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Research Article

Electro-sensitivity of Indian Freshwater Fishes and their Capture in Electric Gill Net

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Abstract

Large scaled carp (*Labeo rohita*) and scale less catfish (*Clarias batrachus*) were first studied for their reactions in a homogeneous electric field created by DC and PDC. Both the species have undergone a sequence of reactions with increasing current density surrounding the fish. The orientation of the fish at the time of electric stimulation played an important role to initiate reaction irrespective of the type of applied current. Fishes when parallel to lines of current conduction exhibited 100% anodic taxis and narcosis at lower voltage gradients and current densities.

To improve the catch per unit effort (CPUE) of gill net which is passive fishing gear and time consuming operation, underwater electrical stimulus have been applied to startle the fish (frightening effect of the negative pole and attracting effect of the positive pole) for enmeshing and entangling in a three panel gill net fortified with negative and positive electrodes. Forty-eighty three % of the mixed fish population could be caught from an enclosed area in the electrified gill net in current densities of 0.55 - 5.0δ by applying 80 - 130V.

The highest sensitivity towards electric stimulation was noticed in Indian carps (*Labeo rohita, Cirrhinus mrigala, Labeo bata*) followed by featherback (*Notopterus notopterus*) and freshwater catfish (*Clarias batrachus*).

Keywords: *Electric Gill Net; Electric Power Transfer; Freshwater Fish*

Introduction

Live fish have been found to conduct electric current through their body when their body conductivity is higher than the surrounding water (fresh water) in which they live.

An electric current will conduct through a fish, if an optimal potential difference is created between their body extremities. The larger body extremities (between head and tail) will intercept a greater voltage gradient and will be satisfactorily influenced by the electrical stimulation. Fishes have been found to undergo a sequence of reactions with increasing current density surrounding the fish. In a homogeneous electric field the reactions of fishes are different when they orient their body axis at different angles in relation to lines of current conduction.

In controlling fish movement, including catching, these reactions of fish in an electric field were utilized over decades. The reactions of fish were also different when they are subjected to currents of different types, such as direct current (DC), pulsed direct current (PDC) and alternating current (AC). Various species of different size groups, particularly length and body profile including their physiological conditions, play an important role in their response to electrical stimulation.

Studies on Indian fishes were carried out on the application of direct current (DC) and alternating current (AC) [1].

The first part of the present study was carried out in the laboratory in a homogeneous electric field produced by DC and PDC 1/sec, 3/sec and 5/sec.

The gill net, popular fishing gear is operated in inland lotic and lentic waters, because of its simplicity in design, fabrication and low man-power for operation and where dragging gears (seine nets) could not be operated due to rough topography and physical obstructions. The gill net, rectangular in shape, with floats on its top and sinkers at its bottom, is provided in order to hang the net in the water like a wall. The net is placed on the migratory path of the swimming fish. Attempting to pass through the net, fish is enmeshed or entangled in the net depending on the hanging ratio of the webbing of the framed net. Generally, spindle shaped fish are enmeshed, while, fishes with projections are entangled in the net [2].

Though fishing with gill net is a very simple method, yet the method has its own drawback, such as long waiting time for the fish to encounter the net. Fish caught in the gill net deteriorate for its quality before the net is hauled in and the fishes are collected from the net after 3 - 6 hours of enmeshing in the net.

According to the varying effect of electric current on the fish, a distinction can be made for (a) attracting fish to the positive electrode, (b) frightening or blocking effect and (c) narcotizing or killing effect.

Based on these concepts, the second part of the study was planned to create sufficient electrical stimulus around a three panel gill net designed by Biswas [2] with the electrodes attached to the nets. The work plan has been designed in such a way that fishes, nearby negative electrodes of the outer panels will be repelled towards the positive electrode of the central panel, besides the attraction effect of the positive electrode.

