

REACTION OF FISHES TO THE UNDERWATER A. C. FIELD

* K. P. BISWAS

AND

S. P. KARMARKAR

Directorate of Fisheries, Dry Dock, Cuttack-753007

A comparative study on the effect of A. C. field on *Puntius ticto*, *Heteropneustis fossilis* and *Tilapia mossambica* was carried out using a slowly rising field intensity.

Well defined reactions appeared in all the species of fish with slight specific variations, depending on their orientation in the electrical field, on reaching the field intensity to a specific value. These reactions can be distinguished as first reaction, when the fish perceive the surrounding field, jerky swimming when parallel to the current lines (longitudinal oscillotaxis), the static position finally adopted by the fish sooner or latter depending on the potential gradient (transverse oscillotaxis), and a state of muscular rigidity (tetanus). After switching off the current, a hypnotic condition prevailed in the treated fishes before returning to their normal swimming condition.

The orientation of fish body in the field had an important bearing on the behaviour reactions and current thresholds necessary for those reactions. Initial reaction, jerky swimming between electrodes and hypnosis after stoppage of current appeared in fishes earlier when the fish body was in parallel to the current lines, whereas fishes responded to transverse oscillotaxis quickly when perpendicular to current lines.

INTRODUCTION

Sharks and rays are reported to be extremely sensitive to A. C. field (Kalamijn,

1966). Shetter (1947) was of the opinion that the rapid reversal of electric current flow in an A. C. circuit affects the nervous

*This work forms a part of the thesis submitted by the author for M.Sc. degree from the University of Bombay.

system of fish. Meyer - Waarden (1957), while describing the reaction of fish in alternating current, stated that the fish did not swim towards one of the two electrodes, as they do in the case of direct and interrupted direct current, but took a transverse position to the direction of the current, between the two electrodes, in such a way that they would tap off a minimum voltage (oscillotaxis). According to Scheminzky and Bukatsch (1941) most of the fish undergo a kind of "hypnosis" after the current is switched off. They do not return immediately to normal swimming position, but stay for a few minutes in a lateral or dorsal position.

Comparative studies have been made on the reactions of fish to alternating sinusoidal currents by Halsband and Meyer-Waarden (1960), Lamarque (1963) and Blanchetau (1961). The behaviour, physiological changes and electrosensitivity of different fish species to alternating current were also studied by Bodrova and Kraiukhine (1958, 1960), Lukashov and Usachev (1963) and Shentiakov (1959).

The present study with *Puntius ticto*, *Heteropneustis fossilis* and *Tilapia mossambica* has been carried out to determine the electrosensitivity and response to A. C. field of different species of fish.

MATERIALS AND METHOD

The current form used for these studies was sinusoidal wave having a frequency of 50 Hz. available from the mains supply. It was directly fed to the electrodes of the experimental tank through an autotransformer and measuring instruments. The potential

difference between the electrodes was raised in one volt steps with the help of autotransformer, which besides acting as a variable resistance, also acted as voltage stabilizer. The fishes used were *Puntius ticto*, *Heteropneustis fossilis* and *Tilapia mossambica*.

RESULTS AND DISCUSSION

Behavioural changes in a homogeneous field and classification of reactions

Identifiable reactions in successive stages occurred in fishes with the increasing field strength, which could be classified as below.

STAGE I (First reaction)

Puntius ticto could perceive the surrounding electrical field by stretching their dorsal, pectoral, ventral and anal fins. Occasional jerks of the body, being paralld to the lines of current conduction, was often followed by tremor of the posterior part of the body with the increasing field strength. The opercular



Fig. 1

Puntius ticto perpendicular to bottom plane with expanded fins and bending of tail during transverse oscillotaxis.

beat slowed down and the fish did not react sharply to external stimuli.

Heteropneustis fossilis exhibited jerks of the head when parallel to current lines. Bending of the posterior part of the body with tremor of the caudal fin was noticed in higher current intensity. Response to external stimuli was reduced to a considerable extent, with slowing of the gill movement.

