Short Communications

No sex difference in the waveform of the pulse type electric fish, *Gnathonemus petersii* (Mormyridae)

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Summary. A communication signal in an African freshwater electric fish, its pulse-like Electric Organ Discharge (EOD), was investigated in order to determine whether inter- or intraindividual variability of the EOD waveform provides a putative cue for communication, in addition to the electric cues already identified. In contrast to an individual's highly stereotyped EODs showing extremely low variation (fig. 1), variability between individuals was considerable (fig. 2). The dependence of an individual's EOD duration on temperature was weak with a Q_{10} of close to 1.5. In none of four quantitative EOD waveform measures can a sexual dimorphism be discerned (table). *Gnathonemus petersii* very likely relies on mechanisms other than discrimination of intraspecific EOD waveforms for mate recognition.

Key words. Electric Organ Discharge (EOD); waveform; communication signal, variability; sexual dimorphism.

Electric fish of the African family Mormyridae discharge their electric organs in short, click-like pulses separated by intervals at least 20 but more often 100–1000 times as long. Every species investigated shows several distinct patterns (or rhythms) of Electric Organ Discharges (EODs) which accompany rest, agonistic[1–10], and courtship behavior (Kirschbaum and Kramer, in preparation). Playback experiments show that EOD time patterns encode intraspecific messages[10], and serve in species recognition[11,12].

A completely different mechanism of communication is 'phase-coupling' of EODs of one fish to those of another by a very short latency, the Preferred Latency Response, PLR[4,6,9,13], or 'Echo' response[14,15]. In *Pollimyrus isidori*, this response is sexually dimorphic: males show a PLR, females a Preferred Latency *Avoidance* (PLA), a lack of response around the same latency of 12 ms[9,13].

The EOD waveform is sexually dimorphic in *Pollimyrus isidori*[16], although some overlap between the sexes has been found[12]. A sexually dimorphic discharge is also reported for *'Brienomyrus brachyistius triphasic'* together with the ability of males to recognize females by their EOD waveform[17].

One way of learning more about the existence and possible significance of sexually dimorphic EOD waveforms in mormyrids is to examine more species. We chose *Gnathonemus petersii* because external morphological sex differences are well known and its electric behavior is probably better described than that of any other electric fish species.

27 animals were investigated in a 250-l tank (26.5 ± 0.2°C, 100 ± 5 μs/cm). The walls of the tank were fitted with electrode arrays made from fine silver wires. The potential difference between opposite electrodes (separation 95 cm) was amplified (100 kHz bandwidth) and digitized (12 bit vertical resolution, 100 kHz sampling rate).

Three EOD samples were taken from each animal when it was positioned centrally with respect to the electrode arrays at the head and tail of the fish. Figure 1A, shows 10 EODs by the same individual recorded at constant temperature within 70 min. The EODs are normalized by computer to the same height of the

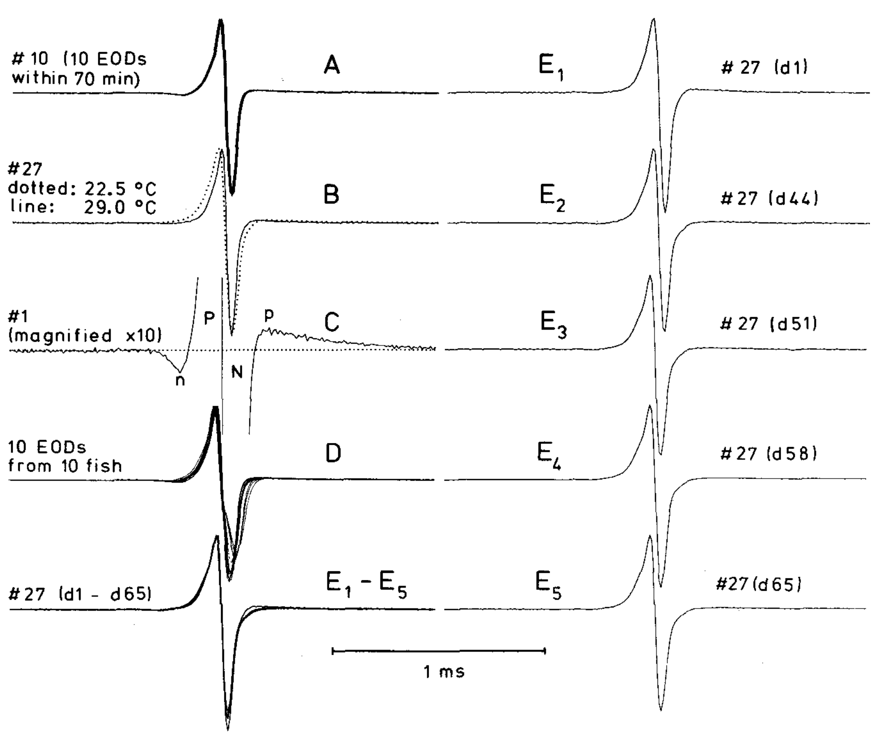

Figure 1. Variability of the Electric Organ Discharge (EOD) of *Gnathonemus petersii*. *A* 10 superimposed EODs recorded from one individual, within 70 min. *B* longer EOD duration at 22.5°C, shorter EOD at 29.5°C (same individual). Two EODs superimposed. *C* explains the four phases of an EOD (enlarged × 10 to show the small n- and p-phases). *D* 10 EODs from 10 individuals, superimposed. *E* five EODs from one individual, recorded over a period of 65 days. Lower left: the same EODs, superimposed.

