ON THE REACTION OF MARINE FISHES IN INTERRUPTED A. C. OF 50 Hz*

K. P. BISWAS
Directorate of Fisheries Dry dock, Cuttack-7, Orissa

The reactions of marine fishes in interrupted A. C. of uniform electrical field and constant current density have been studied in order to determine the optimum effective periods of shock for narcosis and fixation. Higher effective periods were required with gradual decrease in potential difference between head and tail, which in turn depended on the length of fish and its position in electrical field. The body voltage of fish varied directly with the length and inversely with the rise of angle between their body axis and field lines. The fish subjected to higher effective period took longer time for recovery from narcosis. The effect of impulse current was manifested by increased rate of gill movements in *Platax teira, Haetodon ollaris, Crysophus burda, Siganus vermiculatus and Scolopsis leucotaenia,* and lowered rate of movements in others when subjected to different effective periods irrespective of length.

INTRODUCTION

The possibility of using electricity in conjunction with conventional gear in marine fishing has been explored in the past many years. The idea was to attract and stun the fish so that they would tumble helplessly into the trawl net. It would also enable an otherwise unfishable, uneven, bottom to be exploited because the fish living near the ground were attracted towards the electrode (Goffstown, 1958).

Kreutzer and Peglow (1949) claimed that a deep sea electrical trawl, using short sharp electrical impulses up to 2000 volts on oppositely charged electrodes placed at the side of the net's mouth, was able to get 90% of the fish passing between the ship and the net, which would otherwise be frightened by the approach of ordinary net and evade it. In uniform electric field of alternating current of 50 Hz, slight specific differences were observed

* Published with the kind consent of Director of Fisheries, Orissa.

in the voltage gradients to induce a minimum response and electronarcosis in marine fishes (Bary, 1956). Cattley (1955) recommended the use of pulsed A. C. or D. C. for reducing the magnitude of power requirement for fishing in sea, as use of continuous A. C. or D. C. would have been impracticable due to the difficulty in carrying generating equipment aboard the vessel to produce enough power.

The present studies were limited to the reactions of marine fishes in an electrical field of alternating current of 50 Hz in relation to fish length, repeated shocking and fatigue and position of fish body in the electrical field. The effective periods along with pulse threshold for inducing electrotaxis, narcosis and recovery were also studied.

Materials and Methods

The experimental tank consisted of a glass aquarium of 200 cm x 50 cm x 70cm fitted in a wooden frame on a wooden table. Zinc plates of 50 cm x 25 cm were fixed vertically along the breadthwise sides of the tank, which served as electrodes. The aquarium was then filled with sea water to a depth of 10 cm. The electrodes were connected the to the A. C. mains of 220 V 50 Hz through a voltmeter and amperemeter to measure the potential drops between the electrodes and the quantity of current drained. A thermometer, suspended from a clamp attached to the experimental tank recorded the temperature of water during the experiment.

Interrupted A. C. of 220 V was produced through a mechanical impulse transmitter of fixed impulse frequencies of 38/ minute with impulse and pause durations of 0.8 second. The resistance of water was measured by an ohmmeter with silver electrodes and was expressed as ohms per cc.

The test fish after being acclimatised for 24 hours in confined waters in the laboratory and measured for total length and breadth (maximum girth) was released in experimental aquarium to settle. The position of body axis of the fish in relation to field lines was recorded before beginning of the experiment. The fish was then subjected to interrupted A. C. of 220 V which formed a homogeneous electrical field throughout the water column in the aquarium. Sixty amperes of current were drained with impulse potential of 130–140 V between the electrodes during closing of circuit. The density of current in the experimental bath was calculated and expressed as ma/ mm^2 and was kept constant for every set of experiment.

The reaction of fishes in relation to exposure to current for different periods and the requirement of effcective period in relation to size, area of body surface and position of fish body in electrical field were studied in different varieties of fish. The effect of repeated stimulation on the fish in relation to fatigue and recovery was also determined. Except in case of experiments for repeated shocking, a fresh fish was taken for each experiment. The area of body surface was measured by a polar planimeter after the test. The potential drop between the head and tail of the fish was also recorded during electronarcosis and fixation.

Results and Discussion

In a homogeneous field having a density of current of 1.2 ma/mm^2 with fixed impulse frequency of 38/ minute, the fish exhibited reactions like stretching of fins and opercula and tremour of the body accompanied by occasional change of place, depending on the minimum period for which the current passed through the body of fish. This minimum

flow of current through the organism, defined as 'effective period' increased with the administration of increased number of pulses. With the rise of effective period to its threshold value the fish underwent electrotaxis accompanied either by specific movement to the electrode or at random in the field. In some cases the fish did not show any movement in the electric field during electrotaxis but changed its position to right angle to the direction of current flow and bent its body like an arch in the same place to tap off the minimum voltage. Electronarcosis and fixation occurred with more impulses for threshold value of effective periods when the fish was stunned ceasing all voluntary movements and lay on its side at the bottom or floated on the surface.