Materials and Methods

In the first part of the investigation tests have been carried out in a glass tank, 118 cm long, 28 cm wide and 29.5 cm deep. The tank was filled to a depth of 19 cm with freshwater. At the longest extremities of the tank were placed two 3 mm thick 28 cm X 17 cm aluminium plate electrodes, positioned perpendicular to the longitudinal axis of the tank.

DC and pulsed DC to the electrodes were supplied from AC lines through a voltage stabilizer, step down DC inverter to supply DC and a pulser in the circuit to supply pulse DC. The output voltages were 5 - 210V at continuous DC and 3 - 180V at PDC 1/sec, 2 - 160V at PDC 3/sec and 1 - 145V at PDC 5/sec. By providing a variable resistance of 2KΩ in the external circuit, the voltage at the electrodes was regulated from the smallest to highest peak voltages.

Water conductivity and ambient temperature were measured with a conductivity meter and thermometer respectively at the start and was recorded for each set of experiments. Live fish collected from the cultured pond, was held in a glass tank for a week and maintained in good health on a diet of living and formulated feed. Randomly selected fish, one at a time, after measuring total length, girth and surface area was transferred to the experimental tank, kept for 10 minutes and its breathing rate counted by opercular beat, besides observing their normal swimming behavior.

Individual fish was then exposed to a rising current density between the electrodes by raising the potential difference between electrodes with the help of rheostat, provided in the external circuit till visible reactions, such as, perception of the electric field, around its body (1st reaction), forced involuntary movement (2nd reaction) and narcosis, unable to move out of its own accord (3rd reaction) were observed and identified.

The reaction thresholds and the body voltage (potential difference between body extremities in relation to the lines of current conduction) and current density initiating the reactions were measured at each case with the help of a probe electrode and a voltmeter connected to the external circuit.

The physiological stress of the animal was checked by the time taken for undergoing narcosis and recovery from narcosis after switching off the current flow, besides comparing the rate of gill movement before the current exposure and after the recovery from narcosis.

The second part of the test was made in a large tank (180 cm X 105 cm X 80 cm) filled with freshwater upto a depth of 60 cm (Figure 1).

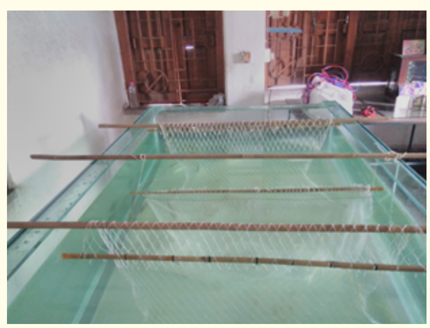

Figure 1: *Arrangement of experimental gill nets.*

Three panel electric gill net of 0.8 X 0.8m (framed) having a uniform mesh of 2.5 cm was used for two outer panels, while a single framed net of the same size (0.8 X 0.8m) with a lower mesh size of 1.5 cm was used as a central panel. Eighty four cm aluminum conduit of 12 mm diameter, each was fitted at the bottom of the two outer panels, which served as negative electrodes. The positive electrode, which was also 84 cm long aluminum conduit of the same specification was attached to the upper part of the central panel, 4 cm below the float line, so that the positive electrode remained under the water surface. The distance between the central panel and the outer panels was maintained at 0.42 m at each side (Figure 2).

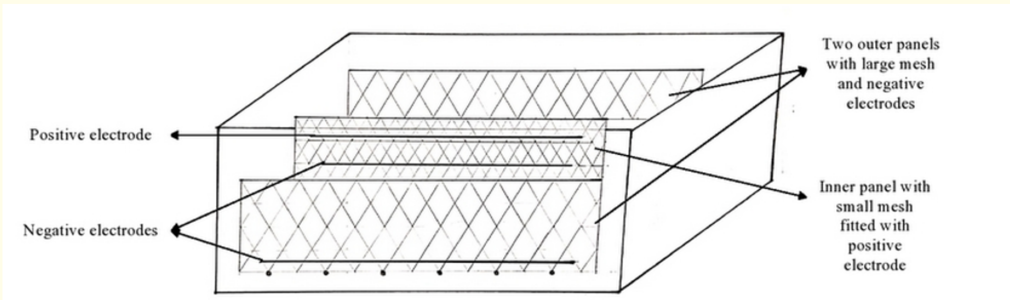

Figure 2: *Schematic diagram of the experimental tank showing electrified gill net with positive and negative electrodes (not to the scale).*