Tilapia mossambica showed 8 to 42% increase in the rate of opercular movement. It exhibited jerks of the body when it was parallel to the current lines. Normal coordinated swimming slowed down and the fish did not react to the external stimuli.

STAGE II (Longitudinal oscillotaxis)

Jerky swimming of *Puntius ticto* between the electrodes, with vibrations of the posterior part of the body was initiated. Violent contraction of the body axis resulted in unbalanced swimming in an elliptical path.

In *Heteropneustis fossilis* forced swimming with strong vibration of the body set in. The fish moved between electrodes making an angle of 45° with their body axis to the current lines. They also swam between the surface and the bottom of water media making 45° to 65° angle with their body axis to the electrode plane.

Involuntary movement between the electrodes with expanded fins and bending of body started in *Tilapia mossambica* in this stage. Strong vibrations of the body accompanied this unbalanced



Fig. 2

Spasmic ejaculation of milt from male *Tilapia mossambica* during tetanus.

movement and the fish took an elliptical path.

None of the above mentioned species responded to any external stimuli at this stage.

STAGE III (Transverse oscillotaxis)

At a higher field intensity, *Puntius ticto* finally placed itself perpendicular to the field lines and at times with bottom plane without any further movement (Fig. 1). Rate of gill movement slowed down further and showed irregular beats. When shifted to any other position the fish oriented itself to its original perpendicular position in the field. *Heteropneustis fossilis* and *Tilapia mossambica* also adopted static position, at 90° angle to the current lines, in the similar way as *Puntius ticto* described earlier. In the case of *Heteropneustis fossilis* the black body colour changed light yellow at this stage, while in *Tilapia mossambica* the greyish body colour darkened to a deep greyish black with reddish tinge on the margins of the fins.

TABLE I

Occurrence of identifiable reactions in fishes.

Temperature of water media - 25°-27°C.

Nature of current

Resistance of water media : 19×10^3 - 16×10^3 ohms/cm²

Sinusoidal A. C. 50 Hz.

Sl. No.	Nature of identifiable reactions	Presence of identifiable reactions in %		
		<i>Puntius ticto</i> (56-95 mm.) out of 154 fishes	<i>Heteropneustis fossilis</i> (106-170 mm.) out of 186 fishes	<i>Tilapia mossambica</i> (121-170mm.) out of 113 fishes
1.	Straightening of fins	27—62	48—74	37—54
2.	Jerks of body	0—85	0—68	0—47
3.	Quivering of posterior part of the body	16—53	5—56	2—23
4.	In co-ordinated jerky swimming between electrodes	0—84	0—65	0—64
5.	Placing body axis perpendicular to current lines	57—100	52—100	47—100
6.	Muscular contraction of body	100	100	100
7.	Tetanus of gill cover and stoppage of gill movement	100	100	100
8.	Harmonic motion of myomeres during tetanus	—	0—62	—
9.	Release of milt during tetanus	—	—	0—64
10.	Change in body pigmentation	—	100	100
11.	Onset of hypnosis	18—61	39—76	12—38

STAGE IV (Tetanus)

Muscular rigidity, in *Puntius ticto*, was accompanied by the full stretching out of the dorsal, pectoral, ventral and anal fins and by the tetanus of maxilla and gill cover. The fish either settled down on its side or remained upright

at the bottom with no visible sign of body movement.

Tetanus of *Heteropneustis fossilis* set in with the contraction of maxilla and gill cover in a fully stretched condition and the bending of the body like an arch. All voluntary movements stopped

TABLE II

Occurrence of identifiable reactions in *Puntius ticto* in relation to its orientation in the field.

Temperature of water media : 25°C.

Resistance of water media : 19×10^3 ohms/cm²

Nature of current :

Sinusoidal A.C. 50 Hz.

Size group . 56 – 95 mm.

No. of fishes tested : 78.

