OBSERVATIONS ON THE SWIMMING BEHAVIOR OF SOME TAENIOSOMOUS FISHES IN AQUARIA AND IN NATURE[1]

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With Plates VII–IX

On account of their strange appearances and peculiar structures, the taeniosomous fishes (Teleostei: Lampridiformes) have hitherto attracted profound attention of zoologists in regard to their swimming behavior. Various opinions have been expressed by many researchers: some insisted on the availability of a strong lateral undulation of the trunk and tail as the most important impetus for the locomotion, whilst others considered the long-based dorsal fin well developed in this fish group probably playing a principal role in the swimming behavior (SCHLESINGER 1911; DU BOIS-REYMOND 1914; BREDER 1926; NORMAN 1931; etc.).

In these years, the senior author has published a series of papers concerning the locomotory mechanism found in this group of teleostean fishes. The works were based upon the results of studies on the anatomical, biochemical and bio-physical peculiarities of the animals (NISHIMURA 1961, 1963, 1964), and in these papers he manifested an opinion that the taeniosomous fishes would in an ordinary state of swimming rely upon a consistent waving motion of the long-based dorsal fin which is passed from the anterior to the posterior along its entire length, that during the locomotion the animals would take a vertical, but slightly tilted, posture, keeping the muzzle obliquely upwards, and that a part of the kinetic energy thus liberated would counteract the gravity which might otherwise bring down these bladderless mesopelagic teleosts to the depths of the ocean.

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Recently a good fortune favored the junior author of having a chance to make observations on living specimens of two species of taeniosomous fishes, *Trachipterus iris* (WALBAUM) and *T. ishikawai* JORDAN & SNYDER, kept in tanks of his aquarium. The present paper deals with records of observations on these specimens, together with unpublished informations gathered by the senior author on the field behavior of *Regalecus russellii* (SHAW), another taeniosomous fish.

Observations on *Trachipterus iris* in aquarium and in nature

On February 20, 1963, a perfect living specimen of *Trachipterus iris* was brought to the Enoshima Aquarium to be displayed in a tank. It had been caught by a diver in Sagami Bay just off the aquarium at the depth of 10 m and was a small individual of 18.2 cm in standard length.

In the aquarium, it was observed that the animal swam gently by undulating the fins, especially the dorsal fin, and keeping the longitudinal axis of the body nearly vertically with the muzzle pointing upwards (Plate VII, Fig. 1 and Plate VIII, Fig. 2). Meanwhile no indication of lateral undulation of the trunk or tail was ever observed. The water temperature was maintained from 17° to 18°C.

The diver who caught this specimen explains that the animal was swimming in nearly the same posture in the sea and so slowly that he could seize the fish with his fingers.

The fish was active in the tank only for four hours and a half; and when it became exhausted, it swam just under the surface with the belly upwards (Plate VIII, Fig. 3).

This erected posture in swimming agrees with the proposed posture by the senior author for ordinarily swimming taeniosomous fishes (NISHIMURA 1961, 1963), and thus a part of his supposition may be said to be ascertained here.

In this connection, it may be of some interest to note that, in this fish, the distal portions of the elongated anterior rays of the dorsal as well as the caudal fin are swollen and appear to contain a kind of gas within them. This is, however, to be proved in future study.

Observations on *Trachipterus ishikawai* in aquarium

The junior author had also an opportunity to observe the swimming behavior of an individual of *Trachipterus ishikawai*, a closely related species to *T. iris*. This individual, about 150 cm in body length, was caught on March 6, 1960, in Sagami Bay, and kept in a tank alive for up to 14 hours. When the animal was brought into the tank, it looked being in so good physical condition that the behaviors observed were considered to reflect in a significant degree those in the intact state in natural environments.

