ON THE RESPONSE OF *CATLA CATLA* (HAM) AND *CIRRHINUS MRIGALA* (HAM) TO THE VOLTAGE GRADIENT OF ELECTRICAL FIELD

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The threshold body voltage (voltage gradient between head and tail) required for first reaction, electro-taxis and electronarcosis depended upon species, conductivity of the fish body, nature of current and wave shape. Larger fishes showed first reaction at a lower body voltage than smaller ones. All the three reactions were dependent on the accommodation of nerves to the electrical field and subsequent fatigue of the fishes. No significant change was observed in the period of narcosis and recovery after repeated stimulation.

INTRODUCTION

Houston (1949) working on commercial varieties of sea fishes in Germany found electrotaxis and electronarcosis at body voltages ranging between 0 5 to 1.5 V and 1.5 to 5V respectively. Cattley (1955) observed that the body voltage in fish varied between 0.5 to 1.5 V and the resistance of the water depended on salinity, turbidity and temperature. Hosl (1955) emphasized the voltage difference between head and tail for effective electrotaxis and electronarcosis. Matsuche (1955) considered this difference in voltage between head and tail to be the factor which determined the narcosis in large and and small fish. Morgan (1951) observed California sardines being attracted to the positive pole in D'C circuit. Drimmelen (1953) noticed cramp condition in fish muscle in A/C field. Norman (1954) reported current density to be a critical factor in directional swimming, the most effective result being found in the use of continuous or interrupted half wave rectified 60 cycles A/C. Halsband (1955) explained the anodic reaction of

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the fish to be due to stimulation of the nerves near the cathode directing the movement to the anode. Harris (1953) found water resistivity to be an important factor in electrotaxis and electronarcosis. Denzer (1955) found that the efficiency of the electrical gear depended not only on the conductivity, but also on the bottom. Mayer-Waarden (1957) recommended impulse current for sea fishing as the conductivity of sea water is 500 times greater than that of fresh water. Bary (1956) found that in mullets the voltage gradient of A/C or D/C required to induce electronarcosis did not depend on temperature and higher gradient was necessary to produce a minimum response in a fatigued fish than in a fresh fish. In the present series of experiments the threshold body voltages (T B V) for first reaction, electrotaxis and electronarcosis for *C. catla* and *C. mrigala* in different types of current in relation to resistance of the medium and state of fish (fresh or fatigued) have been studied.

Materials and methods

The apparatus consisted of a rectangular glass cistern of 92 cm x 61 cm x 61 cm size placed on a wooden table. The depth of the water was maintained at 53 cm by an outlet. A continuous flow of water was maintained. The electrodes consisted of two copper plates of 56 cm x 36 cm size at a distance of 58 cm from each other. The resistance of the water was measured with an avometer before starting the experiments The control panel consisted of one rectifier which converted 220 V A/C to 6 to 72 V D/C from where it passed to the electrodes in the cistern through a rheostat and a switch board having voltmeter and ammeter. The rheostat controlled the D/C supply to the electrodes which could be increased from 0 to any desired voltage. The test fishes after measurement of length and resistance of the body were released into the cistern with two copper hooks, one attached to the tip of the snout and the other to the base of the caudal peduncle. A pair of thin insulated copper wire was connected to the copper hooks so as to measure the body voltage (voltage drop between head and tail) of the fish during first reaction, electrotaxis and electronarcosis. The resistance of the fish body was measured in ohms per cm with the help of a sensitive ohm meter. The fish was placed parallel to the direction of flow of the current. Voltage between the electrodes was gradually raised with the help of the rheostat till the fish showed the first reaction i. e. stretching of the fins, increased gill movement and tremour of the body which at times were accompanied by sudden jerk of the body and then the movements ceased. The voltage was raised further till the fish swam quickly to the electrodes (electrotaxis). The body voltage was simultaneously measured during the first reaction and electrotaxis with the help of a sensitive mV meter. As the fish moved towards the electrode the body voltage was also increased till the fish was narcotised and lay on its side losing voluntary power of movement. The body voltage was measured and recorded as narcosis. Sometimes the fish showed irregular movements till the threshold value for electronarcosis was reached with the increase in input voltage. The input voltage between the electrodes was measured with the help of voltmeter. One fish was used only once for measuring the body voltage to avoid fatigue conditions. The experiments were conducted on *C. catla* and *C. mrigala* so as to observe the differences in body voltages between the species and also between the different sizes.

A comparative study was made of body voltage of *C. mrigala* in respect of D/C and A/C of sinus wave form. To

study the body voltage in A/C a step down transformer with rheostat was used in place of rectifier. In A/C field the fish instead of moving smoothly towards the electrode (electrotaxis) showed movement with sudden jerks and then came to the centre and placed itself perpendicular to the flow of current (oscillotaxis).

