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DIURNAL ACTIVITY PATTERN OF PLAICE AND FLOUNDER (PLEURONECTIDAE) IN AQUARIA

by

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CONTENTS

1. INTRODUCTION

There is a peculiar discrepancy between the predominant nocturnal activity of plaice (*Pleuronectes platessa* L.) as registrated in aquaria (HARDEN and HEMPEL, 1954), and data derived from studies of their normal feeding behaviour (FRANZ, 1910; PETERSEN and BOYSEN JENSEN, 1911; STEVEN, 1930), the gut content (JONES, 1952; HEMPEL, 1956; DE GROOT, 1964), and trawl catches (WOODHEAD, 1960; DE GROOT, 1964), which all indicate that this fish is active and feeds in the daytime. It is tempting to assume that this discrepancy is the result of the abnormal behaviour of the fish in captivity, for instance as a result of unnatural experimental conditions of illumination. Moreover, every registration technique has something in common with a distorting mirror: some characteristics of either determine in how far they reflect reality. The type of registration mechanism used by HARDEN and HEMPEL (1954)—a balanced false bottom—leaves all activity of the fish when keeping contact with the bottom undetected. This is the more important because flatfish frequently "shamble" over the bottom in search for food. The experiments with plaice and with flounder (*Pleuronectes flesus* L.) reported here were designed to find out whether a technique that also regis-

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trates this "bottom activity" would give a more complete picture of the activity of the fish. This picture might show a better correlation with the above mentioned data about gut content and trawl catches, and thus might provide a basis for a better understanding of the factors regulating behaviour.

2. MATERIAL AND METHODS

The activity of the flatfish was recorded in a 100 × 50 × 50 cm fibreglass aquarium, provided with aeration, a closed filter circuit and a 5 cm deep layer of sand on the bottom. The layer of sand seems to be essential since KRUUK (1963) demonstrated that in the daytime the sole (*Solea vulgaris* Quensel) shows prolonged digging-in activity as long as the animal is not covered by sand. Natural light from outside illuminated the aquarium in the laboratory via a horizontal semi-transparant window over it, with the result that at midday the maximal illumination intensity at the bottom was 10–100 erg/cm^2/sec, which is of the same order of magnitude as found in the natural habitat at a depth of 20 m (for details see KRUUK, 1963).

The recording apparatus consisted of 20 contact units. Each unit consisted of a silver contact-ring through which passed a silver wire loaded by means of a polythene thread with a small lead ball 4 mm in diameter. The twenty units were mounted on a "Dexion" aluminium frame work over the aquarium. Whenever a fish swam against a polythene thread or a lead ball contact between wire and ring closed an electric circuit connected to a relay recorder, which resulted in an activity "spike" on a kymograph. The registration units were distributed over three groups, of which the lead balls hung just over the sand, at midwater level and 5 cm below the water surface, respectively. Each group of "one level" units was again divided into two groups, each consisting of three or four units which were together connected with one of a total of 6 relay recorders. This was done in order to avoid that, during a given period, one defective unit would disturb completely the recordings of one level. As a fish swimming at midwater level was registrated by the midwater and the bottom level units, and a fish swimming at the surface by units of all three levels, the activity in a given period at midwater level was determined by subtracting the surface recordings from the midwater recordings. Similarly the bottom activity—more exactly the activity in the lower half of the aquarium—was determined by subtracting both the midwater and surface recordings from the bottom recordings. For periods up to four weeks activity recordings were made of 2 specimens of either plaice or flounder of about 20 cm in length. As

flatfish get tame easily and then often show abnormal activity with regard to the illumination intensity in their aquarium, we used freshly collected animals[1] and treated the fish in such a way as to prevent tameness.

3. RESULTS

The activity at bottom and surface level of 3 specimens of plaice during a 5 day period in April 1963, and of 3 specimens of flounder during a 4 week period in June 1962, is shown graphically in the figures 1 and 2, curves a and b. The midwater recordings are not included because they contain no essential information. The curves reveal *a*, that in the daytime there is a period during which the activity of these flatfish is restricted to the bottom level; and *b*, that during the night there is much additional swimming at higher water levels.

