***135. The Earth Currents in Relation to the Responses of Catfish.*¹⁾**

By Shinkishi HATAI, Seiji KOKUBO and Noboru ABE.

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Hatai and Abe²⁾ found that catfish show a characteristic motion of the body responding to such slight knock as that made with the curved end of a finger against a table surface, the response being shown at least several hours previous to the occurrence of an earthquake. If, on the other hand, the fish remain quiet and show no motion whatsoever at the time of the knocking it was found that no earthquake occurs within several hours. The correct responses are, however, obtainable only when the water in the aquarium in which the catfish are kept is continuous with the earth through inflow and outflow.

What sort of stimulus does the catfish feel previous to the recording of an earthquake? Since the catfish normally lives at the bottom of a muddy creek, pond, or lake, and in addition definitely responds to so small an electrical current as one of less than one microampere we naturally suspected that the earth currents might be one kind of stimulus involved. We therefore attempted to determine the relation between the variation of the earth current and the sensitivity of catfish. At first, the variation of the potential was determined by using carmel electrodes, one of which was placed in the aquarium and the other in the main water reservoir which is located about 63 meters away. It was found later that the potential changes noted between the two water reservoirs are practically identical with the photographic records taken in connecting two points of earth which were located close to the two electrodes placed in the water. The preliminary observations were made by a capillary electrometer and the reaction of the catfish was recorded every hour for a period of two weeks.

As was anticipated the catfish showed a strong tendency to become sensitive in association with the rise of the potential in the aquarium. But the objection to the present test is that catfish will not ordinarily respond to the same stimulus if it is soon repeated. Therefore it is

1) Contributions from the Marine Biological Station, Asamushi, Aomori-Ken. No. 95.

2) Proc. 8 (1932), 375-378.

Fig. 1. Variation of the earth current in relation to the responses of catfish to the occurrence of earthquakes.

our impression that all the responses obtained in the present test may not be correct.

In order to obviate this objection the catfish were tried but three times a day, usually in the morning, at noon, and in the evening, and the photographic method was substituted for direct reading in order to record the continuous change of the earth currents. From the records so far taken during the past 6 months we find that there is some definite relationship between the sensitivity or non-sensitivity of the catfish on one hand and the occurrence of earthquakes on the other with the variation of the earth current.

Typical examples which illustrate the above relationship are shown in Fig. 1.

The photographic records of the earth currents show manifold characters affected probably by various factors such as temperature, humidity, electrical state of the atmosphere, etc. All these variations cannot be correlated with any particular factor or factors as yet but it has been found that in connection with the sensitive response of catfish a sudden fall or rise of the earth current and an immediate return to the original level is recorded (Fig. 1: I, II, IV.). The revolving speed of the recording drum is 2 cm. per hour. Such sudden falls or rises as the above are so characteristic that if one becomes once familiar with their character, they can be readily discriminated from the multitudes of other types which also affected the potential.

The following types of variation are very frequently recorded but none of these are associated either with the sensitive reaction of catfish or the subsequent occurrence of earthquakes:

(1) A very slow rise or fall of the potential or a sinuous variation, however large such undulation may be, neither causes the catfish to react sensitively nor precedes the recording of an earthquake (Fig. 1: V, VI).

(2) An apparently similar type of sudden fall or rise of potential sometimes occurs singly or in succession during a slow undulatory variation of the earth current but there follows neither a sensitive reaction of the catfish nor the recording of an earthquake (Fig. 1: VIII).

(3) In association with the slower rise or fall followed by an equally slow fall or rise, which we may call a triangular type, neither the catfish become sensitive nor an earthquake is recorded subsequently.

(4) It often occurs that the potential either rises or falls abruptly but continues to be either high or low and does not return to the

former position, sometimes for several hours. Such a change of the potential is not associated with either sensitive responses of the catfish or subsequent recording of earthquakes (Fig. 1: VII, b).

The sensitivity of catfish and the subsequent recording of earthquakes are only associated with a single sudden change, either fall or rise, of the potential followed by an immediate return to the former level while the general course of the earth current remains steady.

It is interesting to note that the catfish show sensitive reactions to a knocking sound both before and after sudden changes of the potential. This seems to indicate that the catfish can receive stimulus from the sudden change of the potential before it affects the galvanometer which is being used by us.

There are of course cases in exception to the above and the catfish may become sensitive and earthquakes may subsequently be recorded, even though there has been no abrupt alteration in the earth current (less common); while in other cases the earthquake may not be recorded even though the earth current shows a sharp break (common).

We conclude therefore that the influence of earth current appears to be at least one of the factors involved. The abrupt change of the potential which seems to occur previous to the recording of an earthquake is sufficiently strong to stimulate the ultra-sensitive cutaneous receptive organs of catfish.