In a fixed current density of 1.2 ma/mm^2 the effective periods for electronarcosis and fixation of seventeen varieties of marine fishes ranged from 2 to 6.8 seconds, irrespective of their positions in the electrical field (table – 1).

The specific movements of fishes in these experiments have been classified into four groups during electrotaxis and three during electronarcosis. Meyer-waarden (1955) also reported that the fish did not swim towards the electrodes in an A. C. field but took a transverse position to the electrical field between the electrodes. Fishes of sixteen varieties out of seventeen tried were found to move towards increasing potential during electrotaxis and narcosis, the % of which varied from species to species. Oscillotactic behavior has also been noticed in fourteen varieties and 12 to 58% of fishes placed their body axis perpendicular to the electrical lines of force to tap off the minimum voltage. Only eight species exhibited movement towards the counter pole during electrotaxis which varied between 8 and 50%. Fishes like *Apiniphelus diacanthus, Plutosus arab, Scolopsis leucotaenia, Apogon faciatus, Therapon jerbua* and *Dasyatis gerrardii showed* no movement during electrotaxis and stayed in their initial positions till the narcosis set in with increase of effective periods.

In a constant field intensity of 1.2 ma/mm^2 of interrupted A. C. of sinus wave from *Crysophus burda* of 420 mm required an effective period of 1.6 to 4.8 secs for narcosis and fixation as against 3.2 to 6.4 seconds in case of *Muraena undulata, Epinephelus pantherinus* and *Dasyatis gerrardii.* The optimum effective period for narcosis of *Crysophus burda* of 550 mm was also lowest (1.6 sec) among the other three species when they were stunned in 2.4 seconds (table 2). Slight dffferences in voltage gradient of A. C. required to induce minimum response and electronarcosis have been observed between *Morone labrax, Platichthys flesus* and *Mugil auratus* (Bary, 1956). *Megalops cypernoides* of 360 mm were narcotised in between 1.6 and 2.4 seconds, while *Lates calcarifer* and *Dasyatis gerrardii* were stunned later successively in 3.2 to 4 seconds and 4.8 to 6.4 seconds respectively. Electronarcosis and fixation were induced in *Tetradon* sp of 100 mm length in 5.6 to 8 seconds, while *Haetodon ollaris, Platax teira, Therapon jarbua, Scolopsis leucotaenia* and *Apogon faciatus* of similar size exhibited hypnosis in 3.2 to 4.8, 2.4 to 4, 1.6 to 5.6, 1.6 to 4.8 and 1.6 to 4 secondsrespectively. *Apogon faciatus* of 95mm was stunned earlier in 1.6 seconds, while *Scolopsis leucotaenia* and *Tetradon sp* of same size were narcotised subsequently in 2.4 and 6.4 seconds respectively.

The potential difference between head and tail and the effective periods for inducing electronarcosis in common marine fishes in an interrupted A. C. of fixed impulse frequency and constant density

Table 1 Specific reactions of fishes during electrotaxis and fixation.

Impulse frequency per minute : 38
Impulse duration in sec : 0.8
Density of cnrrent in ma/mm² : 1.2

Name of species	Size group : mm	No of fishes tested	Water temperature : °C	Resistance of water : ohms/cc	Impulse voltage : v	Minimum impulse range for electrotaxis & fixation	Mean effective period for electrotaxis & fixation : sec.	% of specific movement during electrotaxis				Place of narocosis and fixation in %		
								Towards + ve electrode	Towards — ve electrode	Transversal movement in middle	No movement	Near + ve electrode	Near — ve electrode	Near middle
Apiniphelus diacanthus	180-142	16	24	350	140	2-5	3.2	12.5	12.5	12.5	62.5	—	37.5	62.5
Plutosus arab	330-215	10	25	550	130	2-4	3.4	40	—	40	20	50	—	50
Chiloscyllium indicum	450-400	22	26	800	,,	4-7	4.9	73	—	27	—	64	18	18
Muraena undulata	500-415	12	27	300	,,	3-8	5.0	50	8	42	—	8	16	76
Scolopsis leucotaenia	100-95	,,	,,	,,	,,	2-6	3.9	34	34	16	16	36	48	16
Tetradon sp.	300-100	10	,,	,,	,,	6-7	6.8	60	—	40	—	40	20	40
Apogon faciatus	100-95	,,	,,	,,	,,	2-4	2.4	—	—	50	50	0	50	50
Platax teira	160-100	12	,,	,,	,,	,,	,,	50	—	,,	—	50	—	,,
Siganus vermiculatus	260	,,	,,	,,	,,	2-7	3.5	67	—	33	—	67	—	33
Crysophus burda	420-410	10	,,	,,	,,	3-5	3.2	50	50	—	—	50	50	—
Lates calcarifer	370-360	,,	,,	,,	,,	3-4	2.8	,,	—	50	—	,,	—	50
Megalops cypernoides	350-337	12	,,	,,	,,	2	2.0	75	—	25	—	75	—	25
Haetodon ollaris	100-33	,,	,,	,,	,,	4-8	4.8	28	14	58	—	14	14	72
Heniochus macrolepidotus	60	10	,,	,,	,,	6-9	8.0	50	50	—	—	50	50	—
Epinephelus pantherinus	570-550	12	,,	,,	,,	3-4	2.9	67	33	—	—	67	33	—
Therapon jerbua	128-100	18	,,	,,	,,	2-6	2.7	25	—	12	63	42	58	—
Dasyatis gerrardii	420-385	20	,,	,,	,,	4-8	4.8	20	10	20	50	20	40	40

