная этими двумя методами, результатом оценки переноса или того что большое количество фитопланктона было потреблено другими животными не включенными в вычислении.