THE GOBIES AT PAKNAM.

By A. S. Pearse,

Duke University, Durham, North Carolina, U. S. A.

The beach-skipping gobies are of particular interest because they are at present in the very act of becoming land animals. They live on wet, mucky beaches but are veritable terrestrial vertebrates and may live for several days out of water (Harms, 1929). The beach-skippers or mud-skippers, though they do not wander far from water, have eyes well adapted for vision in air. In this respect they are better adjusted to land life than species, such as the climbing-perch (*Anabas testudineus*), which often make long journeys over-land but nevertheless have eyes adapted for seeing in water (Schreitmüller and Relinghaus, 1926; Beer, 1894; Erdmann, 1896; Hess, 1913; Baumeister, 1913; Harms, 1914). Their eyes are better suited for distance perception than those of fishes which are active in water. The fins and tails of beach-skippers are also adjusted to locomotion in air (Eggert, 1929a; Harms, 1929). An active goby can progress much faster than a man over a mud flat. The skins of such fishes are thicker than those of aquatic gobies and thus conserve water (Harms, 1929). The respiratory organs show anatomical and physiological adaptations for breathing in air (Schöttle, 1931).

The activities of the Siamese beach gobies were long ago described by Hornaday (1885), who says: "They progressed by a series of shorts but rapidly repeated jumps, accomplished by bending the hinder third of the body sharply around to the left, then straightening it very suddenly, at the same time lifting the front half of the body clear of the ground by means of the arm-like pectoral fins which act like the front flippers of a sea-lion. These fins are almost like arms in their structure and use, the bones being of great length, and thus giving the member great movement. Their burrows were simply mud holes, going straight down to a depth of three or four feet, large enough in diameter to admit a man's arm easily, and, of course, full of water."

From May 28 to June 3, 1930, the writer was fortunate in

being able to observe five species of gobies which occur at Paknam on the mud beaches along the mouth of the Menam Chao Phya. This opportunity came through the courtesy of Dr. H. M. Smith, Luang Choola, and Nai Pongse Phintuyothin, of the Siamese Department of Fisheries. Four species were studied in some detail and the results of the observations are set forth in the table. The species considered are *Periophthalmus koelreuteri* (Pallas), *Periophthalmodon schlosseri* (Pallas), *Boleophthalmus boddaerti* (Pallas), and *Glossogobius giuris* (Hamilton).

The first three species lived on the mud flats, the third usually somewhat lower down than the first and second, but all three went up and down together with the tides and even invaded the zone above high-tide mark, where they hunted for food among mangrove roots and hydrophytic plants. The fourth species was a strictly aquatic goby, which never came out of the water. In Java, Harms (1914) found beach gobies arranged in more or less definite zones. This was not true of the three common species at Paknam, which continually mingled together. Though these fishes lived together, they were not competing to any extent. They were different in size, food, length of intestine, and types of parasites.

The parasites found in the gobies are summarized in the table. The long-intestined, vegetarian Boleophthalmus was the only fish which harbored intestinal flagellates. This agrees with the observations of Hegner (1924) on the relation of diet to flagellate infestation in mammals. Tapeworm and acanthocephalan cysts were present only in the largest land gobies. Adult nematodes, tapeworms, trematodes, acanthocephalans, copepods, and Spinitectus cysts were found only in the aquatic goby. Certain unidentifiable cysts were present in the smallest land goby and in the aquatic goby. Agamofilaria cysts occurred in the carnivorous land gobies. Parasitic isopods (Gnathia) were often encountered on the gills of all the gobies, but were most abundant on the aquatic species. The largest land goby was most often infested with parasites; but the largest number of parasites per individual and the largest number of species of parasites occurred on the aquatic goby. Perhaps the former was more often infested because it visited a greater variety of habitats; perhaps the

latter contained more parasites per individual because it lived continually in water and was thus susceptible at all times to aquatic parasites. By taking up land life, gobies appear to have escaped from certain types of parasites.

Land gobies have also attained other desiderata by becoming terrestrial. They move faster in air than in water and can thus, with their peculiarly adapted eyes and limbs, seek food and escape enemies better than their aquatic relatives. They probably escape some aquatic enemies besides parasites when they leave the water. They also encounter new dangers in the way of astute enemies and parasites. For example, the Agamofilaria cysts which occur in land gobies probably come to maturity in fish-eating birds or mammals.