Direct observation of the animals in the aquarium led to the same conclusion. In the daytime the fish shambled over the bottom or they swam short distances while keeping contact with the bottom, obviously in search for food. At night the fish were much more mobile, swimming through the aquarium, thereby frequently reaching the surface. When the intensity of illumination was increased at midday by decreasing the absorption of the horizontal screen, it was especially the plaice that tended to spend some hours lying under the sand, thus resembling the sole (KRUUK, 1963).

Figure 1 also shows data about variations of commercial catches (curve c) and of stomach filling (curve d and e) of plaice. It is clear that commercial catches are maximal, and that in the natural habitat the stomach is filled in the daytime, the period during which in the aquarium the fish were active exclusively on the bottom (curve a).

4. DISCUSSION

In evaluating the activity patterns shown in the figures 1 and 2 it should be realized that in the periods with surface level activity the recordings in all probability indicate too much bottom activity because flatfish will meet with difficulties in trying to maintain a high level in a rather small rectangular aquarium. They have no gasbladder, while, moreover, they are not very skilful in turning in the corners. The result is that time and again a fish will sink down when it arrives in a corner of the aquarium. No doubt a circuit tank would be a more adequate experimental

[1] The plaice were kindly supplied by the Netherlands Institute for Fishery Investigations, IJmuiden. The flounder were obtained from fishermen at the Afsluitdijk.

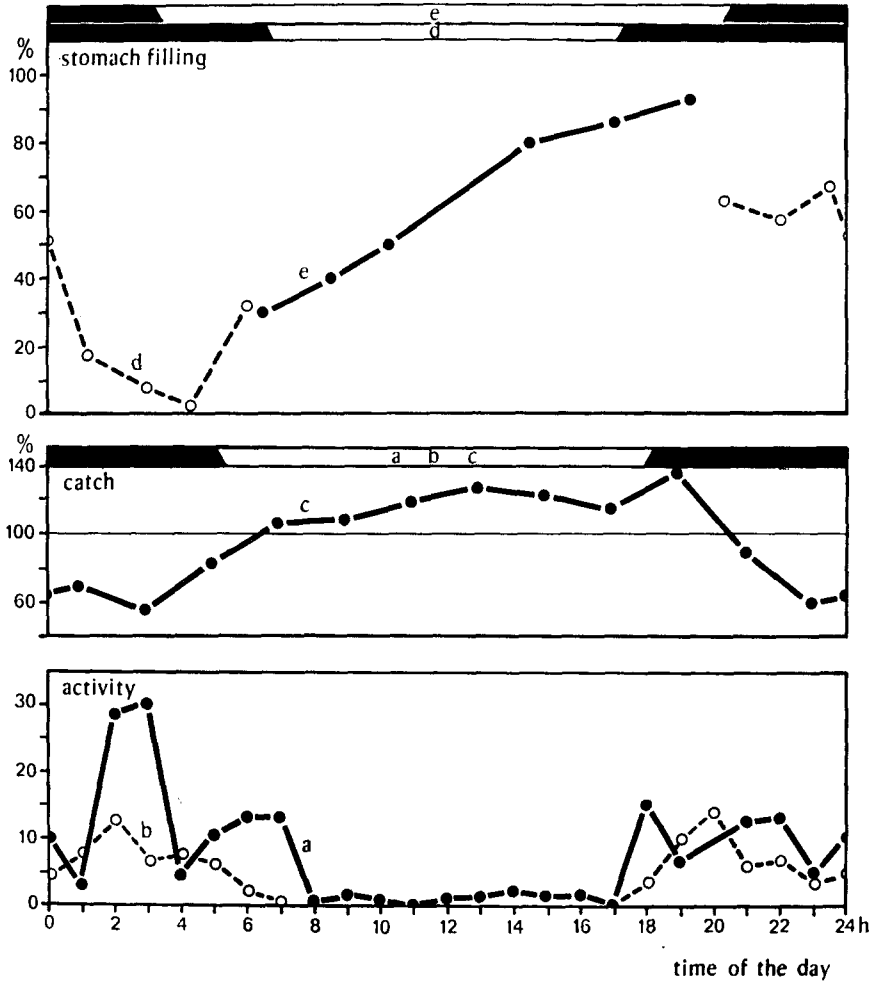

Fig. 1. a, b. Mean number of activity marks per hour and per recording unit produced by three plaices; a, at bottom level, and b, at surface level during four days in April. c. Variations in catches of plaice by commercial vessels in March-April (after DE GROOT, 1964). d, e. Percentage of filling of stomach of plaice; d. caught during the night in November (after DE GROOT, 1964), and e, caught in daytime in May (after JONES, 1952).

environment because in such a tank flatfish swimm considerably more than in a rectangular aquarium (SCHÅFER, 1952; 1955). Therefore further experiments are planned in circuit tanks.

