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Variability of the bioelectric field of the catfish *Ictalurus nebulosus* (Le Sueur, 1819; Pisces, Teleostei, Siluriformes)

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ABSTRACT. The electric dc-field of *Ictalurus nebulosus* (Teleostei, Siluriformes) was recorded by having two specimens swim through a silk screen cylinder at 5 cm distance from two recording electrodes, during an observation period of three months.

The dc-field was usually rather stable; on average potential differences of 37 and 55 µV in water with resistivities of 33 and 48 ohm.m respectively were recorded. From time to time the field strength suddenly increased by a factor of 10, after which the field returned to the original value within about 15 min. Increases of field strength could also be evoked by presenting food, "beef juice", and by approaching the tank.

We propose that the recorded changes in bioelectric field strength reveal a particular, perhaps stress- or arousal-related, physiological condition, and that they are sufficiently strong to be perceived by electrosensitive conspecifics.

KEY WORDS: *Ictalurus nebulosus*, lateral line, electroreception, electric field, bioelectric field, transdermal potential, electrocommunication.

INTRODUCTION

Ampullary electroreceptor organs in catfish respond mainly to signals with spectral components between dc and 100 Hz. (Bullock & Heiligenberg, 1986; Kalmijn, 1974; Kramer, 1996; Moller, 1995). Such low frequency components are generally not produced by specialized electric organs or muscle activity, but are rather a by-product of metabolic processes in organisms, and geophysical processes of the aquatic environment (Peters & Bretschneider, 1972). One of the sources of electrical stimuli to ampullary electroreceptor organs is the fish itself (Butsuk & Bessonov, 1981; Peters, 1973; Peters & Meek, 1973; Roth, 1969; Roth, 1972). It has been demonstrated for instance that freshwater catfish are surrounded by stationary electrical dc-fields upon which ac-components, related with respiration, are superimposed. Such fields have been demonstrated in many species of aquatic organisms (Kalmijn, 1972). They can reveal the presence of an individual to other electrosensitive species. The aim of the present paper is to investigate how stable such fields are and if changes are related to, for instance, feeding.

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MATERIAL AND METHODS

Animals

All tests were performed on two specimens of the freshwater catfish *Ictalurus nebulosus.* The fish remained for about three months in the recording setup, which was a part of full glass tanks of 150x60x60 cm. During their confinement they were fed on minced beef and occasionally maggots and pellets. The experiments were performed at room temperature, which was about 14 or 20 °C. The potentials of two specimens were recorded at two different locations during 590 hours in all.

The specimen at location 'A' was kept in a light:dark regime of L:D = 11.5:12.5, at 20ºC, with water resistivity of 33 Ohm.m. Recordings were made during 330 hours.

The fish at location 'B' was kept in a light:dark regime L:D = 12:12 at 14ºC with water resistivity of 48 Ohm.m. Recordings were made during 260 hours.

Electrodes and equipment, electric field recording

The electric field was recorded by means of sintered silver/silver chloride electrodes, equilibrated for about two months in fresh water, mounted in a pvc cylinder to keep them free from unwanted turbulence, and shielded from light in order to reduce light induced potential changes. PAR 113B differential pre-amplifiers were used to boost the signals. The potentials were recorded on paper chart recorders to provide a clear overview on the course of the field changes. In order to eliminate the effects of electrode drift we made ac-recordings at a bandwidth of $0.1<f<10$ Hz and $0.03<f<30$ Hz at locations 'A' and 'B' respectively, by having the fish pass a set of fixed electrodes**.** By passing the electrodes, the dc-field of the fish causes an ac-wave at the site of the electrodes which can be recorded quite accurately. The 'recording device' was a silk screen cylinder connecting two compartments of the aquarium. The cylinder was 15 cm long, had a diameter of 8 cm, and did not distort the expansion of the electric field. Below the cylinder, at 5 cm distance, two recording electrodes were fixed 7 cm apart. The differential recording allows the detection of the swimming direction of the fish. The whole tank was illuminated from above by a light bulb of 100 W.

