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LINDANE RAISES CATFISH ELECTRODETECTION THRESHOLD

by

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SUMMARY

The detection threshold of the electric sense in catfish, *Ictalurus nebulosus,* was assessed psychophysically in order to investigate the effects of the organic toxicant lindane. In tapwater the detection threshold for ac-stimuli of 1 Hz at 18° C was 8.5 μV/cm. In 0.1 % DMSO in tapwater the threshold was 14 μV/cm. In 50 μg/l lindane dissolved in 0.1 % DMSO in tapwater the threshold went up to 1000 μV/cm. After clearing, the threshold returned to 36 μV/cm. The results demonstrate that catfish ampullary electroreceptors are susceptible to exposure to sublethal doses of organic pesticides. Since ampullary electroreceptor organs are known to respond also to heavy metal pollution, the electric sense seems a promising system to monitor the cumulative pollution of aquatic habitats.

Keywords : Electroreception, electroreceptor organs, lindane, conditioning, psychophysics, behaviour, pollution, BEWS, biomonitor, *Ictalurus nebulosus.*

INTRODUCTION

Ampullary electroreceptor organs of the freswater catfish *Ictalurus nebulosus* are cutaneous sense organs, the receptor cells of which are directly exposed to the aquatic environment. Toxicants administered via the water reach the receptor cells within minutes or seconds. (BRETSCHNEIDER *et al.,* 1979 ; KRAMER, 1984 ; PETERS *et al.,* 1989, 1991 ; ROTH, 1971 ; ZHADAN and ZHADAN, 1975 ; ZWART, 1988). Earlier it has been demonstrated that functioning of electroreceptor organs depends to a great extent on the ionic composition of the aquatic environment. The presence of for instance Cu-ions in a concentration of 1 ppb or less causes a ten-fold increase in the detection threshold of the electric sense (NEUMAN *et al.,* 1991). Previously there were no data available on the effects of organic toxicants on ampullary electroreceptor organs. We performed the following experiment to investigate whether the electric sense of catfish is susceptible to an organic toxicant like lindane.

MATERIALS AND METHODS

Animals

Two catfish, *Ictalurus nebulosus,* with lengths of about 21 cm were kept in glass tanks, dimensions, 100 × 30 cm, water height 10 cm during the course of the experiment. Initially the tanks were filled with copper-free tap water, conductivity 0.22 mS/cm (4.5 kOhm.cm) and pH = 8.2 at 18° C. The conductivity increased to 0.27 mS/cm in the course of one week, due to excretion by the fish, and to feeding. The fish were subjected to a 12 h light, 12 h dark regime, and tested during the dark periods which corresponds to their normal activity pattern. Once a week the water was refreshed. The temperature of the water varied less than 2° C during the measurements. Food, minced beef with gelatin and agar-agar, was administered during the tests through peristaltic pumps at either end of the tank. Food was used as a positive reinforcer (reward).

Protocol

The complete experiment consisted of collecting threshold curves at a temperature of 18° C during a period of 7 weeks. The detection thresholds were measured at a frequency of 1 Hz, twice per night. Each single threshold session consisted of 100 trials. During week 1 control values of the sensitivity limit were assessed. In week 2 the fish were exposed to 0.1 % DMSO in order to test if the solvent itself affects electroreceptor functioning. Control thresholds were measured in clear tap water again in week 3. In week 4 the fish were taken from the tank, and lindane was added to a final concentration of 50 μg/l to test the rate of change of concentration of lindane during a week. During this week water samples were taken every 24 hrs after administration, and analysed by means of gas chromatography. The analyses were carried out on a Carlo Erba type Mega 5360 GC equipped with a ECD400 detector, split injector and a 15 m capillary fused silica column with 0.25 mm DB-5 stationary phase. The fish were put in the tank again in week 5 to give them the opportunity to regain a stable performance. 50 μg/l Lindane in 0.1 % DMSO was added to the tank water in week 6. Lindane loaded water was replaced by clear water again and control threshold values were measured in clear water in week 7. The concentration of 50 μg/l lindane was chosen because it is the LC50 at 4 days exposure for *Ictalurus melas* (Johnson and Finley, 1980). Lindane concentrations in the river Rhine amounted to 0.01 - 0.4 μg/l from 1969 to 1974 (Herbst, 1991).

Stimulation, training, and psychophysics

The stimulation procedure and statistics of the psychophysical approach are described in detail elsewhere (Neuman *et al.*, 1991 ; Peters *et al.*, 1995).