In the aquarium, the animal appeared to try to keep the body vertically with the muzzle pointing upwards by undulating the dorsal fin continuously (Plate IX, Fig. 4). Unfortunately, however, this effort was in vain because the tank was too shallow for the animal to take the intended posture: halfway in the course of erecting the body, its head reached the surface and the tail touched the tank bottom. The fish repeated the hopeless venture many times until it was exhausted, then fell down on the bottom. Figures 5, 6 and 7 on Plate IX illustrate the animal struggling against the sinking by undulating the dorsal fin, but at last exhausted and falling down on the bottom on one lateral side of the body. Either in this species, no sign of swimming by undulating the trunk and tail in a horizontal posture was ever noticed. While the fish was lying still on the bottom, leaning against the side wall of the tank, the undulation of the dorsal fin was continued incessantly (Plate IX, Fig. 8). The temperature of the rearing water measured 23° to 24°C.

The above observations seem to confirm the supposition of the senior author (NISHIMURA 1961, 1963) that the principal swimming impetus in the taeniosomous fishes may be produced by a continuous undulation of the long-based dorsal fin, and that a part of this impetus counteracts against sinking and the animals will fall down when the driving force of the dorsal fin becomes weakened.

Informations on the behavior of *Regalecus russellii*

Since the senior author published his view on the locomotory mechanism of *Regalecus* or the oarfish, he has continued to make an effort of gathering any informations pertinent to the behavior of this most remarkable taeniosome in nature. And up to now two observations were recorded; these will be introduced briefly below.

The first observation was made on January 23, 1962, by fishermen in Toyama Bay on the northwestern coast of middle Honshu. Mr. Takemi TSUDA of the Shin-Minato Junior High School kindly informed the senior author of the results of observations in his personal communications dated March 28 and April 10, 1962. He says:

> The fish was entrapped in a set net. As the net was being pulled up, the animal was found swimming around a little below the surface in a considerable speed by undulating the body and tail. The swimming behavior was much like that of the hairtail, *Trichiurus*. The undulation of the body, however, was not consistent but intermittent; some strong strokes and weak swings took place alternately. In swimming, the pinkish dorsal fin was clearly observed undulating from side to side. As the net was narrowed furthermore, the oarfish began to swim

straightly, frequently showing a manner as if it were going to jump out from the water. When raised into the air, the animal waved the body strongly several times and then lay down quiet on board. It reacted, however, to stimuli by the wavy motion of the dorsal fin for five hours subsequently. This oarfish measured about 350 cm in body length.

It is regrettable that no reference was made as to the orientation of the body during the swimming; but it is very noteworthy that the body undulation observed so clearly in this case was irregular or rather awkward and soon ceased. It is rather difficult to regard this to be an ordinary swimming impetus for the present animal. On the other hand, the undulation of the dorsal fin maintained so persistently seems to suggest that the momentum generated by this organ is very probably contributing to keep this bladderless teleost afloat in its natural habitat in the middle layer of the ocean.

The second observation was made on February 8, 1962, at Wani Ura (鰐浦) of Upper Tsushima Island in the straits between Japan and Korea by Mr. Hasegawa of the village. The story was later passed to the senior author by courtesy of Dr. Satoshi Mito* of the Fisheries Laboratory, Kyushu University, who mentioned it in his personal communication of March 30, 1962, as follows:

Two fishermen, on their way home from squid fishing, found a strange fish of a gigantic size hovering just under the surface at a rather shallow spot in the Bay of Wani Ura. The fish body was held vertically and the head was pointing upwards. They tried to capture this monster, and found, when the fish was taken out of water, that it was a huge, very elongated and laterally compressed teleost with a scarlet dorsal fin, some anterior rays of which were extremely elongated. The surface of body was studded with numerous tubercles. The fish measured 460 cm in total length.

Undoubtedly this is an oarfish; and the observation is quite significant in that it confirms the supposition of the senior author concerning the ordinary swimming posture of the oarfish. It is also recognized from the same observation that the animal is not a swift swimmer but a slow or sluggish creature, though it is not impossible that the behavior here reported is itself an unnatural one appeared under the unusual circumstances in the shallow layer of the sea.

General consideration

It may be now safely concluded that the taeniosomous fishes generally take a slightly inclined vertical posture of the body and keep the head upwards during their ordinary swimming locomotion, that the impetus necessary for maintaining this posture and driving the body is generated mostly from the waving motion of the long-based dorsal fin, and that the swimming speed thus attained may certainly be small under usual circumstances.