Our results indicate that the puzzling "reversed" activity pattern of plaice as registrated by HARDEN and HEMPEL (1954) can be attributed to 2 factors:

a. the abnormally high intensity of illumination in their experimental tank ("diffuse daylight from above") must have inhibited the normal activity of the fish in the daytime, and

b. their registration technique with a false bottom was insensitive to all activity of the fish when it kept contact with the bottom, and this, as our results demonstrate, is their characteristic activity pattern in the daytime. Consequently curve b (surface activity) of figure 1 shows a striking similarity with the swimming activity of plaice as given by HARDEN and HEMPEL (1954, fig. 2, p. 27).

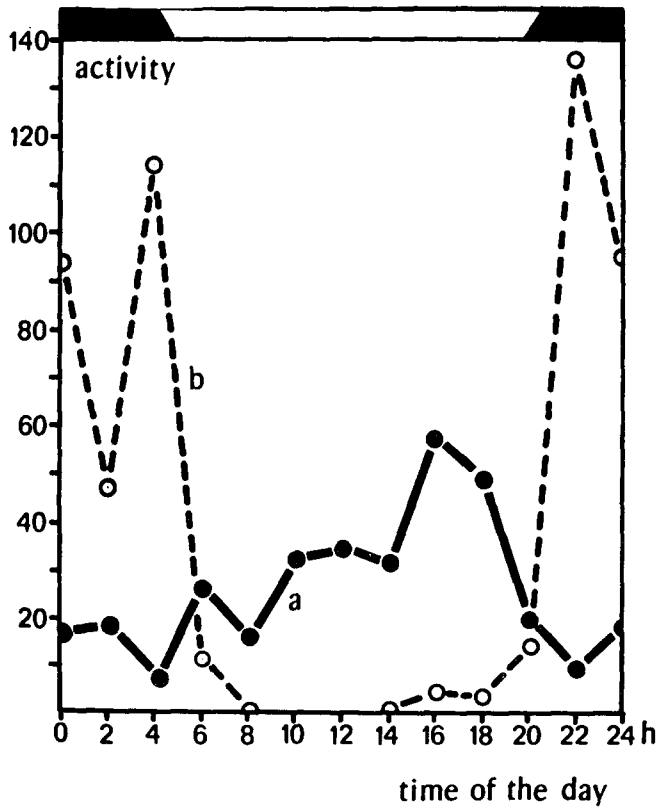

Fig. 2. Mean number of activity marks per two hours and per recording unit produced by three flounders during four weeks; a, at bottom level, and b, at surface level.

From our results and those of KRUUK (1963) it seems that in the course of 24 hours some species of flatfish will perform 5 activities, which can be grouped into two behaviour phases, an active and an inactive phase. When the intensity of the illumination decreases the inactive phase changes into the active phase by the fish coming out of the sand (1) in the afternoon or evening, depending on the species and on the range of prevailing intensities of illumination; after that the fish will start shambling over and swimming along the bottom in search for food (2). At still lower intensities of illumination the fish will leave the bottom and swim for prolonged periods at higher levels in the water (3). With increasing intensity of illumination in the morning behaviour pattern 2 reappears; when the intensity of the illumination increases further the inactive phase starts with digging-in (4), followed by a period of remaining under the sand (5) [1]).

