Life History and Ecological Notes on the Tubenose, *Aulorhynchus flavidus*, a Hemibranch Fish of Western North America[1, 2]

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The tubenose, or tube-snout, *Aulorhynchus flavidus* Gill, attains a length of at least 165 mm, but the mean standard length of adults examined was 142.9 mm. The range of the tubenose is Sitka, Alaska, to Punta Banda, Baja California, and diving observations reveal them to be present through the year in southern California. The fish have been observed and collected in rocky crevices, kelp beds, eel grass, and over sand bottom. They are found from the surface to 100 feet. They feed on small, free-swimming organisms. The major spawning area studied is considered for a possible correlation of the peculiar conditions there with spawning habits. The tubenose mainly establishes its nest on and attaches its eggs to the giant kelp, *Macrocystis pyrifera*. The nests are closely guarded by males who actively drive off intruders. The nest building habit and territorial behavior is reminiscent of that of the sticklebacks, and the morphological evidence of the close relationships between the two groups is in part confirmed. Egg masses have been observed from depths of 17 to 120 ft, but most commonly 35 to 58 ft. The presence of eggs and young fish during the entire year suggests that spawning is not seasonal. It is probable that the tubenose serves as an important link in the food chain of some California game fishes.

LITTLE is known about the life history and ecology of the tubenose, *Aulorhynchus flavidus* Gill, which, along with *Aulichthys japonicus* Regan, has been classified as the Aulorhynchidae. This family has been recognized as closely related to the sticklebacks (Gasterosteidae) by numerous authors, including Gill (1884), Jordan and Evermann (1896a, b), Starks (1902), Jordan (1923: 174), Berg (1940:288, 459; 1955:217), and Atz (1937). In number of dorsal spines, and some other characters, the European marine stickleback *Spinachia spinachia* (Linnaeus) seems to be transitional between the other sticklebacks and the Pacific genera *Aulorhynchus* and *Aulichthys*. It would not be an excessively conservative act to place them in a subfamily, Aulorhynchinae, within the Gasterosteidae.

This problem of relationship and the unique characters of this little fish (Fig. 1) prompted a study of its breeding behavior and other life ways, particularly after it was found to resemble sticklebacks in the construction of a nest and in the parental care it bestows on its eggs. A major objective was the acquisition of information that would make it possible to compare the two groups on a behavioral level.

Observations were made in the field, by means of SCUBA (self-contained underwater breathing apparatus), and in the laboratory, by maintaining specimens in aquaria at the Scripps Institution of Oceanography. Living specimens were collected in an underwater "butterfly net" designed by the author.

SIZE AND PROBABLE AGE

The tubenose, a small, very slender fish, attains a length of at least 165 mm (Clemens and Wilby, 1946).

The size distribution of tubenose (Fig. 2) was determined for several samples, comprising 145 adults, taken by the California Division of Fish and Game in water 125 to 250 ft deep off Point Arguello, California, fol-

[1] Contribution from the Scripps Institution of Oceanography, New Series.

[2] This paper, based on a manuscript prepared by the author prior to his death, has been revised and brought up-to-date by Howard M. Feder, Hartnell College, Salinas, California. Carl L. Hubbs, under whom Conrad Limbaugh worked as a graduate student, and Dr. Richard Rosenblatt, Scripps Institution of Oceanography, assisted in the preparation of the final draft.

Conrad Limbaugh, chief diving officer at Scripps Institution of Oceanography and one of the world's foremost underwater naturalists, had been working on numerous and diverse research projects before he met an untimely death in a diving accident in the Mediterranean on 20 March 1960. Many of his projects, including this paper, were left unfinished. However, because of the extensive field notes and photographic records he maintained, it is anticipated that the results of most of these studies can be assembled and eventually published so the vast wealth of his accumulated knowledge will not be lost.