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WALTERS (1963), remarking the peculiar structures found in the integument of trachipterine fishes, i.e. the existence of a network of narrow subdermal canals and minute surface pores, presented lately an interesting view in regard to the possible function played by such structures during the locomotion of these animals. According to this author, such an integument may work as a stabilizer of the boundary layer by distributed dynamic damping during the forward locomotion of the animal, and an increase in locomotory efficiency achieved in this way is of critical value in the mesopelagic environment where there is less biologically available energy (food) than in surface waters. In proposing this hypothesis, he assumed the trachipterid body to be a rigid, non-undulating plane surface; and this assumption may now be said to have been verified.

The hypothesis by WALTERS is indeed a very fascinating one, and probably the functional structure of the trachipterid integument may at least partly be explained after this view; but its whole validity will have to be cleared by careful experimental studies in future. It is still in doubt whether or not the peculiar integumental structure is solely responsible for the stabilization of the boundary layer over the moving animal body; moreover it seems rather difficult to understand why such an effective damping mechanism has been developed among the slow-moving or, more fitly speaking, hovering animals like the trachipterine teleosts, as is suspected from the present observations. There remains a possibility that the *porous* integument may simply be a compensatory structure in the mesopelagic mode of life: in this habitat, the fish has to reduce its specific gravity on one hand and to counteract the large hydrostatic pressure on the other, and these may be accomplished by the decalcification or degeneration of bones and scales and the very watery composition of muscles and bones (DENTON & MARSHALL 1958; NISHIMURA 1963). Formation of the tough but elastic dermis in many taeniosomous teleosts may possibly be a compensation for this *degeneration* in the skeletal and muscular systems; and the development of a network of subdermal canals and minute surface pores may be accepted as an extreme result in the specialization towards reducing specific gravity but maintaining toughness and elasticity of the integument. Furthermore, it seems highly probable that the trachipterine fishes, like many other meso- and bathypelagic teleosts, are not tireless hunters but simply floating or hovering creatures, having reliance upon quick darts, only when the necessity occurs, with the body axis turning to horizontal position. Such a darting motion may possibly be attained by increased wavy motion of the dorsal fin or by sudden starting of lateral undulation of the trunk and tail, or by both of these (NISHIMURA 1963, 1964). Such a mode of life, i.e. a quiet floating with occasional darts, may be adaptive to maintain a population thriving in the meso- or bathypelagic region where the food supply from the photosynthetic zone of the ocean is very scarce.

Before closing this paper, the authors wish to express their deep gratitude to Dr. S. MITO and Mr. T. TSUDA for their kindness in supplying the authors with interesting informations and to Dr. Takasi TOKIOKA of the Seto Marine Biological Laboratory for his kind reading the manuscript.

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EXPLANATION OF PLATES VII–IX