The conductivity of the water was changed by changing its temperature. The effect of fatique and accommodation of the nerves to the body voltage of the fishes was observed by treating the same fish with repeated shocks. A study was also made to find out effective period for elctro-narcosis and the period of recovery in relation to the accommodation of the nerves to fatigue.

Results and discussion

The behaviour of the fish in response to D/C varied with the increase in voltage in a uniform field, when the fish lay parallel to the direction of flow of current. The voltage gradient between head and tail of the fish (body voltage) varied according to the behaviour of the fishes in the electrical field. The fish during first reaction felt the presence of electrical field which was detected by tremours of the body. With the increase of body voltage the fish showed violent movement towards the electrode (electrotaxis). During electro-narcosis the fish lost its equilibrium, lay on its side with stretched fins and was no longer able to move of its own accord.

It was seen (Table I) that *C. catla* of 183 to 212 mm length and body resistance of 3666 ohms/cm showed first reaction, electrotaxis and electronarcosis at body voltages of 0.1 to 0.2, 0.275 to 0.45 and 0.55 to 0.65V respectively. It was also observed that the larger fishes showed first reaction at a lower body voltage while there was no considerable difference in body voltages for electrotaxis and electro-

TABLE I. THRESHOLD BODY VOLTAGES OF *C. catla* AND *C. mrigala*

(Nature of current: D/C)

Size in mm	Body voltage between head and tail: First reaction	Electro-taxis	Electro-narcosis
C. catla (Body resistance: 3666 ohms/cm) Water: Temp: 22.5°C, Resistance: 37 ohms/cm			
212	.1	.4	.65
205	.112	.275	.6
195	.125	.45	.625
190	-do-	.375	.575
188	-do-	.325	.55
185	-do-	.35	.6
184	.15	.425	.55
183	.2	.4	.525
C. catla (Body resistance: 2950 ohms/cm) Water Temp: 22.5°C, Resistance: 39 ohms/cm.			
216	.15	.325	.375
205	.225	.3	.525
165	-do-	.4	.5
156	-do-	-do-	.6
145	.3	-do-	.575
140	-do-	-do-	.55
C. mrigala (Body resistance: 8600 chms/cm) Water Temp: 23.5°C, Resistance: 61 ohms/cm.			
255	.087	.087	.325
240	.1	.15	.35
237	.112	.125	.35
230	-do-	.275	.3
208	.125	.275	.4
205	-do-	.25	.3
C. mrigala (Body resistance: 4500 ohms/cm) Water Temp: 26°C, Resistance: 34 ohms/cm			
257	.1	.125	.425
230	.112	.3	.55
225	-do-	.15	.425
223	-do-	.275	.45
220	.137	.2	.425
197	-do-	.125	.375

narcosis between the fishes of different size groups. It was also observed that the body voltage depended on the resistivity of the fish body. *C. catla* of 140 to 216 mm length with a body resistance of 2950 ohms/cm showed first reaction, electrotaxis and electronarcosis at body voltages of 0.15 to 0.3, 0.3 to 0.4 and 0.375 to 0.6 respectively.

C. mrigala of 205 to 255 mm length and body resistance of 8600 ohms/cm exhibited the three reactions at body voltages of 0.087 to 0.125, 0. 087 to 0 275 and 0.3 to 0.4 V respectively, in D/C square wave while the corresponding figures for *C. mrigala* of 197 to 257 mm length and body resistance of 4500 ohms/cm were 0.1 to 0.137, 0.125 to 0.3 and 0.375 to 0.55V. *C. mrigala* behaved differently in A/C sinus wave where the fish after the first reaction showed to and fro movement in between the electrodes and then placed themselves perpendicular to the direction of flow of the currrent. It was observed that the body voltages for the three reactions in *C. mrigala* of 205 to 287 mm length were 0.031 to 0.062, 0.037 to 0.062 and 0.162 to 0.225 V respectively in A/C sinus wave (Table II). Increased body voltages were observed in D/C square wave where *C. mrigala* of 222 to 290 mm length showed the three reactions at 0.112 to 0.237, 0.162 to 0.4 and 0.4 to 0.8V respectively.

TBV for *C. catla* were found to increase with decrease in body resistance (Table III). Conductivity of the water was found to play an important role on the TBV of fishes. The TBV of *C. catla* increased with increase in conductivity of the water. *C, catla* of 183 to 212 mm length were found to respond to the three reactions at 0.1 to 0.2, 0 275 to 0.425 and 0.525 to 0.65 volts respectively (Table IV). The curresponding figures were 0.15 to 0.25, 0.3 to 0.425 and 0.525 to 0.7 respectively for the same fish of length 173 to 215 mm.

TABLE II THRESHOLD BODY VOLTAGES OF *C. mrigala* IN A/C AND D/C CURRENTS

Water temperature: 29.5°C.