When a fish changes from an aquatic to a terrestrial mode of existence, profound changes in its anatomy and physiology must take place. These must, in such a highly organized animal as a fish, be accompanied by modifications in the nervous system (Pike, 1924). During past ages aquatic vertebrates undoubtedly gave rise to land vertebrates. It appears probable that many aquatic types were able to breathe air before they attained land life, probably as an adaptation to lack of oxygen in shallow, stagnant bodies of water (Pearse, 1932). The tetrapods had their origin when the climate of the earth was warm, humid, and monotonous (Case, 1926). Land vertebrates evolved from these during the increasing aridity of the Permian Period (Jehu, 1923).

In speculations as to how and why animals have left the stable, dependable ocean in order to take up a precarious existence in highly variable land habitats, various factors have been stressed. Doubtless enemies, desirable foods, lack of oxygen, reproduction, and other things have been more or less effective as contributing causes to such migrations. The writer (1932) has suggested that an important factor in the adjustments of animals to land life is the avoidance of interspecific competition. Many species of animals along the shores of oceans are arranged in definite zones and thus avoid competition (Pearse, 1929). Incidentally, some of them acquire such qualities that they can live on land. The species of beach gobies at Paknam are not arranged in definite zones but compete

very little with one another because they are somewhat specialized in their food habits. They are thus together but segregated. Wherever there is vacant territory or habitat in nature there is a chance for a new species. Safety, unconsumed food resources, lack of competition, desirable breeding places, and other desiderata make the enduring of new hardships expedient. Thus land animals have evolved because certain types could avoid old competitions by acquiring new ranges of adjustment so that they could live in vacant habitats.

Siam at the present time, with its warm, humid[1] climate, wide extent of shallow waters, and well defined seasonal periodicities, is a very favourable place for the study of landward migrations. Along ocean beaches, in klongs and streams, and in many other situations there are animals which, in order to avoid interspecific competition and dangers in their physical or biotic environment or to acquire new advantages, are trending toward land. It is to be hoped that these opportunities will be used. Young biologists should study these animals.

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[1] Humidities and temperatures at Paknam, as determined on the veranda of a residence about twenty feet above the ground, were as follows:

May 28	Temperature, F°.	Humidity, per cent.
6:35 P.M.	85.0	61
8:50 P.M.	84.5	80
May 29		
7:00 A.M.	83.3	76
2:20 P.M.	86.0	64
6:45 P.M.	87.5	61
May 30, cloudy all day		
2:15 A.M.	83.4	74
7:30 A.M.	82.5	77
1:10 P.M.	85.7	70
4:25 P.M.	84.7	69

COMPARISON OF FOUR GOBIES AT THE MOUTH OF THE MENAM CHAO PHYA AT PAKNAM, SIAM.

The figures for foods indicate percentages by volume.

The first figure for parasites shows the percentage of hosts infested, the second figure, the average number of parasites per host.

	Periophthalmus koelreuteri	Periophthalmodon schlosseri	Boleophthalmus boddaerti	Glossogobius giuris
Average length of fish	196.0 mm.	67.1 mm.	133.1 mm.	114.0 mm.
Number of specimens examined	7	10	20	8
Ratio of body length to intestinal length	1:0.64	1:0.43	1:1.45	1:0.43
Food:				
Flesh	...	7.5	...	...
Fishes	10.0	...	...	20.0
Shrimps	...	...	...	40.0
Crabs	82.8	21.0	...	19.0
Insects	...	23.5	...	...
Insect larvae	...	...	...	20.0
Snails	...	5.0	...	...
Chaetopods	...	13.5	...	...
Nematodes	...	...	2.5	...
Plants	...	2.0	...	...
Algae, filamentous	...	...	83.8	...
Diatoms	...	...	12.5	...
Mud	7.2	27.5	...	1.0
Sand	...	...	1.2	...
Parasites:				
Intestinal flagellates	...	...	30–	...
Cestode cysts	100–23.9	...	20–0.3	...
Agamofilaria cysts	100–22.7	20–0.2	...	...
Acanthocephalan cysts	57– 2.9	...	...	...
Unknown cysts	...	20–0.3	...	13–10.50
Procamallanus kerri	...	...	...	13– 0.13
Thelazo glossogobii	...	...	...	13– 0.39
Spinitectus cysts	...	...	...	13– 0.13
Acanthocephala	...	...	...	13– 0.13
Trematodes	...	...	...	13– 0.13
Tetraphyllid tapeworms	...	...	...	25– 6.40
Gnathia sp.	57– 0.6	30–0.7	70–2.9	63– 8.30
Ergasilus mugilis	...	...	...	25– 1.40
Average parasites	79–50.1	24–1.2	40–3.2	22–17.51
Species of parasites	4	3	3	9

Gnathostoma ? (–)

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