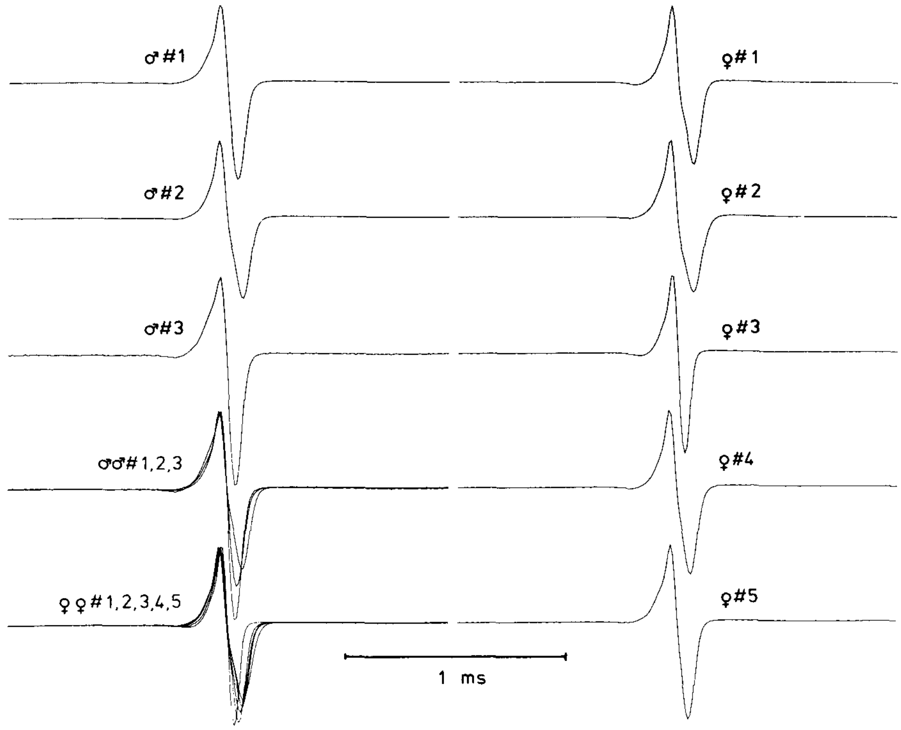

Figure 2. EODs from histologically confirmed males (left) and females (right). The two lower left figures show male and female EODs superimposed. No sexual dimorphism can be discerned by eye.

head-positive peak, P, and to the same X-axis position of the data point nearest to the zero-crossing of the fast transition from the P- to the N-phase (fig. 1C). Apart from the digitization uncertainty of exactly capturing the peak, P, no variation could be detected. In order to investigate this extremely small variation a much faster (×10) A/D conversion would be required.

Over a period of two months, however, there is a detectable waveform change in an individual's EOD (fig. 1E). The amplitudes of the N and the p phases decreased while the time separation of the N from the P peak was maintained.

A change in temperature influences this time relationship. Figure 1B shows EODs from an individual which had been adapted to 22.5°C overnight. The water in the 250-l tank was heated up to 29.0°C within 5 h. A longer discharge duration is associated with low temperature. The Q_{10} of the inverse sum of the P + N durations is 1.49 and thus very close to the values determined for EOD rates in gymnotids with continuous, wave-like EODs[18].

Compared with the temporal stability of the EOD within an individual, the variability between individuals is great (fig. 1D). We therefore looked at the question of whether there were male and female ranges within this variability along the lines of that found for *P. isidori*[16].

EOD waveform variability in *Gnathonemus petersii*

	Males (n = 3)	Females (n = 5)	All fish (n = 27)
P/N amplitude ratio	0.57–0.97	0.76–1.03	0.57–1.03
P/N duration ratio	1.18–1.53	1.06–1.40	1.06–2.25
P/N area ratio	0.73–0.84	0.73–0.89	0.73–0.89
P to N separation (μs)	60–110	60–100	60–110

Computer analysis of digitized EODs of *G. petersii*. P and N phases explained in figure 1C. Note the almost complete overlap of the two sexes in all measures analyzed, showing that there is no sexual dimorphism of EOD waveform in *G. petersii*.

As can be seen from figure 2, and from the results of a computer analysis of male and female EOD waveforms (table), there is an almost complete overlap of the two sexes in all measures analyzed (sex confirmed by gonad histology). There is therefore no evidence for a sexual dimorphism in *G. petersii's* EOD waveform.

Among the three mechanisms of communication discussed above – 1) EOD time interval patterns, 2) EOD latency-coupling, 3) intraspecific EOD waveform variation – only the first two are supported by experimental or observational evidence in *G. petersii*[1–6,8,10,14]. Intraspecific mate recognition using waveform cues is unlikely in this species.

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