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Article V.— ON TWO AMBICOLORATE SPECIMENS OF THE SUMMER FLOUNDER, *PARALICHTHYS DENTATUS*, WITH AN EXPLANATION OF AMBICOLORATION.

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Among various species of flatfishes having a white under side, there is occasionally found a specimen with this side partly or completely colored like the upper. Such specimens are known as *ambicolorate* — a term introduced by J. T. Cunningham in 1893 [5]. They have attracted considerable attention because of their bearing on the theories of coloration in fishes, and quite a literature has grown up about them, particularly in Europe. In America ambicolorate flatfishes have been but little studied; I have found only a single reference to such a specimen. This was an example of the southern flounder, *Paralichthys lethostigmus*, having both upper and under sides "equally dark colored," which was briefly described by Storer in 1861 [8]. Recently two ambicolorate specimens of the summer flounder, *Paralichthys dentatus*, have come into my hands in a collection of fishes from the coast of North Carolina, presented to the American Museum by Mr. Russell J. Coles, of Danville, Va.; and the following notes are based upon them.

The two specimens (Nos. 5067 and 3735, Am. Mus.), are respectively 283 and 451 mm. in total length, including caudal. They were taken in seines with other fishes, off Cape Lookout, North Carolina, one in July, the other in September, 1912. They present none of the morphological abnormalities sometimes found in ambicolorate flatfishes; the migration of the eye from the blind side is complete, the anterior termination of the dorsal fin is not formed into a fleshy protuberance arched forward over the eye, and there are no spines or tubercles on the under side. The coloration of the eyed side is normal, except that the dark spots characteristic of the species are rather faded, especially in the larger specimen. But as this condition is frequently found in normal specimens, it has no bearing on the ambicoloration.

The pigmentation of the under sides of the two specimens is well represented in Figures 1 and 2, and no detailed description of it is necessary. It need only be mentioned that the dark areas are not abruptly demarcated from the pale ones, but blend gently into them along a broken line.

I have carefully compared the two specimens with a normally colored one for any differences in proportions and other regards, but have found none. As shown in the following table, the head and the depth bear about the same proportions to the length, allowing for variation due to difference in size, as in the normal specimen; and the pectoral of the blind side in both instances is about one-fifth shorter than that of the eyed side.

Comparison of Ambicolorate and Normal Specimens of Paralichthys dentatus.

	Ambicolorate		Normal
	(Fig. 1)	(Fig. 2)	
Total length (to end of caudal)	451 mm.	283 mm.	394 mm.
Pectoral of eyed side	48 "	35 "	40 "
" " blind "	38 "	27 "	32.5 "
Ventral of eyed side	27 "	22 "	25 "
" " blind "	27 "	21 "	25 "
Head in total length	4.2 times	3.9 times	4.6 times
Depth in " "	2.8 "	2.9 "	2.8 "
Pectoral of blind side contained in pectoral of eyed side	1.26 "	1.29 "	1.23 "

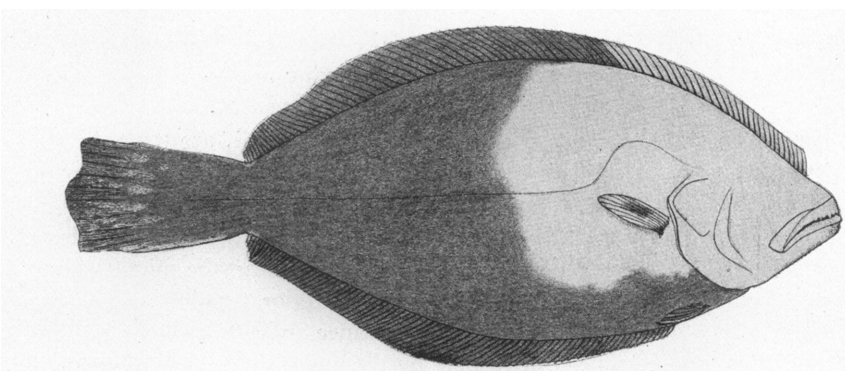

Fig. 1. Under side of an ambicolorate specimen of *Paralichthys dentatus*, 451 mm. in total length.

THEORETICAL CONSIDERATIONS.

Ambicoloration has already been recorded in four genera, and, if we include the present specimens, in nine species of flatfishes, namely:

1. *Pleuronectes flesus*
2. " *italicus*
3. " *limanda*
4. " *platessa*
5. *Solea vulgaris*
6. *Rhombus lævis*
7. " *maximus*
8. *Paralichthys lethostigmus*
9. " *dentatus*

It is thus seen to be a widely distributed abnormality, and will probably be found in still other species, in fact in most, if not all, flatfishes with a normally pale under side, and which live in relatively shallow water.

What is the cause of ambicoloration in flatfishes?

Some of the earlier writers on fishes (Daubenton, Bonnaterre, Lacépède) regarded ambicoloration as a specific character. Later, it was recognized that it could not be a specific character since it occurred in different flatfishes which, except for this abnormality, agreed entirely with well-recognized species. The phenomenon, however, was not easy to explain. Five or six different theories have been put forward to account for it. Among these are: reversion to the ancestral, bilaterally symmetrical condition; *homœosis*, or a mutation in the direction of secondary bilateral symmetry; direct illumination of the under side of the adult fish; the swimming of the embryo in the normal fish position for a longer period than usual, and its consequent longer exposure to light while in this position; germinal factors; some interference with the mechanism of embryonic transformation. Most of these views have been discussed by Bateson [1; 1894], and more recently by Gemmill [7; 1912], so that it is unnecessary to review them again.

