BEHAVIOR OF FISH IN THE ZONE OF RADIATION SOURCE

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A study of the characteristics of behavior of insects (fruit flies) and mammals (mice, rats, guinea pigs, and monkeys) in fields of ionizing radiation have been the subject of previous publications by the author [2, 3] and also by several foreign research workers [6, 8, 9]. Such publications have revealed that animals possess the ability to determine the position of a radiation source and to avoid the zone of its influence.

In view of the fact that, although some information is available in the literature on the perception of radiation by fishes [5, 10], but the information is very limited, we have used carp as the object of investigation in this present work.

METHODS

In order to study the behavior of fish in radiation fields we used the method of free choice of food in the zone of radiation and outside it. The apparatus used in our experiments consisted of a tank filled with water (dimensions 155 × 62 × 45 cm and capacity 310 l) divided into 3 compartments (Fig. 1).

In the lateral compartments, which communicated with the central compartments by means of symmetrically arranged openings (passages), a definite and ample amount of food (large living moths) was placed. The fish were allowed access to the food for 19 h every day. After this time had elapsed any food remaining was collected, roughly dried, and weighed, so as to determine the amount eaten by the carp. A field of γ-radiation was set up round one of the passages by inserting a glass tube containing the γ-material at the side of the passage. The passage to the other compartment was free from radiation and the amount of food eaten in this compartment served as a control. A diagrammatic representation of the passage and radiation source is given in Fig. 1, II. The relatively insignificant dimensions of the passage (30-60 mm) ensured that the fish in passing through were subjected to the effect of a relatively high dose of radiation (the magnitude of these doses will be stated below). Curved plates forming a labyrinth were set up on both sides of the passages, in order to increase the time taken by the fish to pass from one compartment to another and thus prolong the period of their irradiation. In addition to the main passages around which a field of γ-radiation was created, the partition contained special apertures with valves, which were closed only on the side of the central compartment. These apertures gave the fish the possibility of using additional exits from the side compartments and thus avoiding the zone of radiation. Thus, after locating the radiation source in the passage leading to one or other compartment, the fish could get to the food only by passing through the zone of radiation, but they might leave the lateral compartment by using the additional exit situated outside the zone of radiation.

RESULTS

The experiments were carried out using 15 carp between 1 and $1\frac{1}{2}$ years old. In the first experiment the amount of food eaten by the carp (8 fish) from both right and left compartments was determined in the absence of any radiation source. The results of this series are shown in Fig. 2, I from which it is seen, that under normal conditions the fish take food from both lateral compartments in equal amounts.

The results of the second series of experiments (7 carp) are shown in Fig. 2, II. The fish were observed over a 65 day period in this series. After a control interval of 2 weeks duration, during which the amount of food eaten