The negative electrodes at the bottom of two outer panels were electrically connected by 1.45m insulated cable on each side, 25 cm of which was kept uninsulated and exposed in the middle, so that, spike potential could be developed under the positive electrode to form two concentric triangular field when a potential difference was established between anode and cathode.

The tests were carried out in day time. One 0.5KVA AC to DC inverter, capable of supplying 40 - 230V DC was employed as a source of power supply to the gill net. An electronic pulser of low frequency (1/sec - 3/sec) was connected in the outer circuit to obtain PDC.

The water temperature and electrical resistance of the experimental tank varied from 25° - 32°C and 4000 - 6500 ohms/cm^2 respectively.

A total of nine species of common Indian fresh water fishes were used for the study. They were, *Labeo rohita, Cirrhinus mrigala, Labeo bata, Notopterus nototpterus, Oreochromis niloticus, Cyprinus carpio, Chana punctatus, Labeo calbasu and Clarias batrachus*. A known number of multi-species fish population was introduced in the experimental tank after measuring their total length and was allowed to be used with the new environment for a period of 30 minutes.

On switching on the current, fishes between three net panels were found to move forcefully either to the central panel containing positive electrode or entangled in the outer panels, while trying to escape out of the field. Electric exposure lasted for 2 - 20 seconds and the effected fishes were removed carefully, kept in highly oxygenated water for a period of 60 minutes.

All the electrical parameters during experiments were measured with two precision multimeters (AVO Model - 8 and Sanwa P -2). The density of current was measured with the help of a probe to directly read the amount of current flow in the field and was expressed as δ (10^{-6} A/mm^2).

Results

All the *L. rohita* felt the current by the vibration of the body with expanded fins, initially at low current intensity (1st reaction). After receiving initial stimulation, 50% of them remained perpendicular to the field lines in PDC 1/sec, while in PDC 3/sec, their orientation, perpendicular to the field lines were noticed in 75% *L. rohita*. In PDC 5/sec, however, 60% fishes stayed perpendicular to field lines, while 20% at an angle of 50° and rest 20% showed no change in their orientation.

The forced movement to the anode was observed in 75% *L. rohita* in PDC 1/sec, 100% in PDC 3/sec and 80% in PDC 5/sec. Twenty five percent *L. rohita* during the second reaction, moved between electrodes in PDC 1/sec and 20% in PDC 5/sec.

Narcosis of *L. rohita* near the anode was noticed in 100% cases in PDC 3/sec and PDC 5/sec. But in PDC 1/sec only 75% fish responded for anodic narcosis and the rest 25% were narcosed near the cathode (Table 1 and figure 3).

