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OBSERVATIONS ON FEEDING, GROWTH, LOCOMOTOR BEHAVIOR, AND BUOYANCY OF A PELAGIC STROMATEOID FISH, *ICICHTHYS LOCKINGTONI*

Stromateoid fishes (Order Perciformes) occur in either coastal or oceanic regions of the sea. Inhabitants of the latter region are generally rare and sporadic in occurrence, especially as adults. Many of the oceanic species have particular adaptations for pelagic existence (Horn 1975) and their frequent association with floating objects, especially coelenterates (scyphomedusae and siphonophores), is well documented (e.g., Mansueti 1963; Haedrich 1967; Bone and Brook 1973; Horn 1975).

The live capture and successful laboratory maintenance of a juvenile *Icichthys lockingtoni* Jordan and Gilbert (family Centrolophidae), an oceanic fish of the North Pacific, provided the first opportunity to record the feeding, growth, and locomotor behavior of this pelagic stromateoid and, upon the death of the fish, to measure its buoyancy and lipid content (as a factor in buoyancy). In this paper, the laboratory rearing and maintenance of oceanic stromateoids are briefly reviewed, and the adaptive strategy of *I.*

lockingtoni for locomotion and buoyancy in the open ocean is compared with that of another pelagic centrolophid, *Schedophilus medusophagus* Cocco.

Materials and Methods

One *I. lockingtoni* was captured during an open-water skin and scuba diving operation conducted from the RV *Nautilus* in the San Pedro Channel (lat. 33°30'N, long. 118°30'W) off southern California on 24 October 1974. The fish was approached by a scuba diver at a depth of 11 m as it swam slowly beneath a scyphozoan medusa (tentatively identified as a member of the family Pelagiidae) approximately 30 cm in bell diameter. The specimen was captured in a 1-liter jar, placed in a container filled with aerated seawater aboard the ship and transported to the laboratory at California State University, Fullerton, where it was placed in a 95-liter Instant Ocean[1] Tank. Approximately 6 h lapsed between time of capture and placement of the fish in the laboratory tank. Sea temperature at the depth of capture was 15°C and the temperature of the seawater in the tank when the fish was introduced was 13°C. Temperature of the seawater in the tank during the maintenance period ranged from 8.8°C to 22.2°C ($\bar{x} \pm 1$ SD = 14.9 ± 2.2°C) and the salinity from 35.0‰ to 37.5‰ (35.7 ± 2.3‰).

The fish began feeding regularly on 7 November 1974 and was fed daily (except for 8 days, irregularly spaced, when feeding was not possible) by hand with measured amounts of frozen brine shrimp (90% water content). The fish took the food at the surface so that it was possible to keep an accurate record of the amount of food it ingested. The daily diet of frozen brine shrimp ranged in weight from 1.2 to 8 g (0.4–1.4 g dry wt/100 g live wt fish). The feeding rate was based on the amount the fish would consume immediately. Weight and standard length (SL) of the specimen were recorded on 7 November and at irregular intervals throughout the maintenance period by removing the fish in a tray from the tank and placing it on a platform balance beside a metric rule. The weighing and measuring procedure required that the fish be out of water a maximum of 15 s. The conversion of food into fish flesh was obtained by dividing the food intake (dry wt) by the gain in weight of the fish (wet wt) (Hastings and Dickie 1972).

Locomotor behavior was recorded from periodic observations and from analysis of an 8-mm ciné film made of the fish swimming in the tank.

Buoyancy of the specimen was measured immediately after its death (7 April 1975) by weighing it in air and in water of known temperature and salinity. Results were expressed as the percent of the weight in air that the fish weighed in seawater.

After the buoyancy determination the specimen was frozen and later thawed for lipid analysis. Total lipids of the spine, skull, viscera, and flesh (all other tissues) were extracted with chloroform-methanol (2:1, vol/vol) and expressed for each of the four body parts as the percent of total body lipid and as the percent of dry weight of that body part.