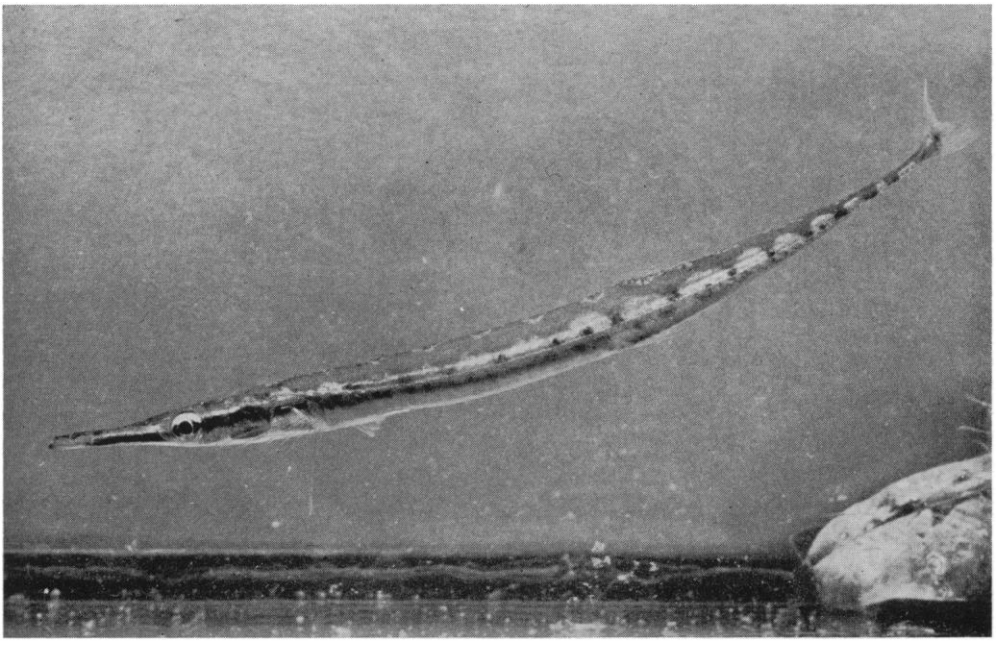


Fig. 1. Adult of the tubenose, *Aulorhynchus flavidus*. A living specimen photographed in a tank at the Scripps Institution of Oceanography.

lowing detonation of explosives in seismic exploration during the winter of 1948–49 (Fitch and Young, 1948; John E. Fitch, personal communication). The mean standard length of the entire sample is 142.9 mm, that of the males 137.4 mm (range 121.3–153.2 mm), and that of the females 145.7 mm (range 125.0–161.1 mm). The slightly smaller males comprised only 34.5 per cent of the sample.

Since the size frequencies of adult males and females seem to be unimodal (Fig. 2), it is probable that the breeding fish constitute a single year group, or that growth ceases on the attainment of maturity. That this fish has an annual life cycle seems to be the more plausible hypothesis.

Distribution

Aulorhynchus has been recorded from Washington Territory (Gill, 1861); California (Peters, 1866); Monterey Bay, San Francisco, Puget Sound, and Sitka (Bean, 1881); Port Townsend in Washington, Alert Bay in British Columbia, and Loring in Alaska (Evermann and Goldsborough, 1907:275); and Queen Charlotte Islands, Strait of Georgia, and west coast of Vancouver Island (Clemens and Wilby, 1946). Published and original records from the Puget Sound region and from the outer coast of Washington and Oregon were listed by Schultz and DeLacy (1936:70). On the basis of descriptions of fishermen, Eigenmann (1892) indicated its probable occurrence in the vicinity of San Diego. The California Department of Fish and Game has sampled the fish from off

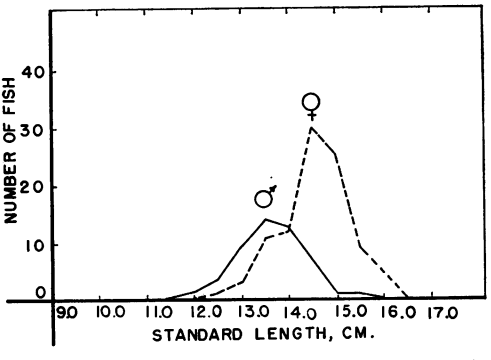


Fig. 2. Standard-length measurements of 145 specimens of *Aulorhynchus flavidus* collected off Point Arguello, California by Dr. Carl L. Hubbs of the Scripps Institution of Oceanography, and John E. Fitch of California Division of Fish and Game, by means of explosives used in seismic work, on 9 December 1948 and 1–14 January 1949. The class interval is 5 mm.