Species	**Length (mm)**	**Body surface Area (mm^2)**	**Type of current used (DC/PDC)**	**Orientation of fish prior to electric stimulation**	**Observed reaction of fish during electrical stimulation**		
					I Reaction	**II Reaction**	**III Reaction**
Labeo rohita	217.5	13508.25	PDC (1/sec)	A- 25% B - 50% C - 25%	A_1 = 100% B_1 = Perpendicular (50%) C_1 = 50%	A_2 = 75% C_2 = 25%	A_3 = 75% B_3 = 25%
	211.25	12615.5	PDC (3/sec)	A - 25% B - 25% C - 50%	A_1 = 100% B_1 = Perpendicular (75%) C_1 = 25%	A_2 = 100%	A_3 = 100%
	216	13175	PDC (5/sec)	A- 20% C - 80%	A_1 = 100% B_1 **= 45°angle (20%)** Perpendicular (60%) C_1 = 20%	A_2 = 80% C_2 = 20%	A_3 = 100%
Clarias batrachus	270 - 290	19997 - 21478	DC	A- 100%	A_1 = 100% B_1 = Perpendicular (100%)	A_2 = 100%	A_3 = 100%
	220 - 290	14867 - 21478	PDC (3/sec)	B - 50% D - 50%	A_1 = 100% B_1 = Perpendicular (100%)	C_2 = 100%	A_3 = 50% B_3 = 50%
	200 - 290	13515 - 21478	PDC (5/sec)	A- 20% B - 20% C - 60%	A_1 = 100% B_1 = No change in position (20%), Perpendicular (40%), Continuous movement (40%)	A_2 = 40% C_2 = 60%	A_3 = 80% C_3 = 20% with anodic curvature
Initial orientation A = Parallel to field lines B = Perpendicular to field lines C = 45°angle to field lines D = Co-ordinated movement.		I Reaction A_1 = Felt the electric stimuli with vibration of the body and expanded fins. B_1 = Changing orientation in the electric field. C_1 = No movement.		II Reaction A_2 = Anodic taxis. B_2 = Cathodic taxis C_2 = Taxis between electrodes. D_2 = Anodic curvature.		III Reaction A_3 = Anodic narcosis. B_3 = Cathodic tetanus. C_3 = No narcosis. D_3 = Narcosis in mid field.	

Table 1: *Visible reactions of fish in an electrical stimulation.*

Water temperature: 19°C - 30°C.

Water conductivity: 0.4 µS/cm.

Figure 3: *Narcosis of Labeo rohita near the anode.*

C. batrachus perceived the current with the vibration of the body and expanded fin in DC, PDC 3/sec and PDC 5/sec. All the fish in DC and PDC 3/sec, during 1st reaction changed their orientation from parallel to perpendicular to the lines of current conduction. In PDC 5/sec, only 40% of them turned perpendicular to field lines, while out of the remaining 60% twenty percent have not changed their orientation and the rest 40% were moving in the field.

The species showed anodic taxis in 100% cases in DC field, but when exposed to PDC 3/sec, 100% fishes moved between the electrodes. In the field of PDC 5/sec, 40% fishes exhibited anodic movement and the rest 60% moved between positive and negative electrodes. During the third reaction, 100% *C. batrachus* were narcosed near the positive electrode in the DC field. In the case of PDC 3/sec, 50% fishes were narcosed near the anode and the rest 50% near the cathode. At higher current intensity, in PDC 5/sec, 80% fishes were narcosed near the positive electrode and the rest 20% fishes exhibited curvature of the body by pointing two body extremities (head and tail) towards the anode and remained motionless near the negative electrode (Table 1 and figure 4 and 5).

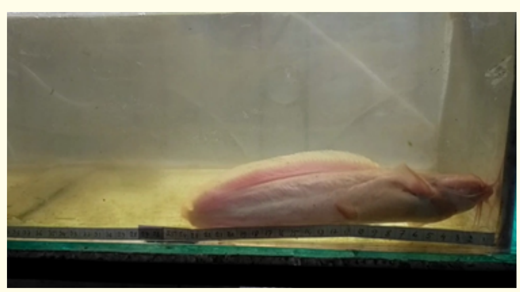

Figure 4: *Clarias batrachus narcosed near the anode.*

Figure 5: *Anodic curvature of Clarias batrachus.*

The electric field pattern created by the electrodes of three panel gill net was measured with the help of a probe before putting the live fishes. At an input voltage of 85V, the voltage gradient (V/cm) and current density (δ) varied with the increase of tangential and vertical distances from the negative electrodes. At a tangential and vertical distance of 15 cm from the negative electrode, a voltage gradient of 16.5 V/cm was recorded together with a current density of 55δ. The increasing trend of voltage gradient and current density with the increase of tangential distances from the negative electrode was observed. Sixty centimeters (60 cm) away from the negative electrode, the voltage gradient was found to be 25 V/cm and a current density of 85δ (Table 2 and figure 6).