It remains to be seen whether behaviour pattern 3 has something to do with the supposed spawning migration of soles and other flatfish, that have been observed to swim close to the surface at night in certain periods of the year (DE VEEN, 1963; 1964). If this is in accordance with reality

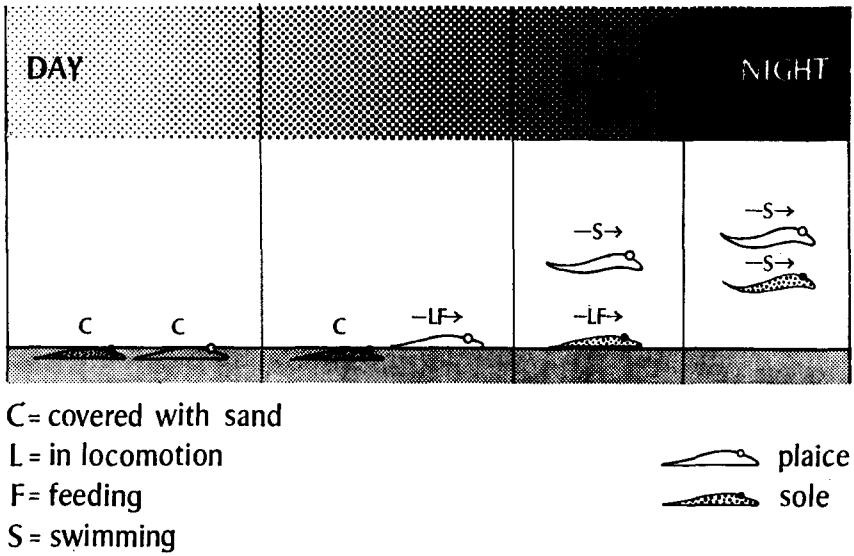

Fig. 3. Tentative comparison of the behaviour of plaice and sole with respect to the illumination intensities occurring between midday and midnight.

[1]) Note added in proof: the detailed description of behaviour and feeding of plaice and flounder by F. BREGNBALLE fits well in this general picture (Medd. Komm. Havsunders., Fiskeri 3, 133–182 (1961).

it might be possible to devise experiments in order to establish the mechanisms of this migration.

In the sole activity starts and stops at lower intensities of illumination —under the experimental conditions used by KRUUK (1963) below 0.08 erg/cm²/sec and above 0.35 erg/cm²/sec respectively—than in the plaice and the flounder, which in our experiments remained active well above 100 erg/cm²/sec. In figure 3 a tentative and schematic picture is given of the behaviour of sole and of plaice such as is assumed to be governed by the intensity of illumination.

Flatfish expose themselves to being caught by the bottom trawl particularly during activity 2: during the period (7–17 h) with exclusively bottom activity in the aquarium (fig. 1, curve a) plaice take in food (our observations in the aquarium agree with the increase in filling of the stomach in the natural habitat as determined in caught fish, fig. 1, curves d and e), and are caught maximally (fig. 1, curve c). Although KRUUK (1963) did not registrate separately the activity at bottom and surface levels his results make it highly probable that soles perform activity 2 during the night: then their stomach is filled and the catch maximal.

The chance of flatfish being caught is less when they perform the behaviour patterns 3 (swimming at higher water levels at minimal intensities of illumination) and 5 (being buried under the sand at maximal intensities of illumination). KRUUK's experiments (1963) indicate that in daytime the catch of soles is minimal because these fish are then buried in the sand. As shown above the catch of plaice is maximal (fig. 1, curve c) during this period because in many natural habitats the maximal intensities of illumination are not high enough for plaice to dig in.

The nightly performance of behaviour pattern 3 (swimming at higher water levels) by plaice in the aquarium (fig. 1, curve b) coincides with minimal catches (fig. 1, curve c). Therefore, the low catch of plaice during the night may in part be due to the bottom trawl passing underneath the swimming fish. Changes in reactivity to stimuli from the gear may also contribute to the total catch pattern for 24 hours.

5. SUMMARY

Activity recordings of plaice and flounder in aquaria under natural conditions of illumination demonstrate that in the daytime there is a feeding period during which the activity is restricted to the bottom level, whereas there is much additional swimming at higher water levels during the night.

The registration technique with a balanced false bottom used by

HARDER and HEMPEL (1954) leaves the feeding activity on the bottom undetected. This accounts for the discrepancy between the predominantly nocturnal activity of plaice as registrated by these authors and the diurnal activity in the normal habitat as concluded from data derived from trawl catches and the gut content of caught fish. A tentative comparison is made between the behaviour of plaice and sole.

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