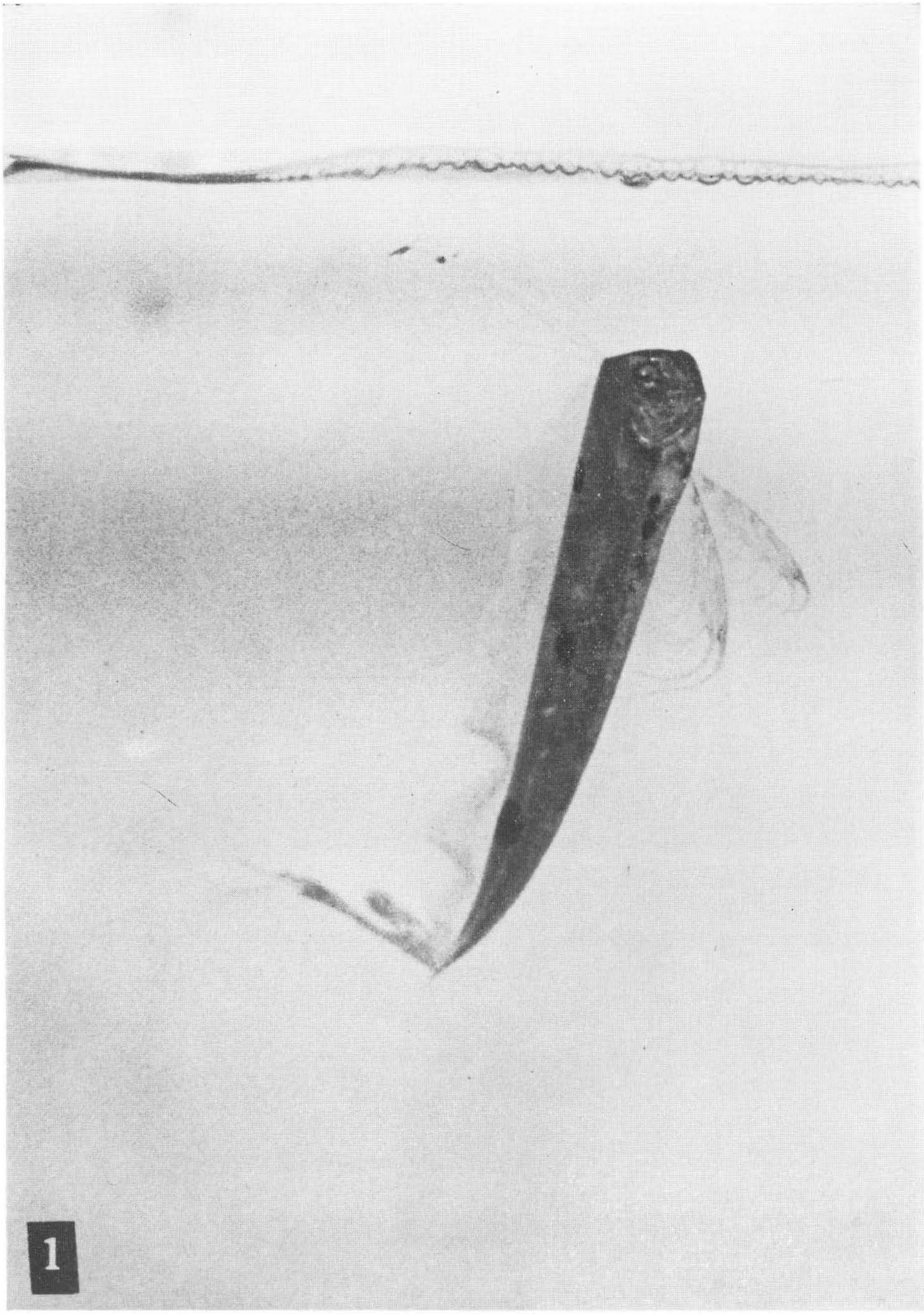
Figs. 1 and 2. The swimming posture of *Trachipterus iris* (WALBAUM) in the aquarium. Note the dorsal fin in a conspicuous waving motion along its entire length. The horizontal line near the top of the pictures shows the water surface.

Fig. 3. The same fish weakened and swimming just beneath the surface with the belly upwards. The waving motion of the dorsal fin is still persisting.

Fig. 4. *Trachipterus ishikawai* JORDAN & SNYDER in the aquarium. The healthy animal trying to hold a vertical posture in a small tank which did not allow the animal to take the intended posture.

Figs. 5, 6 and 7. After hopeless efforts, the same animal became exhausted and began to sink to the bottom, and at last it was laid on one lateral side of the body.

Fig. 8. On the bottom of the tank, the animal soon arose from the lying posture and then kept arisen leaning against the side wall; meanwhile it continued the undulation of the dorsal fin.