RESULTS

Control

In order to test the setup for sensitivity to mechanical turbulence, a silicon rubber dummy fish was pushed through the recording cylinder at a speed of 30 cm/s, which caused rather rough water motion. This resulted in potentials of less than 10 μV.

Stability and variability

At location 'A' the average potential change of 7565 passages during 330 hours was 37 μV, with standard deviation 28 μV, and S.E.M. 0.3 μV.

At location 'B' 815 passages during 44 hours gave an average potential change of 55 μV, with standard deviation 0.9 μV, and S.E.M. 0.03 μV. In a second recording session 4562 passages were counted during 216 hours. The average potential change was 84 μV, with standard deviation 59 μV, and S.E.M. 0.9 μV.

In general we observed that, if no food or novel stimuli were presented , the form and strength of the bioelectric field was stable (see Fig. 1A).

Administration of food and stress

During the recording period we observed 19 sudden increases in field strength. The recorded field strength went up by a factor of 10, and returned to the original level in 15 min or more. In nine of these cases the increase could not be related to any apparent cause (see Fig. 1B). In one case the increase could be related to an observer approaching the tank (Fig. 1C). The remaining increases were due to the administration of food or 'beef juice'. In five cases, feeding the fish caused an increase of the bioelectric field indeed, as well as an increase in locomotor activity. Putting pieces of minced meat into the water almost immediately caused an increase of the field strength, which could last for more than 15 min. In four cases the increase in field strength was caused by putting a few drops of 'beef juice' into the water (Fig. 1C). Taking a fish out of the tank and putting it back later induced a similar increase in field strength to feeding. Withholding food for one week decreased the bioelectric field to values as low as 10 μV.

DISCUSSION AND CONCLUSION

The many thousands of recordings made during hundreds of hours in these two fish demonstrate that the bioelectric field of *Ictalurus nebulosus* is stable for a considerable time. From time to time this stable field increases either spontaneously, i.e. without known cause, or as the result of novel stimuli such as the administration of food. Calculations showed that the recorded field patterns can be simulated by a head-negative and tail-positive dipole source, with a current of 1 μA, in water with a resistivity of 33 ohm.m, with the current sink and current source 7 cm apart. The recorded potentials depend on the swimming speed of the fish, the bandwidth of the preamplifier, the distance between recording electrodes and fish, the span between the recording electrodes, and the conductivity of the cylinder. A more precise description of the field form and the field sources can not be accounted for at this moment.

The interesting finding of the present study is that administration of food causes increases in field strengths that strongly resemble the 'spontaneous changes'. The speed of the change suggests neural control. The time course of the subsequent recovery points to the involvement of some humoral component. These sudden increases of the bioelectric field could not be missed by other, passing, electrosensitive catfish. The field change is a sufficiently conspicuous stimulus to contain a 'message' to other electrosensitive conspecifics. If all aquatic organisms show similar increases in electric field strength when they have fed, they may become more conspicuous to their electrosensitive predators as well.

The conclusion is that the bioelectric field of catfish is, as a rule, rather stable, but that it can increase in strength tenfold either spontaneously, induced by the administration of food, or by alarming events. The sudden increase lasts for about 15 minutes. The precise origin of the field change is not known. Most likely neural or hormonal control of epithelial ion pumps is involved. The changes of the bioelectric field are so conspicuous and characteristic that most likely they may be considered as signals carrying information to other conspecifics or other electrosensitive species.