Distance from electrode (cm)			Voltage gradient (V/cm)		
From +ve	From -ve	Vertical	From +ve	From -ve	Vertical
10	10	5	34	6.5	18
20	20	10	27.5	11	16.1
30	30	15	20.5	13.1	16
40	40	20	18.9	15.1	15
50	50	25	16	17.9	14.9
60	60	30	14.5	21.5	14
70	70	35	12	26.5	14
80	80	40	10	32	13.9

Table 2: *Three dimensional voltage gradient pattern of electric gill net.*

Input voltage: 90 V.

Water temperature: 29°C.

Water resistance of water: 5200 ohm/cm^2.

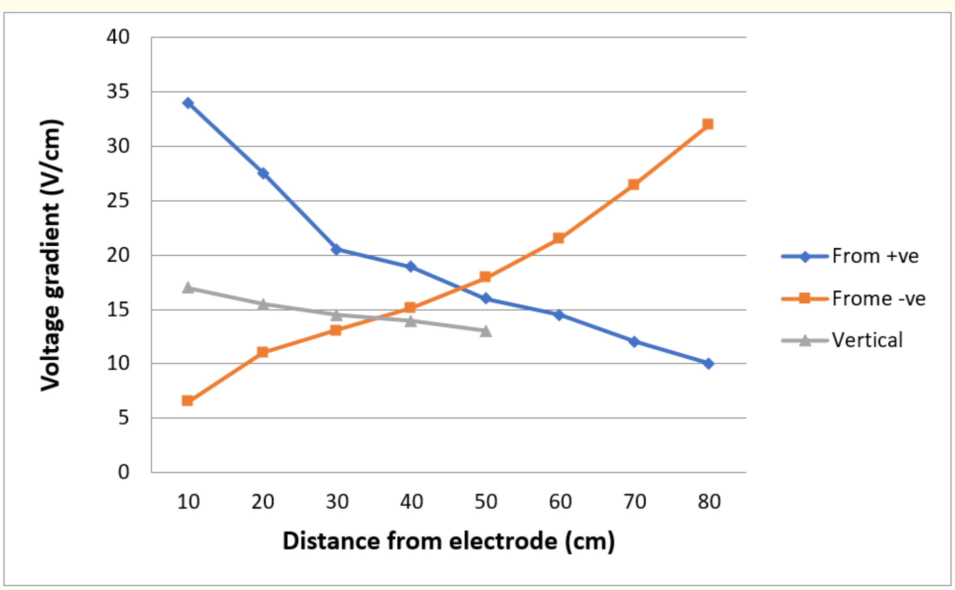

Figure 6: *Three dimensional voltage gradient pattern of electric gill net.*

Forty - Eighty three% of the total fish population was either enmeshed or entangled in electrified gill net panels (Figure 8 and 9) when the same net without being electrified failed to catch any fish. The fish population caught in the electrified net increased from 40 to 80%, when the density of current in the influenced zone rose from 0.55 to 1.5δ. With the further rise of the current density of 1.7 - 2.5δ and finally to 5δ, the percentage of capture was reduced to 46% in 1.7δ and again increased to 57, 71 and 83 percent with the rise of current density from 2.5 to 5.0δ. The exposure time of the current (effective period) was 10 to 36 seconds (Table 3 and figure 7).

Experiment No.	% of total fish population caught in non-electrified net	% of total fish population caught in electrified net		
		Density of current in influence zone (δ)	Time of electric exposure (second)	% of total fish population caught in electrified net
1.	Nil	0.55	26	40
2.	Nil	0.65	36	65
3.	Nil	1.1	19	66
4.	Nil	1.2	16	74
5.	Nil	1.5	33	80
6.	Nil	1.7	14	46
7.	Nil	2.5	13	57
8.	Nil	2.5	10	83
9.	Nil	5.0	14	71

Table 3: *Fish catch in non-electrified and electrified gill nets.*

Electrode: Aluminium conduit.