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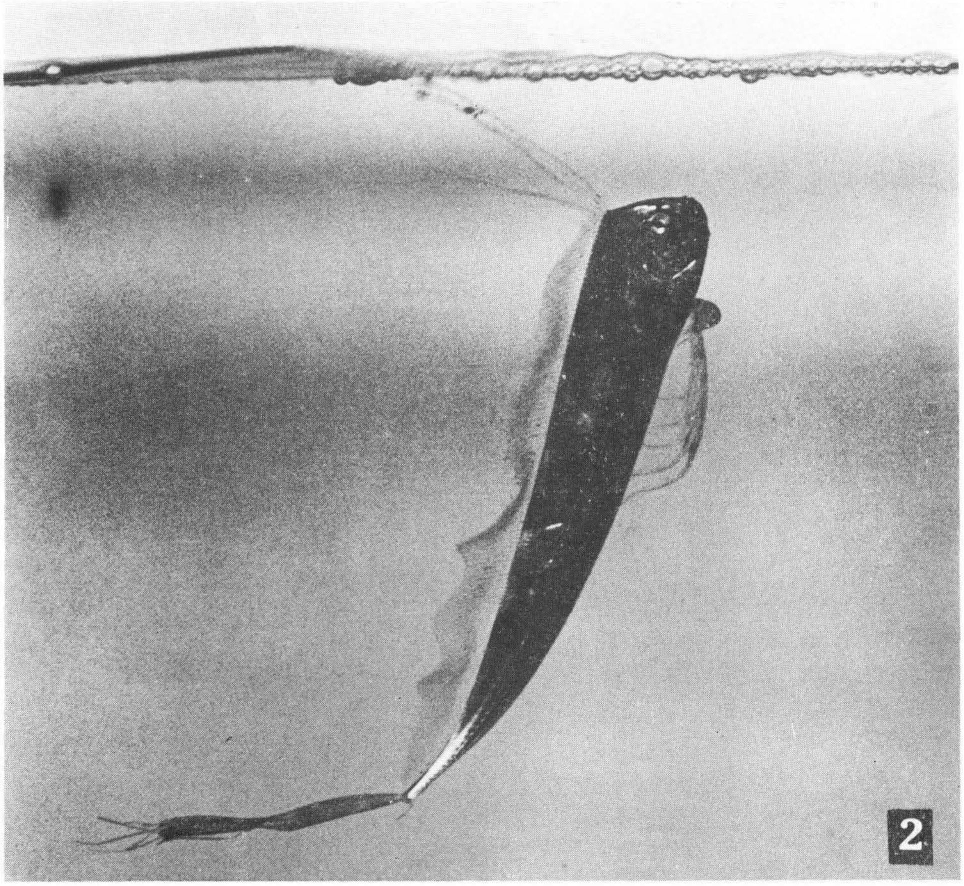

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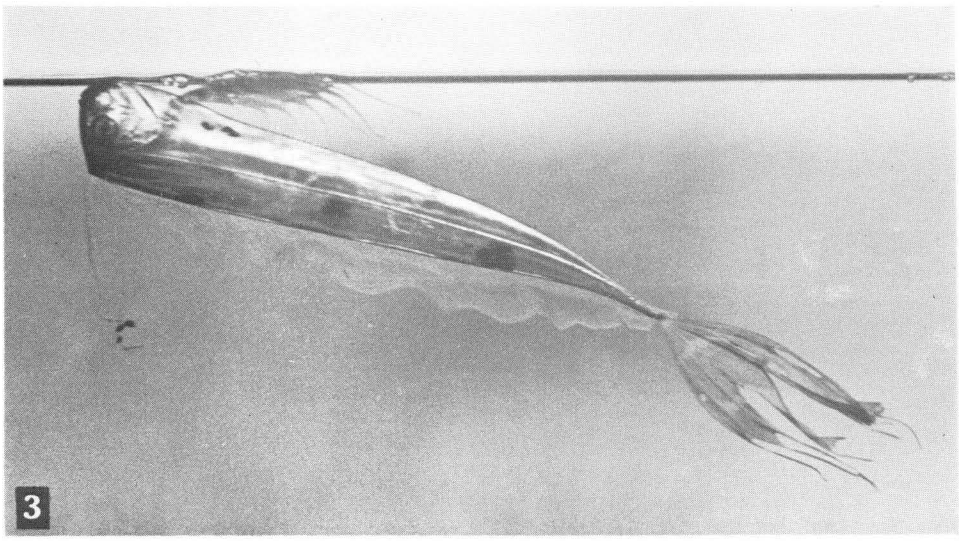