Results

The specimen of *I. lockingtoni* became conditioned within 1 wk of capture to take food directly from the hand. Chunks of frozen brine shrimp offered at the surface were quickly approached and usually taken in a single bite. Throughout the maintenance period, the fish occasionally swam upside down, apparently a normal mode of swimming, and sometimes fed in this position. The fish also bit at other available objects in the tank, including human fingers at feeding time, grasping them and then rolling and twisting its body as if to tear free the objects. Vision appeared to be the primary sense used in locating food.

The specimen measured 105 mm SL at the time of capture. On 7 November, when the fish began to feed regularly and the record of food intake and growth was begun, the fish weighed 30.6 g and was 115 mm SL (Table 1). The specimen lived 165 days, until 7 April 1975, when the temperature of the tank increased unexpectedly to 26°C apparently causing death. At death, the fish weighed 54.5 g (78.1% increase over its 7 November weight) and had grown to 168 mm SL (46.1% increase). Its weight peaked on 5 February at 64.6 g then declined to the final value.

During the 151-day period (7 November-7 April), 65.7 g (dry wt) of frozen brine shrimp were ingested by the fish (Table 1). Based on this intake and the weight gain recorded (23.9 g wet wt), the overall conversion factor was 2.7. For the 90-day

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

TABLE 1.—Size, food intake, and food conversion, at cumulative intervals, of *Icichthys lockingtoni* maintained in the laboratory over a 151-day period.

Date	Fish length (mm SL)	Fish weight (g wet wt)	Food intake[1] (g dry wt)	Conversion factor (food intake ÷fish wt gain)
7 Nov. 1974	115	30.6	—	—
22 Nov. 1974	120	33.8	3.8	1.2
14 Dec. 1974	125	36.5	11.7	2.0
4 Jan. 1975	135	43.2	21.2	1.7
5 Feb. 1975	—	64.6	38.9	1.1
7 Apr. 1975	168	54.5	65.7	2.7

[1]Based on 90% water content.

period ending on 5 February when the fish's weight reached a maximum, *I. lockingtoni* ingested 38.9 g of food (dry wt) and gained 34.0 g (wet wt) for a food conversion of 1.1.

The fish swam slowly and continuously most of the time but infrequently hovered in one position. The short (12.6% SL, 168 mm SL), fanlike pectoral fins were the primary propulsive elements when the fish cruised slowly in the tank. Each pectoral fin was flapped in a semirotary manner, alternately to the opposing fin, at approximately 1 stroke/s. At short-term increased speeds, the pectoral fins were held against the body and thrust obtained by sinuous movements of the posterior trunk and caudal region. The small (6.5% SL, 168 mm SL) pelvic fins were actively used during swimming especially in braking and turning. As mentioned, the fish was adept at swimming for short distances upside down and at other attitudes about its longitudinal axis.

The weight of the fish in seawater (20°C, 33‰) immediately after death was 0.36 g or 0.66% of its weight in air (slight negative buoyancy).

Lipids constituted 4.9% of the dry weight of the spine, 10.6% of the skull, 17.0% of the viscera, and 4.4% of the flesh. Spine lipids made up 2.2% of the total body lipids, skull lipids 2.9%, visceral lipids 35.3%, and flesh lipids 59.6%.

Discussion

The stromateoid characteristic of associating with pelagic coelenterates as juveniles is particularly well developed in *I. lockingtoni*. Many of the small (<200 mm SL) specimens captured have been taken with medusae (Fitch 1949; Haedrich 1966; Fitch and Lavenberg 1968). The locomotor behavior and feeding behavior of *Icichthys* recorded in this report are traits well suited for living with medusae. The ability to swim at various attitudes about the longitudinal axis and to hover and maneuver using the paired fins would be advantageous in moving among and avoiding the stinging tentacles of medusae. The grasping of large objects followed by a rolling and twisting of the body appears to be a feeding pattern especially appropriate for tearing chunks from the tentacles and other tissues of coelenterates. Haedrich (1966) reported that the stomachs of *Icichthys* often contain siphonophore remains. A feeding behavior also consisting of grasping objects and twisting the body has been observed (R. L. Haedrich pers. commun.) in two other pelagic centrolophids, *Hyperoglyphe perciforma* (Mitchill) and *Schedophilus medusophagus*.