Point Arguello (Fitch and Young, 1948) and off Santa Rosa Island (Fitch, 1952). Specimens of the tubenose have been collected by the staff of the Scripps Institution of Oceanography at Cuyler Harbor, San Miguel Island; Beechers Bay, Santa Rosa Island; Forneys Cove and Pelican Bay, Santa Cruz Island; several localities about La Jolla, and Mission Bay, California; and from South Coronado Island, and the south sides of Punta Banda and Punta Rocosa, northwestern Baja California. The author has observed the tubenose by diving at Van Dam State Park, Morro Bay, La Jolla, and Point Loma, California, and at Punta Rocosa, Baja California, as well as off the islands of San Miguel, Santa Rosa, Santa Cruz, and Santa Barbara, California, and the Coronado Islands, Baja California.

The range of *Aulorhynchus* has been given as from San Nicholas Island and Monterey, California, north to Sitka, Alaska (Jordan and Evermann, 1896a, b). The same range has been indicated by other authors (Starks and Morris, 1907; Barnhart, 1936; Taranetz, 1937; Clemens and Wilby, 1946). Fitch (1952) indicated a southward extension to Punta Banda, Baja California. The known range of this fish from Sitka, Alaska, to Punta Rocosa, northwestern Baja California, thus very closely coincides with the North American distribution of the giant kelp, *Macrocystis,* which extends from Sitka, Alaska, south to Isla Asunción, central Baja California (Dawson, et al., 1960), and it undoubtedly occurs in the appropriate habitats through its entire range. The significance of the coincidence in the ranges will become evident when the breeding habits are outlined.

Abundance and Schooling Habit

Clemens and Wilby (1946) reported the tubenose to be a common shore fish. Diving observations reveal it to be present throughout the year in southern California, and at times they may become extremely abundant. One school of approximately 2,000 adults was noted in the La Jolla kelp beds.

The specimens taken by the Department of Fish and Game off Point Arguello were from large schools (Fitch and Young, 1948; John E. Fitch, personal communication). Those taken by the Department off Santa Rosa Island were from an immense midwater school estimated to be near one-fourth mi. wide, at a depth of 30 to 70 ft.

Habitat

Jordan and Gilbert (1881) reported that the tubenose inhabits sheltered bays near shore from Monterey to Puget Sound. The fish has been collected near a dock, in the kelp, and in a bay in Alaska (Evermann and Goldsborough, 1907). Clemens and Wilby (1946) considered it a shore fish that may be observed near eel grass or near the surface. The author has observed it over rocky areas in shallow water in northern California, but often in deeper water in southern California. They have been examined and collected in habitats as varied as rocky crevices, kelp beds, eel grass, and over sand bottom at the tip of Scripps Pier, La Jolla, California. The adults occur from the surface to 100 ft, at depths averaging about 36 ft; the half-grown (juveniles), from the surface to 40 ft, at depths averaging about 16 ft.

Habits of the Adults

Food.—The tubenose has been noted to feed on small planktonic crustaceans, presumably in British Columbia (Clemens and Wilby, 1946). Stomach analysis of specimens caught in California has revealed that they feed on small, free-swimming organisms including amphipods, mysids, fish larvae, and zoea larvae of crabs. An adult male maintained in a 20-gallon sea-water tank readily ate newly hatched young of its own species, but refused nonliving organic material. One young hatched from the egg and was reared to a standard length of 46 mm on brine shrimp nauplii and other fine food.

Swimming.—Clemens and Wilby (1946) observed small schools of *Aulorhynchus* at the surface of the water, swimming slowly. The fin movements, however, were rapid, and their mouths were snapping constantly.

Like sticklebacks, the tubenose is capable of rather fast forward lunges and can back up slowly. When moving slowly forward or backward, it employs only the pectoral fins; when moving forward rapidly, the caudal fin is used. The stiffness of the body of the adult does not allow the fish to turn quickly. Consequently, when approached from the front, the fish either comes forward in a large arc or backs up and then goes forward in a new direction.

Spawning

The spawning area.—The characteristics of the area where the breeding of the tubenose was chiefly studied need to be considered, for the peculiar conditions found there are related to the observed spawning behavior of the tubenose.