RESULTS

The average concentration of lindane during the pretrial period in week 4, and the test period in week 6 is shown in Fig. 1. The concentration changes drastically in both cases, but remains stable enough from day 1 to 5 to to fulfill the requirements of this experiment. After day 5 the concentration falls to about 10 % of the initial value.

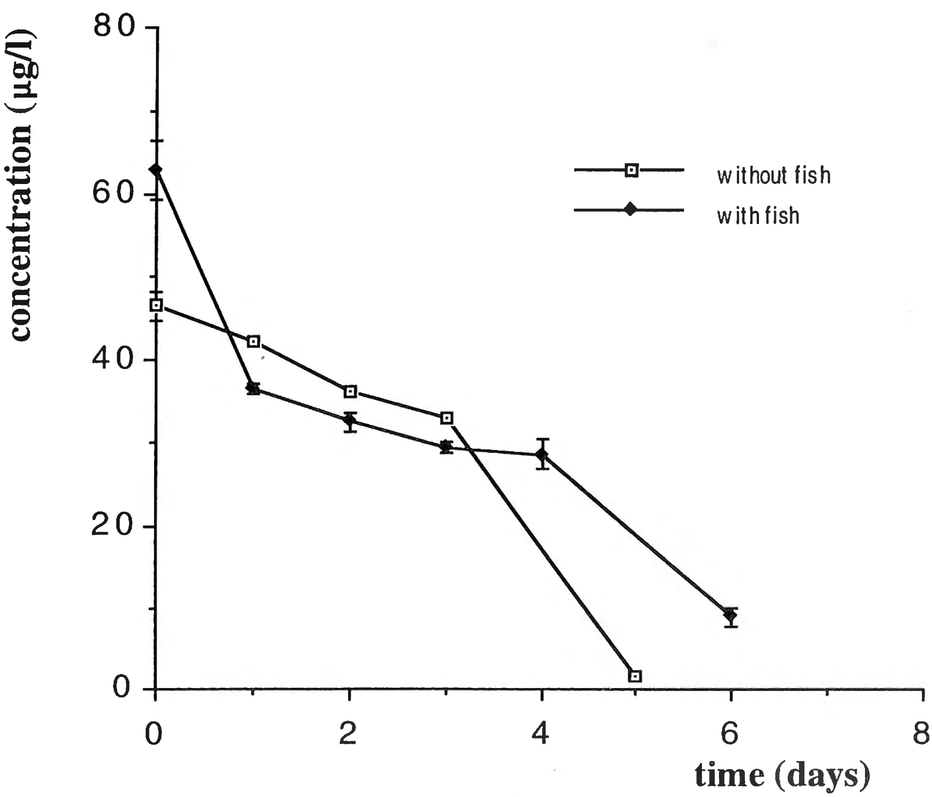

Fig. 1. — Concentration of Lindane in absence of fish during week 4, and in the presence of fish during week 6.