Sl. No.	Nature of identifiable reactions	Presence of identifiable reactions in %		
		Parallel to current lines	45° to current lines	Perpendicular to current lines
1.	Straightening of fins	62	48	27
2.	Jerks of body	85	21	—
3.	In co-ordinated jerky swimming between electrodes	84	24	—
4.	Transverse oscillotaxis	57	88	100
5.	Muscular contraction of body	100	100	100
6.	Tetanus of gill cover and stoppage of gill movement	100	100	100
7.	Harmonic motion of myomeres during tetanus	—	—	—
8.	Release of milt during tetanus	—	—	—
9.	Change in body pigmentation	—	—	—
10.	Onset of hypnosis	62	45	18

and the fish either sank to the bottom on its side or remained with its head standing erect resting on the posterior part of the body perpendicular to the bottom plane. Dorsal, pectoral and ventral fins remained fully stretched at this stage. Alternate contractions and relaxations of myomeres were observed under this condition. The body colour of light yellow deepened to deep yellow.

The tetanic condition of *Tilapia mossambica* set in with the stoppage of all voluntary movements and sinking of the fish to the bottom on its side with stretched dorsal, ventral and anal fins. Contraction of maxilla and the closure of gill covers also occurred at this stage. The greyish black body colour faded to white when facing the electrode. On being perpendicular to current lines, the

TABLE III

Occurrence of identifiable reactions in *Tilapia mossambica* in relation to their orientation in the field.

Temperature of water media : 26°C.

Nature of current :

Resistance of water media : 17×10^3 ohms/cm²

Sinusoidal A. C. 50 Hz.

Size group : 121-165 mm.

No. of fishes tested: 68.

Sl. No.	Nature of identifiable reactions	Presence of identifiable reactions in %		
		Parallel to current lines	45° to current lines	Perpendicular to current lines
1.	Straightening of fins	54	37	—
2.	Jerks of body	47	—	—
3.	In co-ordinated jerky swimming between electrodes	64	—	—
4.	Transverse oscillotaxis	—	47	100
5.	Muscular contraction of body	100	100	100
6.	Tetanus of gill cover and stoppage of gill movement	100	100	100
7.	Harmonic motion of myomeres during tetanus	—	—	—
8.	Release of milt during tetanus	64	—	—
9.	Change in body pigmentation	100	100	100
10.	Onset of hypnosis	38	24	12

colour of the fish darkened to a deep black. Spasmic ejaculation of milt from males continued under the tetanized condition (Fig. 2)

STAGE V (Hypnosis)

After the stoppage of current flow the entire body relaxed from the tetanized state and the gill cover started beating slowly in a regular rhythm. The rate

of gill movement gradually increased and regained 52 to 96% of the normal rate in *Puntius ticto*. All the fins remained in a stretched condition with no sign of voluntary movements. The fish remained in this condition for 21 to 274 seconds.

Heteropneustis fossilis also continued in a hypnotic state immediately after the stoppage of current flow for 1 to 2

seconds. Operculum started beating slowly at the beginning and regained its normal rate by 62 to 93% after the vanishing of the hypnotic state.

Tilapia mossambica remained under the hypnotic condition with expanded dorsal, ventral and anal fins for a period of 5 to 165 seconds after switching off the current. During this condition the fish did not exhibit any movement except that of the gill cover which resumed slowly.

OCCURRENCE OF IDENTIFIABLE REACTIONS.

Stretching of dorsal, ventral, pectoral and anal fins were observed in 27 to 62% of fishes in the case of *Puntius ticto*, 48 to 74% in the case of *Heteropneustis fossilis* and 37 to 54% in the case of *Tilapia mossambica* (Table-I). Jerks of body occurred in 0 to 85%, 0 to 68% and 0 to 47% in *Puntius ticto*, *Heteropneustis fossilis* and *Tilapia mossambica* respectively. Quivering of posterior part of the body was noticed in 16 to 53%, 5 to 56% and 2 to 23% respectively in the above species. Jerky swimming between electrodes was observed in 0 to 84% of *Puntius ticto* when parallel to current lines. 0 to 65% of *Heteropneustis fossilis* and *Tilapia mossambica* had undergone forced swimming under similar condition. Transverse oscillotaxis set in 47 to 100% of all the fish when perpendicular to current lines. Muscular rigidity accompanied by tetanus of gill cover and stoppage of opercular movement took place in all the fish irrespective of varieties. Alternate contractions and relaxations of myomeres were observed in *Heteropneustis fossilis* only. Spasmic ejaculation of milt was recorded