Water temperature: 30°C.

Water resistance of water: 5500 ohm/cm^2.

Figure 7: *Multi-species gilling around positive of the central panel.*

Figure 8: *Cirrhinus mrigala entangled around the positive electrode of the central panel of electrified gill net.*

Figure 9: *Entangling of Labeo rohita in the outer panel of electrified gill net.*

The response of a group of four - six fishes at a time of 110 - 235 mm size range of 4 species (*L. rohita, C. mrigala, L. bata, O. niloticus)* was studied at current densities between 0.45 - 5.0δ. 100% forced movement towards the electrified gill net (central panel containing positive electrode) within 2 - 30 seconds was observed. None of the fish escaped out of the net during the trials (Table 4).

Among individual fish species, the anodic attraction and subsequent enmeshing and entangling were highest in the case of *L. rohita* (between 44 - 67%) followed by *C. mrigala* (between 12 - 31%), *L. bata* (between 6 - 25%), *C. batrachus* (between 8 - 12%) and *O. niloticus* (3%) (Table 5).

Species	Total length range (mm)	No. of fish	Potential difference between electrodes (V)	Range of current density (δ)	% of total fish exhibited	
					Forced movement towards electrified net and caught	Escaped out of the net
L. rohita	195 - 235	5	130 - 135	0.2 - 3.8	100 (10 secs)	-
C. mrigala	205 - 220	5	130	2.2 - 3.2	100 (10 secs)	-
L. bata	160 - 175	6	120 - 130	1.25 - 1.5	100 (2 - 3 secs)	-
O. niloticus	110 - 140	4	128 - 130	4.5 - 5.0	100 (15 - 30 secs)	-
L. rohita	185 - 215	4	80 - 85	0.45 - 1.2	100 (3 secs)	-
C. mrigala	195 - 215	5	80	0.5 - 1.25	100 (2 - 3 secs)	-
L. bata	160 - 195	5	80 - 82	0.75	100 (2 secs)	-

Table 4: *Response of different fish to electrified gill net.*

Electrode: Aluminium conduit.

Water temperature: 28 - 29°C.

Nature of current: Direct current.

Water resistance of water: 5200 - 5700 ohm/cm^2.

Field strength		% of fish attracted to anode and gilled or entangled					% of total population gilled/ entangled
Applied voltage between electrode (V)	Current density (δ)	*Labeo rohita*	*Cirrhinus mrigala*	*Labeo bata*	*Clarias batrachus*	*Oreochromis niloticus*	
65	0.45	44	31	25	-	-	80
85	1.25	59	19	10	9	3	74
90	0.9	55	20	25	-	-	95
95	1.1	51	28	21	-	-	93
100	1.6	67	12	10	8	3	83
110	1.5	50	25	25	-	-	95
116	1.7	58	21	21	-	-	93
120	1.8	61	18	6	12	3	71
145	2.5	50	30	20	-	-	93

Table 5: *Percentage of fish species gilled or entangled in electrified gill net.*

Electrode: Aluminium conduit.

Water temperature: 28 - 30°C.

Nature of current: Direct current.

Water resistance of water: 5500 - 5700 ohm/cm^2.

Discussion

The orientation of fish before the electric stimulation plays an important role to initiate reactions at the time of electrical exposure. Fishes when parallel with the lines of current conduction perceived current at low voltage gradient and exhibited the involuntary forced swimming and narcosis when the threshold values of these reactions are reached. In the present study, irrespective of the nature of the current applied for stimulation, both the species exhibited 100% anodic taxis and narcosis when they were parallel to the lines of current conduction. The minimum response for the above reactions was observed when they were parallel to the equipotential lines and the fishes were observed to maneuver for orienting parallel to equipotential lines if the threshold values for taxis and narcosis have not reached quickly. This is because, the fish received a higher potential difference when parallel to lines of current conduction.