Table 2 Requirement of effective periods for narcosis and fixation of fishes of different varieties.

Resistance of water in ohms per cc : 300
Inpulse frequency per minute : 38
Impulse duration in sec : 0.8
Density of current in ma/mm² : 1.2

Tempreature of water: 27°C

Length of fish mm.	Position of fish body axis to electrical field	Potential drop between head and tail : v	Effective periods required for narcosis & fixation											
			Muraena undulata	*Scolopsis bucotaenia*	*Tetradon* sp.	*Apogon faciatus*	*Platax teira*	*Crysophus burda*	*Lates calcarifer*	*Megalops cypernoides*	*Hoctodon ollaris*	*Epinephelus pantherinus*	*Therapon jarbua*	*Dasyatis gerrardii*
550	Parallel	33	2.4					1.6				2.4		2.4
420	,,	25	3.2					2.4				3.2		3.2
,,	45°angle	19	4.8					3.2				4.8		4.8
,,	Perpendicular	11	6.4					4.8				6.4		6.4
410	Parallel	25	4.8					2.4						4.8
,,	45° angle	18	—					4.0						,,
360	Parallel	22	—						3.2	1.6				,,
,,	45° angle	16	—						4.0	2.4				6.4
100	Parallel	6	—	1.6	5.6	1.6	2.4				3.2		1.6	
,,	45° angle	45	—	3.2	7.2	3.2	3.2				4.0		3.2	
,,	Perpendicular	2.3	—	4.8	8.0	4.0	4.0				4.8		5.6	
95	Parallel	5.7	—	2.4	6 4	1.6								

Table 3 Requirement of impulse threshold and effective periods for electrotaxis & fixation of different varieties of fish.

Impulse frequency per minute : 38
Impulse duration in sec : 0.8
Density of current in ma/mm² : 1.2

Name of species.	Length of fish: mm	Breadth of fish: mm	Water temperature: ° C	Resistance of water: ohms/cc	Poeition of fish body axis to electrical field.	Potential drop between head & tail: V	Impulse threshold required for electro narosis & fixation.	Effective period required for narcosis & fixation:secs.
1	2	3	4	5	6	7	8	9
Apiniphelus diacanthus	180		24	350	Parallel	12.6	3	2.4
-do-	175		,,	,,	,,	12.3	,,	,,
-do-	150		,,	,,	,,	10.5	,,	,,
-do-	,,		,,	,,	45°angle	7.90	5	4.0
-do-	148		,,	,,	Parallel	10.3	3	2.4
-do-	142		,,	,,	,,	10.0	,,	,,
Plutosus arab	312	28	25	550	,,	18.7	2	1.6
-do-	215	25	,,	,,	,,	12.9	4	3.2
Chiloscyllium indicum	450	65	26	800	,,	27.0	,,	,,
-do-	448	65	,,	,,	,,	26.9	,,	,,
-do-	440	62	,,	,,	,,	26.4	5	4.0
-do-	420	55	,,	,,	,,	25.2	6	4.8
-do-	415	52	,,	,,	,,	24.9	7	5.6
-do-	400	45	,,	,,	,,	23.7	,,	,,
Muraena undulata	500	50	27	300	,,	30.0	3	2.4
-do-	423	35	,,	,,	,,	25.4	4	3.2
-do-	423	,,	,,	,,	45°angle	18.9	6	4.8
-do-	423	,,	,,	,,	Perpendicular	2.1	,,	6.4
-do-	415	40	,,	,,	Parallel	24.9	6	4.8
-do-	415	,,	,,	,,	Perpendicular.	2.4	7	5.6
Scolopsis leucotaenia	100	37	,,	,,	Parallel	6.0	2	1.6
-do-	,,	,,	,,	,,	45°angle	4.5	4	3.2
-do-	,,	,,	,,	,,	Perpendicular	2.3	6	4.8
-do-	95	30	,,	,,	Parallel	5.7	3	2.4

(Contd.....)