Size in mm	Body voltage between head and tail: First reaction	Oscillo-/Electro-taxis	Electro-narcosis
A/C. Resistance of water: 200 ohms/cm			
287	.031	.043	.175
280	.037	.037	.225
260	.062	.062	.162
225	.037	.037	.2
210	.062	.062	.162
205	-do-	-do-	.2
D/C. Resistance of water: 9 ohms/cm			
290	.237	.3	.8
287	.25	.375	.6
250	.162	.162	-do-
232	.112	.2	.4
230	.162	.3	-do-
222	.175	.4	.45

It was observed that the TBV of *C. mrigala* to cause the three reactions depended on accommodation of the nerves and subsequent fatigue of the fish. Though these two factors varied with the physiological condition of individual fishes, most of the fishes responded at a lower body voltage for the three reactions in A/C sinus wave after the first stimulation. Accommodation of the nerves of the fish set in when the fish was subjected to repeated stimulation and afterwards the fish responded to only increased body voltages (Table V).

No appreciable differences were observed in *C. mrigala* for accommodation of nerves and fatigue in D/C square wave from those in A/C (Table VI). Repeated stimulations did not have any significant effect on the effective periods for narcosis and recovery in the case of *C. mrigala*

TABLE III CHANGES IN THRESHOLD BODY VOLTAGES FOR *C. Catla* IN RELATION TO RESISTIVITY OF THE FISH BODY

Nature of current : D/C

Size in mm	Resistivity of fish body in ohms per/cm	Resistance of the water in ohms/cm	Body voltage between head & tail		
			1st reaction	Electro-taxis	Electro-narcosis
183	3571	33	.125	.425	.675
—do—	3143	—do—	.3	.5	.75
172	4400	—do—	.25	.375	.55
—do—	3571	—do—	.275	.525	.6
180	4400	34	.137	.4	.625
—do—	3666	—do—	.175	.35	.625
175	5500	—do—	.175	.3	.4
—do—	2750	—do—	.225	.35	.55
145	3933	39	.225	.375	.7
—do—	2950	—do—	.3	.4	.575
170	4800	40	.187	.45	.675
—do—	3000	—do—	.275	.55	.65

TABLE IV THRESHOLD BODY VOLTAGE OF *C. catla* IN WATERS OF DIFFERENT CONDUCTIVITY

Resistance of the fish body: 3666 ohms/cm

Size in mm	Body voltage between head and tail		
	First reaction	Electro-taxis	Electro-narcosis
212	.1	.4	.65
205	.112	.275	.6
195	.125	.45	.625
190	-do-	.375	.575
188	-do-	.325	.55
185	.137	.35	.6
184	.15	.425	.55
183	.2	.4	.525
Resistance of water: 34 ohms/cm			
215	.15	.4	.6
197	.25	.35	.675
188	.125	.325	.525
187	.112	.3	.55
180	.175	.35	.625
177	.15	.4	.575
173	.125	.425	.7

(Table VII). The recovery periods did not exhibit any relation to the effective periods of narcosis. Meyer-Waarden *(loc. cit)* while describing the reaction of fish to the electrical field expressed that the body voltage was responsible for the different behaviours of the fishes. He also emphasized that a TBV was required for the above reactions. It is observed from our studies that the TBV required to produce the three reactions varied with different species. Matsuche *(loc. cit)*. has also reported the above findings According to him larger fishes of a species were affected to a greater extent than smaller ones of the same species by the same potential difference. Our experiments showed that larger fishes exhibited first reaction at a lower voltage while there was no considerable difference in body voltage for the second and third reactions between fishes of different size groups. This was possibly due to the difference in resistivity of the fish body. Fish with lower conductivity of the body reponded to the reactions at lower body voltages.

The fishes behaved differently in A/C field of sinus wave, showed to and fro movements between the electrodes and

TABLE V EFFECT OF FATIGUE AND ACCOMMODATION OF NERVES ON THRESHOLD BODY VOLTAGE OF *C. mrigala* IN A/C SINUS WAVE

Size in mm.	Body voltage during 1st reaction				
	1st stimulation	2nd stimulation	3rd stimulation	4th stimulation	5th stimulation
287	.05	.037	.037	.043	.031
280	.031	.043	.05	.043	.037
260	.075	.1	.062	.062	.075
225	.037	.037	.025	.025	.025
210	.062	.062	.043	.043	.037
205	.062	.062	.06	.037	.05
	Body voltage during Oscillotaxis				
287	.05	.037	.037	.031	.043
280	.037	.05	.05	.043	.037
260	.071	.1	.062	.062	.075
225	.037	.037	.05	.025	—
210	.062	.075	.05	.05	.057
205	.062	.062	.05	.037	.037
	Body voltage during Electronarcossis				
287	.187	.125	.162	.162	.175
280	.187	.175	.325	.187	.225
260	.2	.175	.162	.125	.1
225	.2	.175	.175	.15	.15
210	.162	.075	.175	.075	—
205	.2	.15	.125	.125	.15