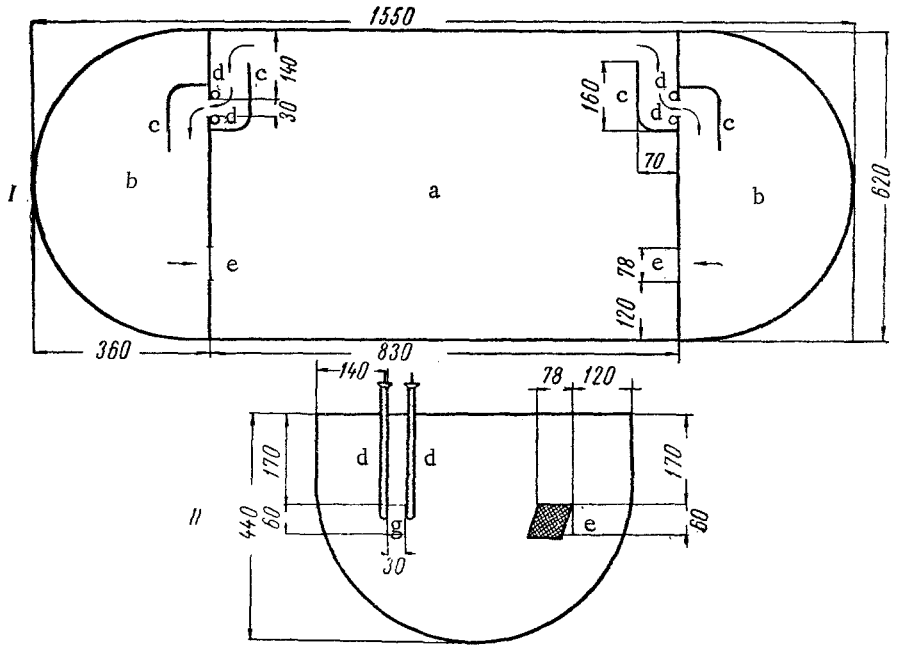

Fig. 1. Diagram of apparatus for studying fish behavior in a zone of radiation. I) View from above: a) central compartment; b) lateral compartment; c) plates forming a labyrinth around the exit; d) site of radiation source in passage; e) supplementary exit. II) Elevation: d) glass tube with radiation source; e) supplementary exit with valve; g) main passage.

from both compartments was determined, 2 radiation sources (Co^{60} and Cs^{137}), of total activity 108 mg-eqv Ra, were placed in the passage to the left compartment. The radiation sources were maintained in the tank for 17 days, and during this time the carp ate $1\frac{1}{2}$-7 times more food from the control, right compartment than they did from the left. Removal of the radiation source led to equal amounts of food being taken from both right and left compartments. The γ -radiation source was then established in the passage leading to the right compartment (for a period of 14 days). Once again the fish reacted to this situation by taking less food from the right than from the left compartment. Subsequent removal of the source led to equalization of the food taken from the two compartments (c.f., Fig. 2, II).

Statistical treatment of data obtained, using the criterion of significance [11], has shown that the difference in food consumption as a result of placing the radiation source at the entry to one of two compartments is a real difference (98% level of reliability).

The described experiments suggest that fish, like other animals, are able to determine the position of a radiation source and to avoid its influence.

The intensity of total radiation from the two γ -sources was measured with the help of a ferrous sulfate dosimeter (V. S. Grammatikat) and found to equal 108 mg-eqv Ra. A diagram showing positions of the dosimeter in relation to the radiation intensity constitutes Fig. 3. It was found, that the intensity of the dose in the center of the passage was equal to 2.48 rad/min.

Visual observations on the speed at which the fish swam through the passage enabled us to determine that the whole journey from entry into the labyrinth on the central compartment side to exit from the labyrinth on the opposite side took an average time of 3 sec (extremes 2-5 sec). Knowing the dosage strength in the center of the passage, it was calculated that the fish received an average dose of about 0.12 r in the time taken to pass through the zone of radiation. Observations on the behavior of the fish showed that in 75% of cases, the fish used the additional exits in leaving the lateral compartments.

It should be noted that in the course of experiments which were carried out prior to the setting up of labyrinths to passage ways, we had not observed any obvious reaction of fish to a γ -source of similar activity. Only with the