Late in the fall of 1950, a small patch of kelp was observed at the surface approximately 800 to 1,000 yards north of the pier at the Scripps Institution of Oceanography and about 900 yards from shore. This region had previously been thought to have a sand bottom overlying a ridge adjacent to the Scripps Submarine Canyon (Shepard, 1949; Limbaugh and Shepard, 1957). The kelp patch enlarged, and by January, 1951, was about 50 ft wide and 200 ft long at the surface. Because *Macrocystis* does not grow in this region on sand, an exposed solid substrate was suspected. On 4 January 1951, diving revealed a rock ledge projecting from a sand bank at a depth of 54 to 60 ft. Many adult tubenose, estimated to number 2,000, were schooling from 2 to 15 ft off the bottom among the kelp plants. The fact that the rocks were free of organisms, and that the kelp plants were young and foliose, indicated that a recent shifting of sand had bared the rocks.

Among the exposed rocks were hundreds of spiny lobsters, *Panulirus interruptus* (Randall), and a few crested gobies, *Rhinogobiops nicholsii* (Bean). No other fishes were observed near the bottom. Near the surface of the kelp bed many kelp perch, *Brachyistius frenatus* (Gill), and a few small half-grown kelp bass, *Paralabrax clathratus* (Girard), were observed. During February 1951, a few more species of fishes and the eggs as well as young of *Aulorhynchus* were observed. In late February, a storm removed a large portion of the kelp, and sand was rapidly filling in over the rocks.

The observed spawning may have been correlated with the proximity of the canyon, with the paucity of other fishes and of other organisms (other than the spiny lobster), or with the newness of the kelp patch.

Nest formation.—Apparently a direct relationship exists between the tubenose and the distribution of the kelp, *Macrocystis*. Observations have demonstrated that this fish deposits its eggs mainly on this plant, though the eggs have also been collected in a number of other situations: in the holdfasts of the bull kelp, *Pelagophycus*; attached to eel grass; on a temperature recording device suspended from the tip of Scripps Pier; and on coralline algae near young plants of *Macrocystis*.

The male tubenose binds the seaweed together with very strong, silvery, weblike strands which are extruded from the urogenital region. As a result of this activity, the stipes that later bear eggs are bent sharply so that the growing terminal blades are pointed downward. It is in this manner that the nest is formed (Fig. 3). The nest of the tubenose is similar to that of the sticklebacks, but it is not known whether the nidamental organ of the tubenose is homologous to the peculiar organ of the sticklebacks (Ikeda, 1933).

Small schools of heavy adults, presumed to be ripe females, have been observed schooling 4 to 10 ft above the nests. These fish circled slowly in relatively large circles 8 to 10 ft in diameter. The females probably continue to school during the breeding season, although it is possible that the formation of these small schools was a fright response caused by the presence of the diver.

Egg deposition and behavior of males.—Direct observation with diving equipment has revealed that the eggs are deposited by the female just below the fast-growing tip of the young stipes that emerge from the holdfast region of the plant. Small masses are attached to this stipe at the junctions of the branches leading to the pneumatocyst-bearing fronds. The eggs do not adhere to the kelp but to each other. Each egg mass encircles the stipe and the base of the pneumatocyst (Fig. 4). The eggs are not placed in the nest itself, but are actually above it, as is clearly shown in Figs. 3 and 4. The nest seems to be important, since some sort of a nest was observed even when the eggs had been deposited in such unusual places as on the surface and in the crevices of holdfasts of *Macrocystis* and *Pelagophycus*; in coralline algae, near young kelp (*Macrocystis*); on eel grass (*Zostera*); on strands of surf grass (*Phyllospadix*) attached close together on a cable; and even on a temperature recorder. The role of the nest in the spawning behavior of the tubenose, however, remains an enigma. It may be that the nest is a necessary releaser, without which the female would not spawn, but further work will be required to indicate its function.