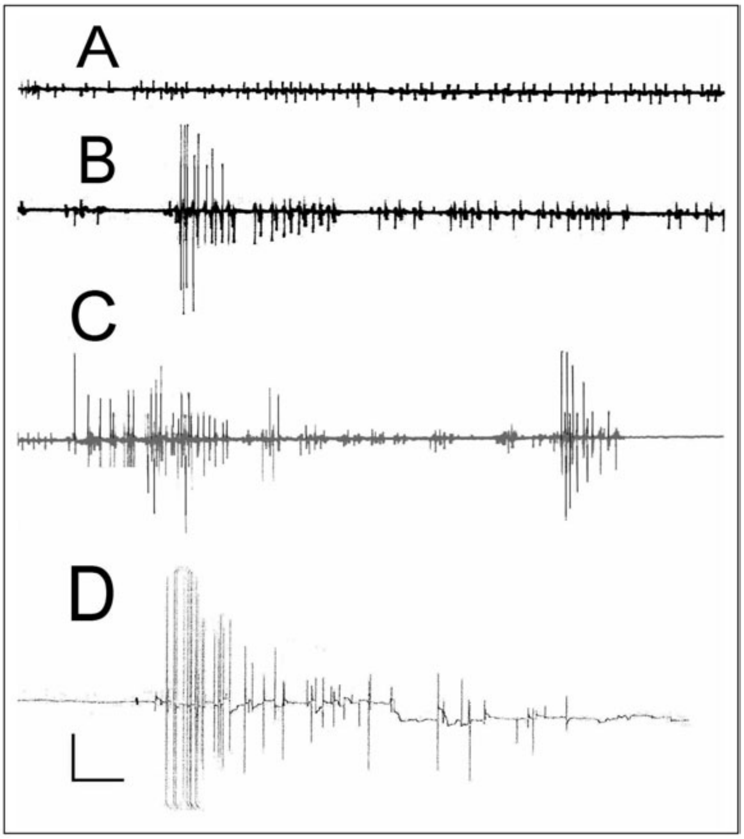

Fig. 1. – Examples of paper chart recordings of potential changes caused by a catfish, *Ictalurus nebulosus*, passing a set of electrodes spaced 7 cm apart at a distance of 5 cm in freshwater at room temperature. The original recordings were scanned after which the background was removed.

A: Location 'A'. Regular to-and-fro passages reveal a stable electric field. The recorded potential changes are on average 55 µV. Scale bars 250 µV and 2 min.

B: The same setup as under A. Here the field strength suddenly increases without any known cause. The recording was made on thermosensitive paper, which did not always receive enough heat to record the passages properly.

C: The same set-up as under A and B. The field strength increases twice. The first time after injection of 'beef juice' in the water; the second time after an observer entered the room and approached the tank.

D: Location 'B'. Sudden increase in field strength in the second setup. This recording was made with a carbon copy recording system. Scale bars 33 µV, 5 min.

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REFERENCES

BULLOCK, T.H. & W. HEILIGENBERG (1986). Electroreception. In: *Wiley series in biology* (ed. R. G. NORTHCUTT). John Wiley & sons, New York: 722 pp.

BUTSUK, S.V. & B.I. BESSONOV (1981). Direct current electric field in some teleost species: effect of medium salinity. *J. comp. Physiol.,* 141: 277-282.

KALMIJN, A.J. (1972). Bioelectric fields in sea water and the function of the ampullae of Lorenzini in elasmobranch fishes. *SIO reference series,* 72-83: 1-21.

KALMIJN, A.J. (1974). The detection of electric fields from inanimate and animate sources other than electric organs. In: *Electroreceptors and other specialized receptors in lower vertebrates*, vol. III/3 (ed. A.E. FESSARD, A.E.). Springer-Verlag, Berlin: 147-200.

KRAMER, B. (1996). Electroreception and communication in fishes. In: *Progress in Zoology*, vol. 42 (ed. RATHMAYER, W.). Gustav Fischer, Stuttgart: 119 pp.

MOLLER, P. (1995). Electric Fishes, History and Behavior. *Fish and Fisheries Series*, vol. 17. Chapman & Hall, London: 584 pp.

PETERS, R.C. (1973). Electro Actography in Fresh Water Fish. *Experientia,* 29: 378-380.

PETERS, R.C. & F. BRETSCHNEIDER (1972). Electric phenomena in the habitat of the catfish, *Ictalurus nebulosus* LeS. *J. comp. Physiol.,* 81: 345-362.

PETERS, R.C. & J. MEEK (1973). Catfish and electric fields. *Experientia,* 29: 299-300.

ROTH, A. (1969). Elektrische Sinnesorgane beim Zwergwels *Ictalurus nebulosus* (*Amiurus nebulosus*). *Z. vergl. Physiol.,* 65: 368-388.

ROTH, A. (1972). The function of electroreceptors in catfish. *J. comp. Physiol.*, 79: 113-135.