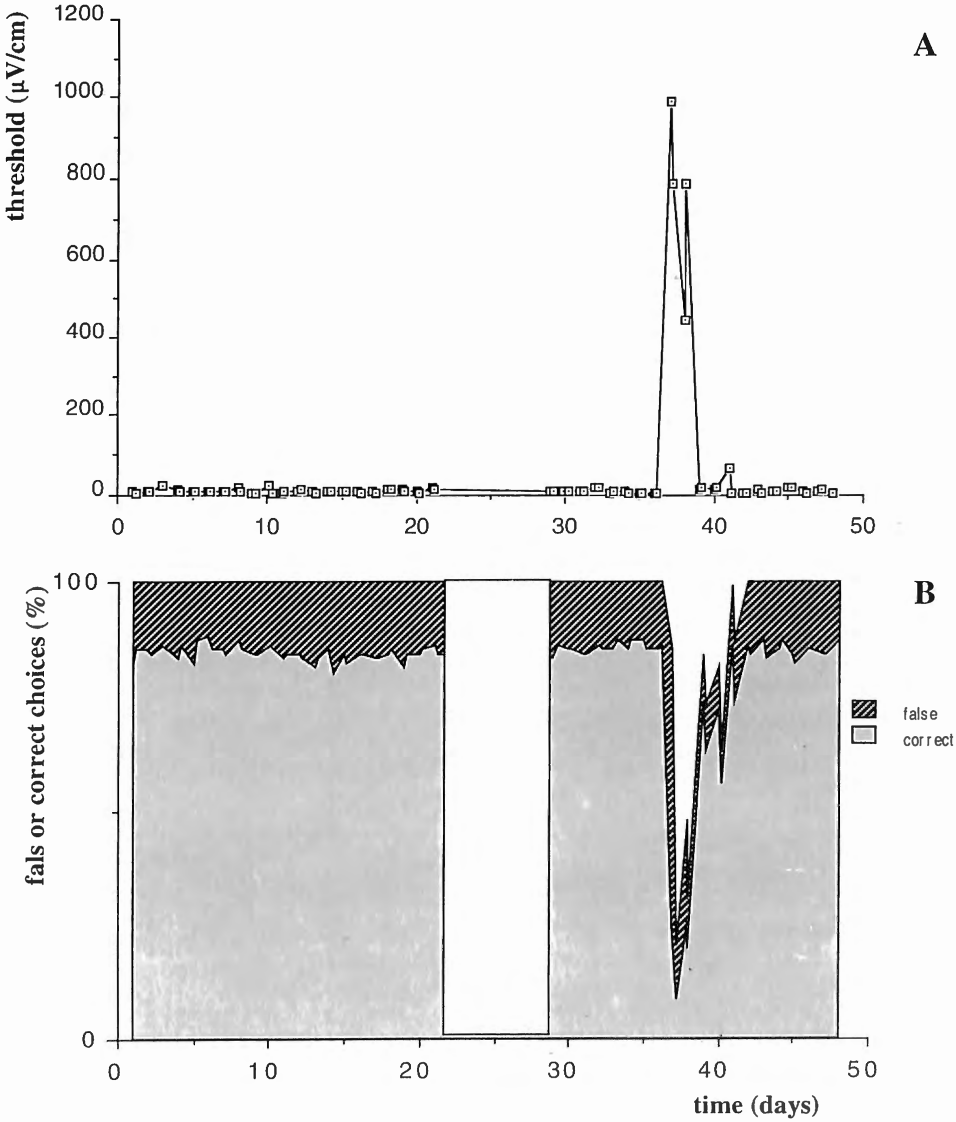

Fig. 2. — Threshold and performance of fish #1. a. Detection threshold in µV/cm, at 18° C and 0.22 mS/cm. In week 4 the fish was taken out of the tank in order to test the stability of the (50 µg/l) lindane concentration in 0.1 % DMSO test solution. The fish was exposed to the test solution in week 6 ; b. Percentage correct choices, false choices, and nogos. During application of the test solution the number of nogos increases dramatically, but the ratio between correct and false choices shows that the fish still performs at threshold level.