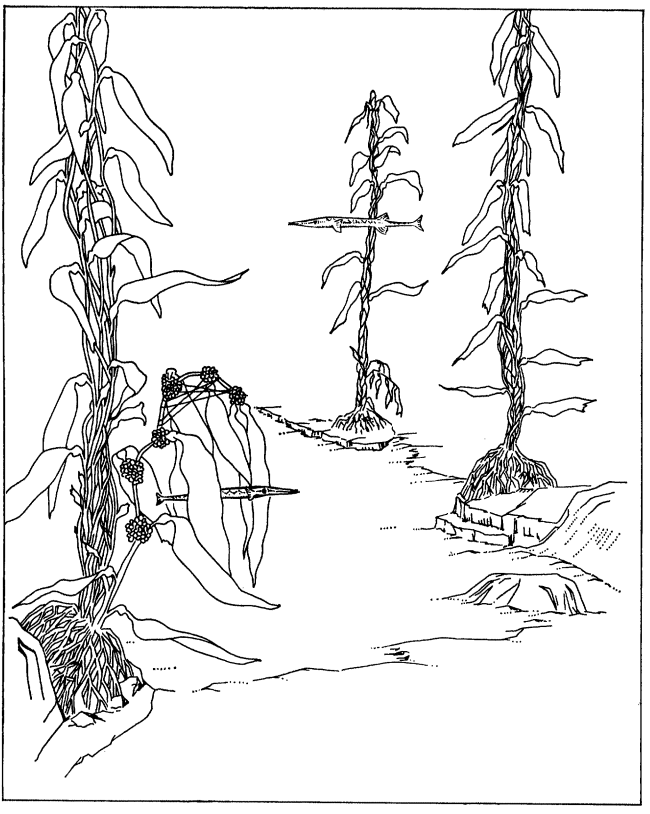


Fig. 3. An underwater view of nests of the tubenose, *Aulorhynchus flavidus,* showing how stipes bearing egg masses are bent downward. The fish observed here are males guarding the nests.

The egg masses vary in diameter from about 13 to 33 mm. The masses are usually in series, with as many as ten on a single stipe. Ordinarily, each pneumatocyst on the section of a stipe that bears spawn is accompanied by a mass of eggs. The older, more-developed eggs are on the lower, older, earlier formed part of the stipe. Observations indicate that a new batch of eggs may be spawned on a pneumatocyst if an egg mass breaks free of its attachment.

The nests are closely guarded by the males, who drive off intruders by dashing directly at them. A male may occasionally leave its nest, but to swim only a few feet before returning shortly. Some nests may contain no eggs. On rare occasions a nest has been observed unaccompanied by a male. One nest containing only hatched eggs was still attended by an adult male. If young were present, they were not observed.

Eggs.—Eggs of the tubenose have been observed and taken directly from the giant kelp plant, *Macrocystis,* at depths of 35 to 58 ft. Numerous eggs were observed at these levels. Eggs were found at depths less than 35 ft in La Jolla only once, although a thorough search was undertaken. Some were collected at 17 ft in the eel grass and on a temperature recorder off Scripps Pier. The deepest collection was from the holdfast of a bull kelp at a depth of 120 ft off La Jolla.

Each egg is approximately 2.0 mm in diameter. The shape is round to slightly oval (Fig. 5A), except where the egg is flattened by attachment to another egg (Fig. 5C). The eggs adhere to each other so securely that it is almost impossible to separate them without injury.

Orton (1955) reported that recently spawned eggs vary from pale honey-tan through various shades of brownish-orange to dark reddish-amber. Eggs within a particular cluster were uniformly of the same color. She found that the eggs of each color became progressively paler as development

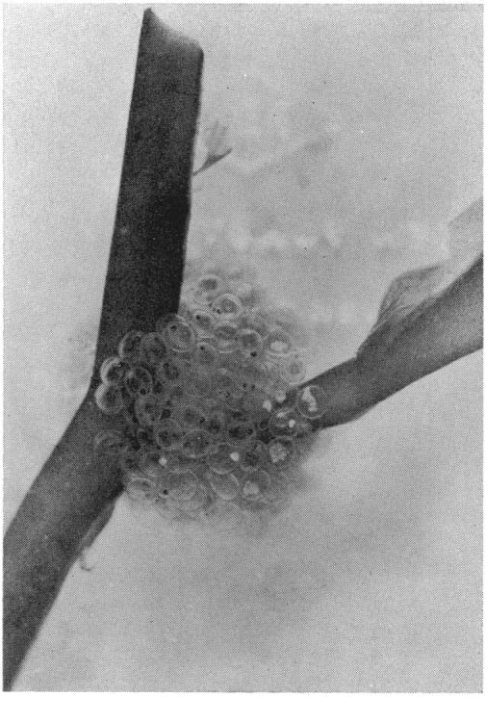


Fig. 4. A mass of developing eggs of the tubenose, *Aulorhynchus flavidus,* encircling the stipe of a *Macrocystis* plant at the base of an air bladder.