then placed themselves perpendicular to the direction of flow of the currrent to tap off minimum voltage. According to Drimmelen (1953) this occurred due to "cramp" condition of the muscle. The TBV required for the three reactions were lower in A/C sinus wave than in D/C square wave and increased with conductivity of the water. Higher TBV need increased input voltage for which Denzer (*loc. cit*) suggested battery operated gear in small conductivity and heavy electric gear for higher conductivity. Short pulses are more suited to sea water because of their high conductivity. No appreciable difference was observed in TBV of the fishes in D/C square wave when the fish were subjected to repeated stimulation; but most of the fishes responded at a lower body voltage in A/C sinus wave after first stimulation. This was possibly due to the accommodation of the nerves to the electrical field and subsequent fatigue. Cattley (*loc. cit.*) observed that the recovery rate of fish depended on exposure to the current. But no significant effect was observed on the effective periods of marcosis and recovery in relation to repeated stimulation.

CONCLUSION

The behaviour of fish in an electrical field depends, irrespective of species, on the body voltage and is not dependent on the nature of current and shape of wave. The fish exhibits distinct behaviour patterns in an electrical field with rise of body voltage. The TBV for first reaction increases with decrease in size while the second and third reactions do not follow the same pattern. The nature of current and wave shape play an important part on the TBV for the three reactions, A/C sinus wave requiring less TBV than D/C square wave. The TBV does not depend on the

TABLE VI THE EFFECT OF FATIGUE AND ACCOMMODATION OF NERVES ON THRESHOLD BODY VOLTAGES OF *C. mrigala* IN D/C SQUARE WAVE

Size in mm.	Body Voltage during Ist. reaction				
	Ist. stimulation	2nd. stimulation	3rd stimulation	4th stimulation	5th stimulation
340	.15	.15	.162	.175	.237
300	.2	.262	.125	.2	.162
300	.162	.2	.187	.175	.2
295	.25	.2	.187	.225	.187
290	.3	.25	.275	.237	.25
287	.25	.237	.175	.187	.2
250	.325	.15	.112	.137	.162
232	.075	.112	.1	.112	.1
230	.143	.137	.112	.112	.162
222	.262	.175	.325	.175	.275
	Body voltage during Electrotaxis				
340	.15	.15	.162	.175	.325
302	.212	.2	.237	.35	.262
300	.25	.175	.2	.2	.187
295	.275	.25	.237	.237	.2
290	.375	.275	.3	.3	.275
287	.375	.25	.175	.187	.2
250	.15	.15	.2	.162	.162
232	.1	.2	.3	.1	—
230	.225	.3	.3	.3	.3
222	.275	.4	.125	—	—
	Body voltage during Electronarcosis				
340	.45	.525	.625	.575	.55
302	.5	.6	.6	.6	.6
300	.75	.8	.75	.55	.3
295	.75	.7	.7	.525	.625
290	.8	.8	.8	.8	.8
287	.6	.55	.6	.7	.8
250	.55	.5	.55	.7	.6
232	.3	.3	.3	.4	.3
230	.575	.4	.5	.4	.4
222	.45	.45	.5	.45	.5

TABLE VII EFFECTIVE PERIODS FOR ELECTRONARCOSIS AND RECOVERY IN RELATION TO FATIGUE AND ACCOMMODATION OF NERVES OF *C. mrigala* IN D/C SQUARE WAVE

Size in mm.	Effective period for electronarcosis in secs.				
	1st stimulation	2nd stimulation	3rd stimulation	4th stimulation	5th stimulation
340	45	29	25.5	6	25.5
303	15	97	94	43	52
302	103	110	62.5	27.5	190
300	46	21.2	6	6	7
295	25.5	17.5	5.5	17.2	4
290	107.5	15.5	39	18.5	39.5
287	51	30.6	17 2	9	8.2
250	159	87.8	21	7	8.2
232	25	28	10.5	149	60
230	25	85	24	15.5	67
222	25	52	11	17	5.5
	Period of recovery in secs				
340	3	2	1	8	1.2
303	126	217	201	5.2	2
302	4 2	6	2	1.2	2.4
300	1.2	1.5	1.2	1	1.2
300	41	4	4	1.8	1.5
295	4 6	1.2	2.6	2.4	1.6
290	8.4	1.4	3.2	2	2.1
287	3.4	1.8	1.2	1.1	1.3
250	88	120	5.6	1	1.5
232	25	1.5	1	120	12
130	10	120	101	100	329
222	1	1	4.5	1.2	.8

conductivity of the water. Repeated stimulation seems to have no effect on TBV both in A/C and D/C.

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