in 0 to 64% of male *Tilapia mossambica*. Change of body colour during current exposure took place in 100% of *Heteropneustis fossilis* and *Tilapia mossambica*. 18 to 62% of *Puntius ticto*, 39 to 76% of *Heteropneustis fossilis* and 12 to 38% of *Tilapia mossambica* remained under hypnotic condition.

Straightening of the dorsal, pectoral, ventral and anal fins were observed in 62%, 48% and 27% of *Puntius ticto* when parallel, at 45° and perpendicular to the current lines (Table-II). 85% and 21% of the fish showed jerks of their body when parallel and at 45° to the current lines. Jerky swimming between the electrodes was observed in 84% and 24% of the fish when parallel and 45° to the current lines respectively. 100% of the fish exhibited transverse oscillotaxis when they were perpendicular to the current lines, whereas 88% and 57% of them showed the same reaction when at 45° and parallel to the current lines respectively. Tetanic condition set in in 100% fish irrespective of their position in the electric field. 62% remained under hypnotic condition when they were parallel to the current lines. At 45° and perpendicular to the current lines 45% and 18% underwent hypnosis.

Straightening of fins was observed in 54% and 37% of *Tilapia mossambica* when parallel and at 45° to the field lines (Table-III). Jerks of the body and jerky swimming between the electrodes occurred in 47% and 64% respectively when they were parallel to the current lines. 100% of the fishes showed transverse oscillotaxis when they were perpendicular to the current lines. The reaction was noticed in 47% when they

TABLE IV

Temperature of water media : 27°C

Resistance of water media : 16×10^3 ohms/cm²

Nature of current :

Sinusoidal A. C. 50 Hz.

Size group : 111-170 mm.

No. of fishes tested: 126.

Sl. No.	Nature of identifiable reactions	Presence of identifiable reactions in %		
		Parallel to current lines	45° to current lines	Perpendicular to current lines
1.	Straightening of fins	74	48	—
2.	Jerks of body	68	34	—
3.	In co-ordinated jerky swimming between electrodes	65	31	—
4.	Transverse oscillotaxis	—	52	100
5.	Muscular contraction of body	100	100	100
6.	Tetanus of gill cover and stoppage of gill movement	100	100	100
7.	Harmonic motion of myomeres during tetanus	62	—	—
8.	Release of milt during tetanus	—	—	—
9.	Change in body pigmentation	100	100	100
10.	Onset of hypnosis	76	57	39

were at 45° to field lines. Tetanus and change of body colour occurred in the case of all fish irrespective of their position in the field. Release of milt in spurts from 64% of male fishes during muscular contraction took place when the fish body was parallel to the current lines. Hypnosis persisted in 38%, 24% and 12% of the fish when parallel, 45° and perpendicular to the current. Straightening of fins, jerks of body and jerky swimming were present in 65 to 74% of *Heteropneustis fossilis* when

parallel to the current lines (Table-IV). At 45° to the field lines 31 to 48% of the fishes showed the reaction. 100% of fishes exhibited transverse oscillotaxis when perpendicular to the current lines. Only 52% showed the reaction when body was at 45° to the field lines. Muscular contraction of body and change in body pigmentation to different degrees persisted in 100% irrespective of their position in the field. Alternate contractions and relaxations of myomeres during tetanus existed in 62% when parallel to

the lines of force. Hypnotic conditions persisted in the case of 76%, 57% and 39% when parallel, at 45° and perpendicular to the current line.