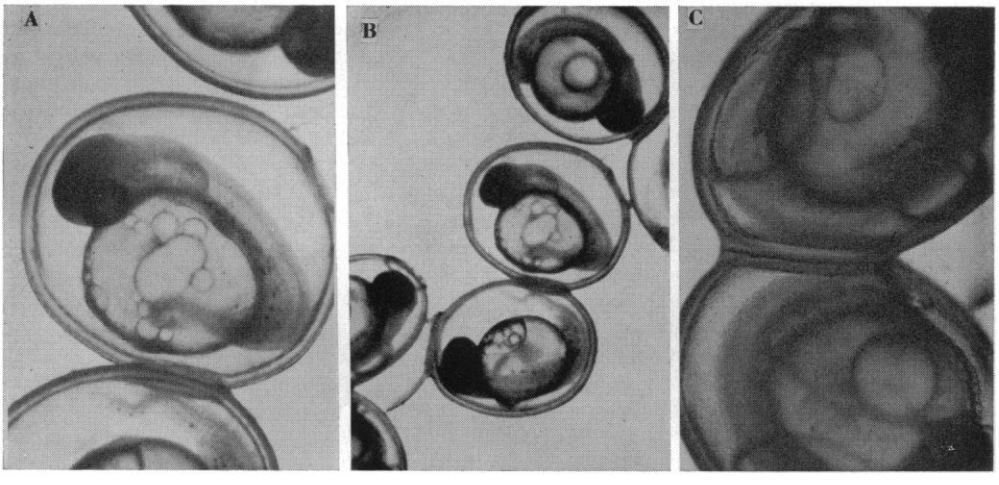
proceeded, and at hatching the small yolksac was pale yellowish or slightly greenish-yellow. Eggs from the full range of color variation produced normal embryos. Nothing is known of the factors that regulate these color differences.

Spawning period.—The eggs have been found in the apparently detached surface kelp off Point Loma, California in August. In January and February eggs have been washed ashore at La Jolla. In June half-grown tubenose, one to three inches long, were observed by diving at Van Dam State Park in northern California. Also in June, half-grown specimens were observed schooling with the labrid, *Oxyjulis californica* (the señorita), off La Jolla. Young *Aulorhynchus* were dredged during the months of March and August near the Coronado Islands. Post-larvae were taken at San Miguel Island on 17 September 1954. A fully mature female was found at La Jolla on 7 May 1956. Eggs have been taken on 28, 29, and 30 January; 1, 4, and 28 February; 2, 11, 13, and 15 March; and 2 May. The occurrence of eggs and young throughout much of the year indicates that spawning is not sharply restricted to any particular season.

Spawning range.—Specimens 1.15 to 2.15 in. (28–55 mm) long have been taken at Port Townsend, Alaska (Evermann and Goldsborough, 1907) and small juveniles have been observed by the author in northern and southern California, the Coronado Islands, and in northwestern Baja California. The species almost certainly breeds throughout its range.

Development and Young Fish

Eggs (Figs. 4 and 5 A–C) maintained in laboratory aquaria hatch in approximately 2 to 3 weeks. The hatched larvae meas-



Figs. 5 A–C. Enlarged views of developing eggs of the tubenose, *Aulorhynchus flavidus.* The embryos are well advanced. These eggs were a part of the general mass shown in Fig. 4.

ure approximately 5.5 to 7.0 mm in total length, but there is a tendency for premature hatching and the smaller sizes may be the result of this occurrence, according to a personal communication from Dr. Grace Orton, Scripps Institution of Oceanography, La Jolla, California. Ordinarily under laboratory conditions the larvae do well for a short time only. However, one specimen that hatched on 3 March was reared to a standard length of 46 mm.

Shortly after the larvae hatch in the field they form schools near the bottom, usually in quiet water near rocks or seaweed. Schooling behavior continues throughout life and is disrupted only during spawning, when the male establishes its territory and guards its nest. The young probably take less than one year to mature.

Importance

The tubenose is present throughout the year in southern California and at times may become very abundant.