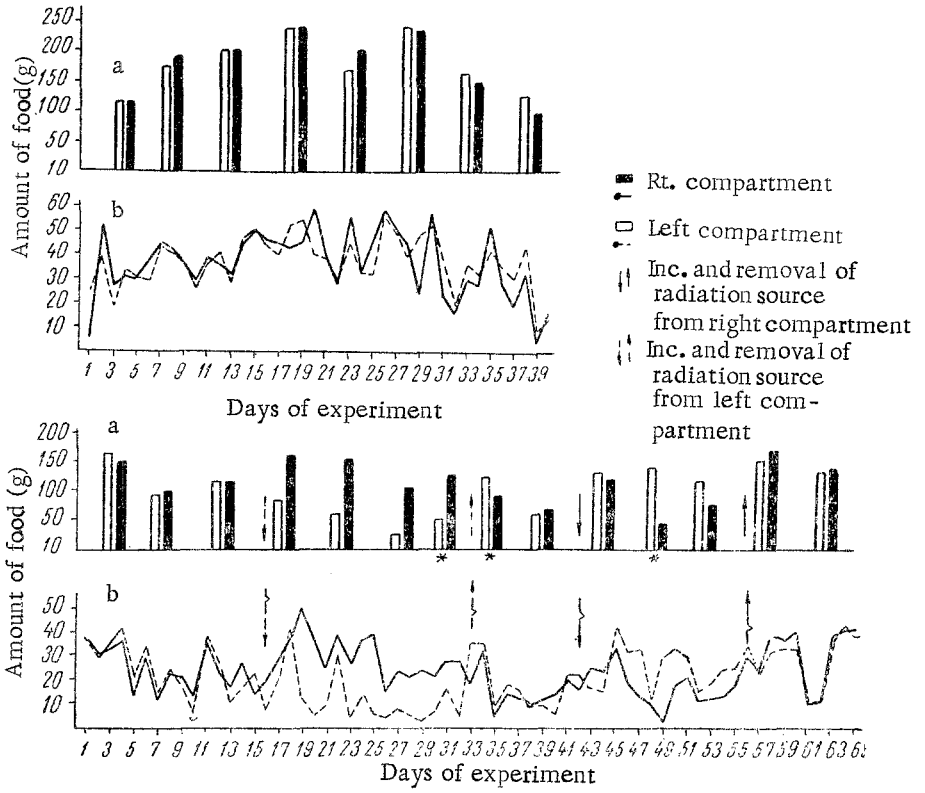

Fig. 2. Food consumption by carp from the compartments of the apparatus for each 5 days of the experiments. (a, asterisk) conversion to 5 days) and daily (b). I) Without radiation; II) after insertion of radiation source in passages of apparatus. Black histogram (a) and continuous line (b) - right compartment; white histogram (a) and dotted line (b) - left compartment; continuous arrow - insertion and removal of source from right compartment; dotted arrow - ditto for left compartment.

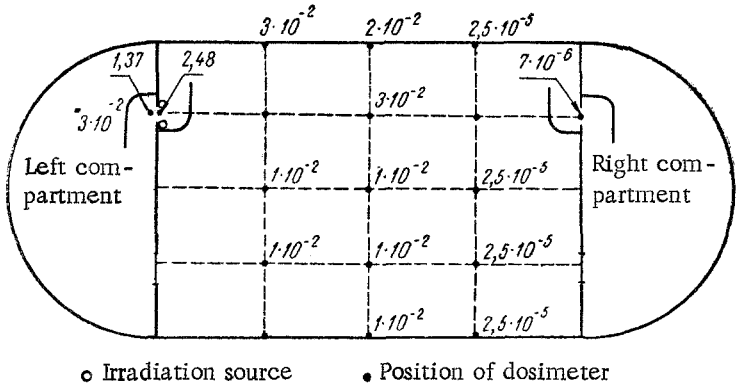

Fig. 3. Intensity of radiation (in rad/min) in different parts of the aquarium as measured with the help of a ferrosulfate dosimeter (accuracy ±5%). Radiation sources of total activity of 108 mg/eqv. Ra. are situated in passage to left compartment.

assistance of labyrinths, which increased the exposure time of the fish to radiation by a factor of 6, was it possible to obtain definite results. This suggests, that not only is the intensity of radiation important in promoting the avoiding reaction of the fish but the length of time to which the fish is subjected to radiation is equally so [4, 7].

It is possible to explain the mechanism whereby fish avoid the influence of the radiation zone in terms of an inhibition due to learning. During the 2 week period (prior to inclusion of the radiation source) the fish develop a simple conditioned reflex to food and to the apparatus—the carp consume food from both compartments of the aquarium in equal amounts. However, under the influence of a new stimulus—the source of radiation—placed en route to one of the food sources, the conditioned reflex relative to one food source undergoes inhibition, so that there is an increase in the amount of food taken from the other compartment outside the zone of irradiation. That the unusual stimulation of radiation has a definite inhibitory effect, is evident from the fact that the food consumption from one compartment undergoes a marked reduction after placing the radiation source at its entrance, to be followed by an equalization of food consumption from both compartments immediately after removal of the source.

That the avoiding reaction to radiation is not influenced in any way by the presence of substances in the water which the fish can taste is demonstrated by the results of our experiments with mice [2]. The possibility of visual sensations playing some part in determining the behavior of fish in the zone of radiation can also be excluded: if carp are deprived of their visual perception they still respond to irradiation in the same way [5].

The important role of the mid brain in the perception of light by fish is already well-known [6], so it is not surprising that injury to the mid-brain has the effect of preventing the development of any conditioned reflex to γ -radiation.

In these experiments we have not set out to determine the threshold of sensitivity to radiation in fish. We can only say that, under the conditions of the experiment we have described, the total dose received by the carp (about 0.12 r) was considerably greater than the minimal dose to which mice reacted (0.001-0.05 r in the case of total irradiation) in our previous experiments [2]. The lower susceptibility to damage by radiation shown by fish as compared with mice is of obvious relevance here. It is well known that the lethal dose for carp (2000 r and more) exceeds the comparable dose for other species of animal (500-800 r).

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