The resistance of individual fish to conduct electricity through their body varies greatly among species. The resistance of a fish acts to reduce the voltage gradient, it encounters between head and tail and it is the change in the gradients that are needed to many fish react at different current intensities [3].

The forced movement to the positive electrode was best observed in *L. rohita* and *C. batrachus* in PDC 3/sec (100%). In the other two frequencies (1/sec and 5/sec) 20 to 25% *L. rohita* exhibited forced swimming between the two electrodes. In PDC 5/sec, 60% *C. batrachus* showed movement between electrodes. Halsband [4] while discussing the basic principles of electric fishing expressed similar findings that have been successfully utilized for catching fish with electricity for fish population studies in the stream.

In the heterogeneous field created by the electrodes of three panel gill nets, the voltage gradient exhibited a gradual slope as the tangential and vertical distances from the negative electrode increased. With regard to current density, it increased progressively with the increase of input voltage. The highest current density at a given input voltage was recorded at the furthest point from the negative electrode and nearest to the positive electrode.

In Hirakud Reservior (Odisha, India), with the fishing experiments of several types of gill nets (simple gill net, vertical line and framed net) the catch per square meter was 0.071 - 0.084g, 0.09 - 0.103g and 0.127 - 0.128g respectively [9]. The period of operation (hours of putting a net into the water) of those gill nets were, however, not mentioned in their communication. If the operation period is taken as one hour, then the catch per unit effort will be negligible.

In the present study, the conventional simple gill net failed to catch a single fish in the limited space (experimental tank) within an hour.

The enmeshing and entangling of fish, irrespective of species was due to the frightening effect of fish in the effective zone nearby the negative electrodes and attracting effect of the positive electrode of the gill net panels. Fishes in the vicinity of negative electrodes get startled with the exposure of electric shock and moved forcefully either to the positive electrode or tried to escape out of the electric field and get enmeshed and entangled in the panels where negative electrodes were attached. Those who moved violently to the positive electrode either to get rid of the irritating effect of negative electrodes or attracted towards the positive electrode were also gilled and entangled in the central panel containing the anode. The current density was found to play an important role in such fright reflex and the attraction effects of fish. The effective period (exposure time) was limited to 10 - 36 seconds. This gave an additional benefit of reducing the period of operation of electric gill net over the conventional one.

The highest sensitivity towards the influence of electric field was noticed in *L. rohita* (44 - 67%) followed by *C. mrigala* (12 - 31%), L. bata (6 - 25%), *C. batrachus* (8 - 12%) and *O. niloticus* (3%) with the overall influence of electric field between 71 - 95%. This difference in specific reactions has been observed by other investigators [5-7].

Unfortunately, no publications have been brought to our knowledge about studying the working of an electrified gill net on any fish species in India or elsewhere, so that the comparative effectiveness of this prototype electric gill net could be evaluated. However, the results obtained from the present study, the possibility of its application in the field for catching fish in the gill net with electrical intervention cannot be ruled out and trials in a bigger way with the larger net can be attempted.

Conclusion

Electrical stimulation through an electrified gill net do have a beneficial effect in increasing the catch per unit effort (CPUE) than the passive and time consuming conventional gill net. By applying 80 - 130 Volt DC or PDC 3/sec, 40 - 83% of freshwater fishes could be caught within 10 - 36 seconds. No conflict of interest with conventional gill netter is appeared since the area of operation of electrified gill net will be localized.

Bottom dwelling and off-bottom fishes were found to be attracted, more in number, to the electrified gill net and caught by either enmeshing or entangling. The technique will be very effective in rough bottom water areas with dense vegetation, where catching of fish by dragging gear is not possible due to underwater obstructions. Either DC or PDC 3/sec will be very effective to power the electrified gill net, preferably PDC 3/sec, in view of low energy consumption.

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