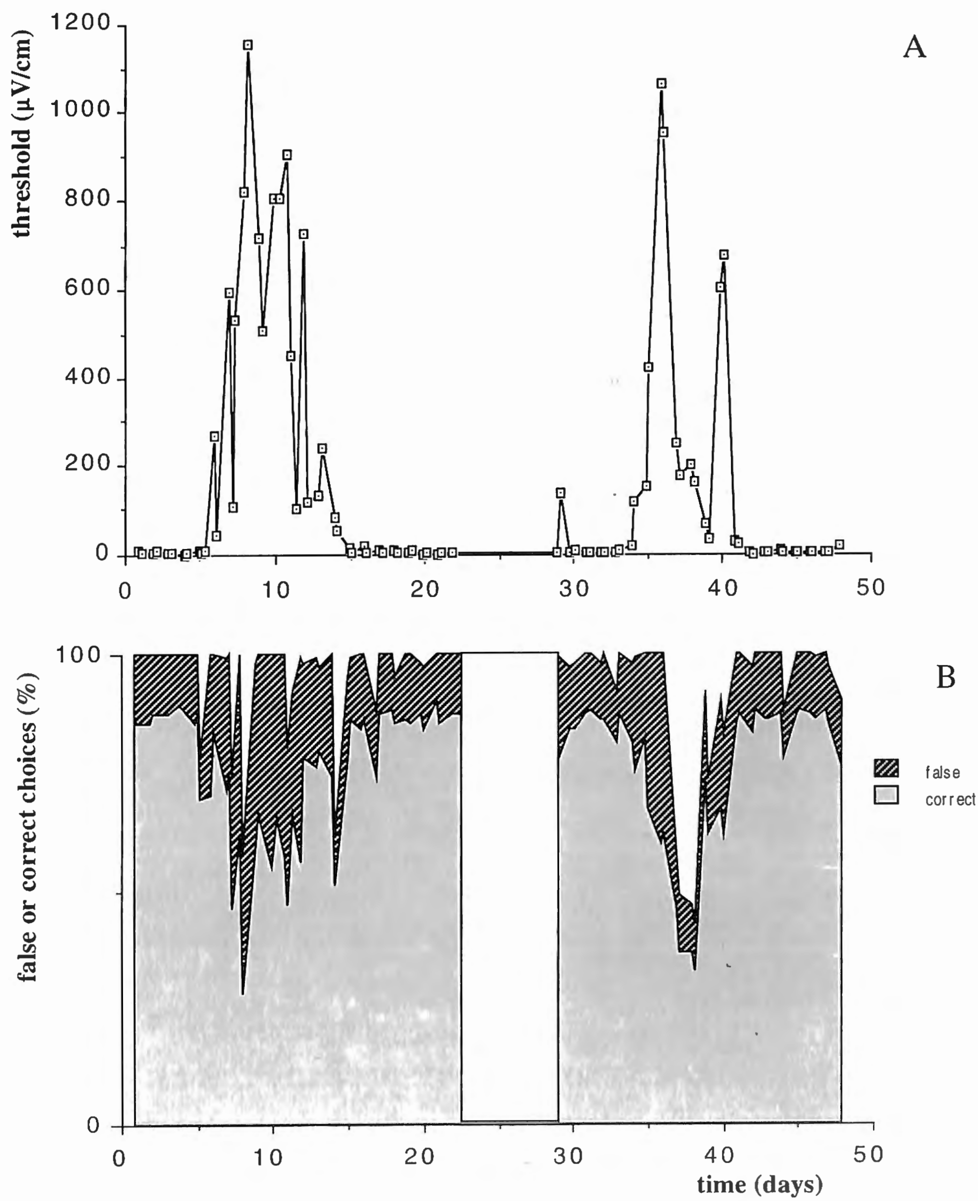

Fig 3. — Same as Fig. 2 for fish #2. On the whole this particular specimen performed less stably than fish 1 (cf. Fig. 2).

Figs 2 and 3 present the electrodetection thresholds and the percentages of correct choices, false choices and nogos in the course of the experiment. One of the fish (Fig. 2) performed extremely well, whereas the other (Fig. 3) performed rather variably. In the well performing specimen the mean theshold remained at 8.5, 14, 14, and 8.5 μV/cm respectively in the first four weeks, whereas only during the test period, week 6, the threshold went up to a value of about 1000 μV/cm. Afterwards the threshold returned to 36 μV/cm again. The percentage of correct choices remained constant at 85 % throughout the experiment, and only during the test period did the number of nogos increased temporarily. The other specimen had more difficulties in performing reliably. Already in the first week the threshold started to climb and resulted in an average value of 272 μV/cm. Also a relatively large number of nogos occurred, even before DMSO or lindane was administered to the water. During DMSO administration the threshold went up to 466 μV/cm, and returned to 24.5 μV/cm in week 3. On the other hand, during weeks five, six and seven, the response pattern strongly resembled that of its companion, although the rise in threshold began before lindane was added. In weeks 5, 6, and 7 the mean threshold values were 8.5, 507, and 36 μV/cm respectively. There is a response to lindane, but the general level of performance is less stable. It is striking that in the best performing subject (Fig. 2) the threshold and the performance in general is not affected by the relatively high concentration of DMSO (0.1 %).

DISCUSSION

The concentration measurements convinced us that the actual concentration of lindane during the experiments was sufficiently constant to allow conclusions about possible effects of the pollutant on electroreceptive behaviour. As for the performances of the two fish we have to be more careful. The best performing fish (Fig. 2) prompts the conclusion that DMSO has no influence on the electroreceptive abilities, whereas lindane has a drastic effect. The data of the other specimen support this finding to a certain extent, but the overall variability makes the results less conclusive. On the other hand, earlier psychophysical experiments on the electrosensitivity of catfish have also shown that sometimes, without any apparent cause, the threshold can increase spontaneously.

We conclude from this pilot experiment that the electric sense of catfish is not only susceptible to heavy metals (NEUMAN et al., 1991) but also to an organic toxicant : lindane. It is not inconceivable that electroreception will also suffer from organic compounds other than lindane. Since it has been shown that ampullary electroreceptors are also sensitive to the composition of the water, we propose that the electric sense of catfish can serve as a biomonitor system which responds to sub-lethal doses of toxicants. Because there is a strong physiological resemblance between the electric sense and the lateral line system, we expect that the susceptibility of the electric sense is representative for the sensitivity of the lateral line system as well. We think that the sensory systems in the integument of aquatic organisms are well suited to monitor the quality of environmental water. Electroreceptor organs are particularly attractive because the stimulus, an electric current, can be very easily and reliably applied.

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