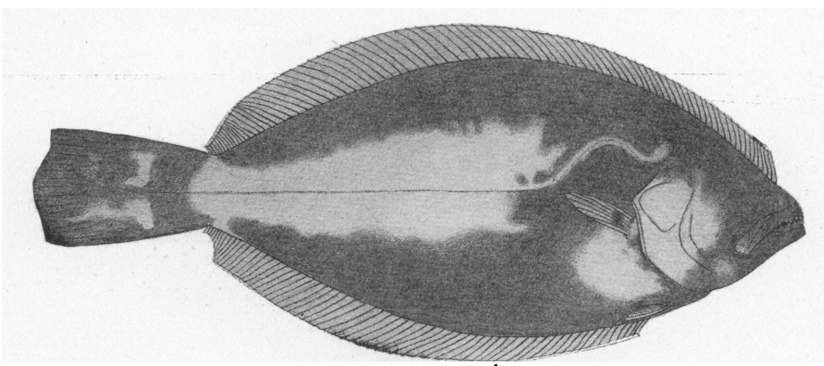

Fig. 2. Under side of an ambicolorate specimen of *Paralichthys dentatus*, 283 mm. in total length.

To the writer it seems needless to search for an obscure cause of the abnormality; we have a satisfactory explanation of it in the two series of experiments by Cunningham [4], as was indeed indicated by this writer himself. These observations are, first, that on the action of light on the under side of flatfishes [3]; secondly, that on flatfishes that had been living for a considerable time on a slaty bottom [4]. Neither of these observations by itself will suffice to explain the abnormality, but the two together afford as satisfactory an explanation of it as seems possible.

From Cunningham's classic experiments on the action of light on flatfishes [3, 5] it is known that the white under side of these fishes when exposed to light, becomes more or less pigmented like the upper, the intensity and extent of the pigmentation depending, (1) on the age of the fish, the action being the more intense the younger the specimen, and, (2) on the duration of the exposure. At a first glance these experiments might seem to offer a key for the solution of the problem of ambicoloration. It might be thought that the swimming of ambicolorate flatfishes is abnormal; they bend or twist in some such way that part of the pale under side is exposed to light, and so gradually becomes pigmented. It was an explanation similar to this, in fact, that was offered by Giard [6].

But are the movements of ambicolorate flatfishes in any way abnormal? In two instances on record specimens have been kept in aquaria under observation for months,— by Cunningham in 1894 (plaice), and by Cuénot in 1905 (sole) — and absolutely nothing abnormal was noticed in their movements. There is thus evidence that the coloration of the under side is not due to its direct exposure to light.

Moreover, on the view of direct exposure, how can we account for the peculiar distribution of the pigmented areas? Why, for instance, should there be in the specimen shown in Figure 2, a pale band along the arched portion of the lateral line if, as we must believe from the darkened area around it, this entire region of the fish had been exposed to light? There is frequently in ambicolorate specimens a narrow, dark band on the middle portion of the lateral line, while either side of it is pale. How can we account for this dark band if this entire region of the fish, judged by the pale area around it, had not been exposed to light? It is thus seen that there are strong reasons against the view that ambicoloration is caused by direct exposure to light, due to abnormal movements of the fish.

But the phenomenon finds a ready explanation in the light of a second observation made by Cunningham [4]. He found, quite unexpectedly, in the case of five flatfishes — two flounders, two plaice, and a sole — which had lived in a tank with a slate bottom for a year and a half, that the two flounders and the two plaice showed a striking ambicoloration, and the sole too was colored on the under side to some extent. The only light that had reached these specimens was from the front of the tank, the bottom and sides being of slate; and they had behaved normally, neither twisting nor turning so that light might strike them from above. On taking one of these specimens out of the tank and placing it on a slab of slate, Cunningham found that the fish did not leave a solid imprint of its under side, but that there were areas at which it was not in contact with the slate and so left no imprint. And the imprint of the entire fish, curiously, was an exact negative of an ambicolorate specimen. Cunningham then concluded that the effect must be due to the light entering horizontally or obliquely, and reaching areas which were not in contact with the bottom and in course of time pigmenting them. To test this view, he placed a flounder on a sheet of photographic paper in a dark room, the specimen resting just as it had done on the slate bottom, and exposed it for a few seconds to light striking the fish more or less horizontally. The photograph thus made was an exact picture of an ambicolorate specimen, even to the narrow band of color along the lateral line of the fish, the light apparently being reflected and reaching this area. This experiment afforded a striking confirmation of this view.

In the light of this experiment we may conclude that in nature ambicoloration is produced whenever a fish lives on a hard instead of a sandy bottom, so that it cannot bury itself completely with the under side. Light falling through the shallow water strikes the flounder horizontally or obliquely, and penetrates to the areas not in contact with the bottom and gradually colors them. If at successive periods different parts of the under side of the fish come to be in contact with the bottom, these different areas become pigmented, and in the course of time the entire under side may resemble the upper, producing a perfect so-called "double" flatfish.

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