The food conversion values for *Icichthys* of 2.7 for the 151-day period and 1.1 for the initial 90-day period are comparable to or, in the latter case, more efficient than average total conversions (1.75-2.7) reported by Phillips (1972:19) for brook trout and brown trout fed a variety of diets at temperatures ranging from 8.3° to 15.6°C. The feeding rates of 0.4-1.4% for *I. lockingtoni* were lower than those of 2-3% at which maximum conversion occurred in channel catfish (Tiemeier et al. 1969). Useful comparisons between different experiments and different species are limited since a variety of physical and biological factors influence energy requirements and conversion efficiencies and since food conversions, as calculated here, are less meaningful and often different from caloric conversions (Phillips 1972). The most important result of the present study, however, is that the conversion efficiency of *I. lockingtoni* did change, generally declining with age of the fish (see below).

Limited success has been achieved in maintaining pelagic stromateoids in the laboratory. Maul (1964) recorded rapid growth in two species of centrolophids *Schedophilus* (= *Mupus*) *maculatus* and *Schedophilus* (= *Mupus*) *ovalis*, fed on a diet of shrimp in a large (700-liter) aquarium. The former species increased in weight from 7 to 95 g in 61 days, and *S. ovalis* increased in length from 100 to 198 mm SL over the same period. R. L. Haedrich (pers. commun.) has kept two other centrolophids, *S. medusophagus* and *Hyperoglyphe perciforma*, for 2- to 3-mo periods in small (40- to 100-liter) tanks at Woods Hole Oceanographic Institution. D. Gruber at the Southwest Fisheries Center in La Jolla has hatched and reared a series of larvae of *I. lockingtoni* (E. H. Ahlstrom pers. commun.). One larva that hatched on 12 June 1975 at a notochord length of 3 mm grew to 90 mm SL by 30 August 1975 (80 days).

The rare and sporadic live capture of stromateoids prevents the development of appropriate procedures for long-term maintenance. To date, maintenance trials indicate (pers. obs.; R. L. Haedrich pers. commun.) that the fishes will grow rapidly for short periods but then lose interest in feeding and gradually decline in health, especially as the adult stage is reached when pelagic stromateoids generally change their mode of life and occupy greater depths. The initial growth and high conversion efficiency followed by the reduced growth and lowered efficiency of *I. lockingtoni* are consistent with these observations.

The apparent adaptive strategy for pelagic existence of juvenile *I. lockingtoni* involving locomotor behavior, buoyancy, and lipid content parallels that described (Bone and Brook 1973) for juvenile (85-200 mm SL) *Schedophilus medusophagus* from the North Atlantic. There is no swim bladder in either species in this size range, the lipid content of both is low and both species are slightly negatively buoyant (weight in water 0.35-0.53% of weight in air for *S. medusophagus*). In each case, the pectoral fins are important in generating both thrust and lift.

The two species also appear to undergo similar changes in mode of life as the adult stage (about >200 mm SL) is reached and the fishes become independent of floating objects and occupy greater depths in the water column. Data, particularly on adult *S. medusophagus*, indicate that certain density reducing mechanisms (increase in lipid and water content, decrease in dense tissues, i.e., muscle and bone) are more prominent than in the juvenile stage. Horn (1975) found that a large (285 mm SL) specimen of *S. medusophagus* was neutrally buoyant, swam in a slow, near-anguilliform manner and had relatively small pectoral fins of minor importance in generating thrust and lift. Lipid content in the same specimen was relatively high, especially in the bones (spine 23% and skull 21% lipid by dry wt) (Lee et al. 1975).

Data are yet insufficient on adult *I. lockingtoni* to fully demonstrate parallel strategies in the two species. The relative length of the paired fins of *Icichthys*, however, decrease with age (Haedrich 1966) at a rate and magnitude similar to that in *S. medusophagus*. In addition, the muscles of large (270 mm SL) *Icichthys* are soft and loosely packed as in *Schedophilus*. Data on buoyancy and lipid content of adult *I. lockingtoni* are needed to test the hypothesis.

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