It is probable that this fish serves as an important link in the food chain of some of the California game fishes. It has been found in the stomachs of kelp bass, *Paralabrax clathratus* (Girard) and sand bass, *P. nebulifer* (Girard). Their eggs have been taken from the stomachs of sand bass, scorpionfish, *Scorpaena guttata* (Girard), and cabezon, *Scorpaenichthys marmoratus* (Ayres).

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Literature Cited

Atz, J. W. 1937. Neptune's knight: the seahorse. *Bull. N. Y. Zool. Soc. 40(2):57–65.*

Barnhart, P. S. 1936. Marine fishes of southern California. *Univ. of Calif. Press, Berkeley 209 pp.*

Bean, T. H. 1881. A preliminary catalogue of the fishes of Alaskan and adjacent waters. *Proc. U. S. Natl. Mus. 4:239–72.*

Berg, L. S. 1940. Classification of fishes, both recent and fossil. *Trav. Inst. Zool. Acad. Sci. URSS 5:87–517.*

———. 1955. The classification of the fishes living and extinct. *Trans. Inst. Zool. Acad. Sci. USSR 20:1–286. (In Russian.)*

Clemens, W. A. and G. V. Wilby. 1946. Fishes of the Pacific coast of Canada. *Fish. Res. Bd. Canada 48:1–368.*

Dawson, E. Y., M. Neushul, and R. D. Wildman. 1960. Seaweeds associated with kelp beds along southern California and northwestern Mexico. *Pacific Nat. 1(14):1–80.*

Eigenmann, C. H. 1892. The fishes of San Diego, California. *Proc. U. S. Natl. Mus. 15 (897):123–78.*

Evermann, B. W. and E. L. Goldsborough. 1907. The fishes of Alaska. *Bull. U. S. Bur. Fish. 26: 219–360.*

Fitch, J. E. 1952. Distributional notes on some Pacific coast marine fishes. *Calif. Fish & Game 38(4):557–64.*

——— and P. H. Young. 1948. Use and effect of explosives in California coastal waters. *Calif. Fish & Game 34(2):53–70.*

Gill, T. 1861. On a new type of Aulostomatoids, found in Washington Territory. *Proc. Acad. Nat. Sci. Phila. 13:168–70.*

———. 1884. On the mutual relations of the hemibranchiate fishes. *Proc. Acad. Nat. Sci. Phila. 1885:154–66.*

Ikeda, K. 1933. Effect of castration on the secondary sexual characters of the anadromous three-spined stickleback, *Gasterosteus aculeatus. Japanese J. Zool. 5:135–57.*

Jordan, D. S. 1923. A classification of fishes including families and genera as far as known. *Stanford Univ. Publ. Univ. Ser. Biol. Sci. 3(2): 1–243.*

——— and B. W. Evermann. 1896a. The fishes of north and middle America. *U. S. Natl. Mus. Bull. 47:1–1240.*

———. 1896b. A check list of the fishes and fishlike vertebrates of north and middle America. *Rept. U. S. Comm. Fish Fish. 1894–5, Pt. 21, app. 5:207–584.*

——— and C. H. Gilbert. 1881. Notes on the fishes of the Pacific coast of the United States. *Proc. U. S. Nat. Mus. 4:29–70.*

Limbaugh, C. and F. P. Shepard. 1957. Submarine canyons. *Geol. Soc. Am. Mem. 67, 1: 633–9.*

Orton, Grace L. 1955. Color variation in certain marine fish eggs. *Copeia (2):144–5.*

Peters, W. 1866. Mittheilung über Fische . . . etc. *Monatsber. Akad. Wiss. Berlin:509–26.*

Schultz, L. P. and A. C. DeLacy. 1936. Fishes of the American Northwest. *Jour. Pan-Pac. Res. Inst. 11(1):63–78.*

Shepard, F. P. 1949. Terrestrial topography of submarine canyons revealed by diving. *Geol. Soc. Am. Bull. 60:1597–1612.*

Starks, E. C. 1902. The shoulder girdle and characteristic osteology of the Hemibranchiate fishes. *Proc. U. S. Nat. Mus. 25:619–34.*

——— and E. L. Morris. 1907. The marine fishes of southern California. *Univ. Calif. Publ. Zool. 3(11):159–251.*

Taranetz, A. J. 1937. Handbook for identification of fishes of Soviet, Far East, and adjacent waters. *Bull. Pac. Sci. Institt. Fish & Ocean. 11:1–103. (In Russian.)*

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