Bary, (1956) reported that in a uniform electric field of alternating current of 50 Hz. slight specific differences were observed in the voltage gradient to induce a minimum response and electronaracosis in marine fishes.

The response of *Puntius ticto*, *Heteropneustis fossilis* and *Tilapia mossambica* to sinusoidal A. C. field in which the fish successively faced the anode and the cathode 50 times per second could be clearly demarcated and broadly grouped into five stages appearing one after the other, with an increasing field intensity. The first reaction (stage-I) may depend partly on the excitation of the lateral line, which corresponds to the theory of catelectronic excitation of sensory nerves, the lateral line being a long nerve (Bodrova and Kraiukhin, 1960). Longitudinal oscillotaxis, appearing in all the three species of fish was also reported by Lamarque (1963). The transverse oscillotaxis occurred in all the species. This reaction was described by Halsband *et al.* (1960) and Lamarque (1963). But Meyer Waarden (1955) reported that the fish did not swim towards the electrodes in an A. C. field but took a transverse position to the electric field between the electrodes. Onset of tetanus in high current thresholds has been reported by both Halsband *et al.* (*loc. cit.*) and Lamarque (*loc. cit.*). All the fish studied have undergone muscular contraction and rigidity at higher current densities. During tetanus, however, *Heteropneustis fossilis*

showed alternate contractions and relaxations of myomeres resulting in their simple harmonic motion, when their body axis was oriented parallel to the lines of current conduction. In the case of male *Tilapia mossambica* the release of milt in a spurt during muscular contraction was noticed when facing the electrodes. Nothing has been reported so far as to the discharge of milt by fish during electrical stimulation. The presence of hypnotic condition as described by Scheminzky. *et al.* (1941) was observed to a variable degree in all fish under study. Among them, *Heteropneustis fossilis* and *Puntius ticto* were more prone to the hypnosis than *Tilapia mossambica*. A similar reaction of fish was also reported by Halsband *et al.* (1960). Halsband *et al.* (*loc. cit.*) described the discolouration of fish, after a pigmentary contraction as separate reaction. But in fish under study the change in the body colour took place during transverse oscillotaxis and tetanus to a variable degree.

ACKNOWLEDGEMENTS

Thanks are due to Prof. A. J. Borde, Principal, Wilson College for kindly permitting us to work in the Zoology Laboratory of Wilson College.

REFERENCES

- Bary, B. Mc. 1956. *Marine Research*; 1:1
Scottish Home Department, London.
- Bodrova, N. V. and B. V. Kraiukhin. 1958.
Trudy Sovesheh; ikhtiol Kom. 8:124

- Bodrova, N. V. and B. V. Kraiukhin. 1960. *Trudy Inst. Biol., Vodokhran.* 3, 6: 266.
- Balancheteau, M. 1961. *Bull. Cent. Etud. Rech. Scient Biarritz.*, 3, 3 : 277.
- Halsband, E. and P. F. Meyer - Waarden 1960. *Arch. Fish. Wiss.*, 11, 1 : 48.
- Kalmijn, A. J. 1966. *Nature.*, 212 (5067): 1232.
- Lamarque, P. 1963. *Lanature paris.*, 3339: 137.
- Lukashov, V. N., V. V. Usachev. 1963. *Trudy Kaso, Nauchno issled Inst. Morsk ryb. Khoz. Okequogr.*, 19 : 3.
- Meyer-Warrden 1955. *Eleetronik.*, 4, 7: 159.
- Meyer-Waarden. 1957. *Electrical Fishing.*, FAO Fisheries Study No. 7 Rome.
- Schemizky, Fe. and F. Kukatsch. 1941. *Elektrobiologie.*, The Hague Netherlands, 19: 1.
- Shetter, D. A. 1947. *Misc. Cors.*, 16, 8 :9.
- Shentiakov, V. A. 1959. *Trudy. Inst. Biol., Vodokhran.* 1-4 : 309.
-