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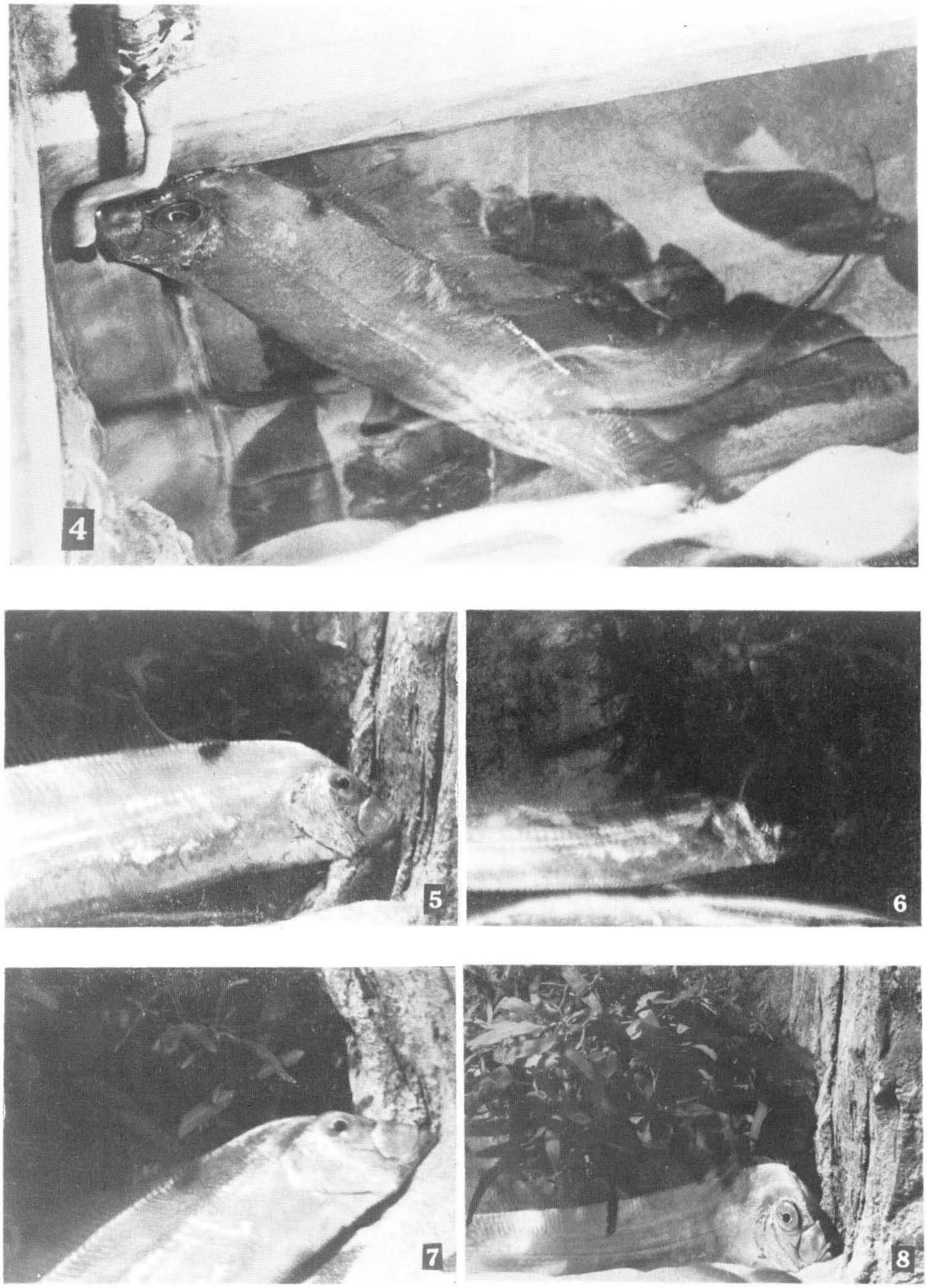

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