1	2	3	4	5	6	7	8	9
Tetradon sp.	300	80	27	300	Parallel	18.0	6	4.8
-do-	,,	,,	,,	,,	45°angle	13.5	9	7.2
-do-	100	30	,,	,,	Parallel	6.0	7	5.6
-do-	95	28	,,	,,	,,	5.7	8	6.4
Apogon faciatus	100	30	,,	,,	,,	6.0	2	1.6
-do-	,,	,,	,,	,,	Perpendicular	1.8	5	4.0
-do-	95	25	,,	,,	Parallel	5.7	2	1.6
Platax teira	160	130	,,	,,	Parallel	9.6	2	,,
-do-	100	100	,,	,,	,,	6.0	3	2.4
Siganus vermiculatus	260	93	,,	,,	,,	21.6	2	1.6
-do-	,,	,,	,,	,,	45° angle	11.7	4	3.2
-do-	,,	,,	,,	,,	Perpendicular	5.6	7	5.6
Crysophus burda	420	100	,,	,,	Parallel	25.2	3	2.4
-do-	410	90	,,	,,	,,	24.6	3	,,
-do-	,,	,,	,,	,,	45° angle	18.4	5	4.0
Lates calcarifer	370	100	,,	,,	Parallel	22.2	3	2.4
-do-	360	98	,,	,,	,,	21.6	4	3.2
-do-	,,	,,	,,	,,	45° angle	16.2	5	4.0
Megalops cypernoides	350	125	,,	,,	Parallel	21.0	2	1.6
-do-	337	120	,,	,,	,,	20.2	2	,,
-do-	335	118	,,	,,	45° angle	14.8	3	2.4
Haetodon ollaris	100	67	,,	,,	Parallel	6.0	4	3.2
-do-	100	67	,,	,,	Perpendicular	3.9	6	4.8
-do-	33	20	,,	,,	Parallel	2.0	5	4.0
-do-	,,	,,	,,	,,	Perpendicular	1.2	8	6.4
Heniochus macrolepidotus	60	40	,,	,,	Parallel	3.6	6	4.8
-do-	,,	,,	,,	,,	Perpendicular	2.4	8	6.4
Epinephelus pantherinus	570	140	,,	,,	Parallel	34.2	3	2.4
-do-	,,	,,	,,	,,	45° angle	25.7	4	3.2
-do-	550	135	,,	,,	Perpendicular	8.1	8	6.4
Therapon jarbua	128	45	,,	,,	Parallel	7.7	2	1.6
-do-	,,	,,	,,	,,	Perpendicular	2.7	6	4.8
-do-	120	40	,,	,,	Parallel	7.2	2	1.6

(Contd.....)

1	2	3	4	5	6	7	8	9
Therapon jarbua	120	40	27	300	45° angle	5.4	4	3.2
-do-	,,	,,	,,	,,	Perpendicular	2.4	6	4.8
-do-	105	30	,,	,,	Parallel	6.3	2	1.6
-do-	100	25	,,	,,	,,	6.0	2	1.6
-do-	,,	,,	,,	,,	45° angle	4.5	4	3.2
-do-	,,	,,	,,	,,	Perpendicular	1.5	7	5.6
Dasyatis gerrardii	420	185	,,	,,	Parallel	25.2	4	3.2
-do-	,,	,,	,,	,,	45° angle	19.0	6	4.8
-do-	,,	,,	,,	,,	Perpendicular	11.1	8	6.4
-do-	410	180	,,	,,	Parallel	24.6	4	3.2
-do-	,,	,,	,,	,,	45° angle	18.4	6	4.8
-do-	385	165	,,	,,	Parallel	23.1	6	,,
-do-	,,	,,	,,	,,	45° angle	17.1	8	6.4

(Concld.)

Table 4 Effect of interrupted A. C. of 50 Hz on *Apinephelus diacanthus*

Implulse voltage : 140
Impulse frequency per minute : 38
Impulse duration in secs : 0.8
Density of current in ma/mm^2 : 1.2

Resistance of water in ohms per cc: 350
Water temperature: 24° C

Length of fish. mm	Position of fish body axis in electrical field.	Potential drop between head and tail: V	Effective period of electrical stimulation in secs.	Behaviour of fish during electrical stimulation	Place of fixation of fish in electrical field.	Time required for recovery in secs	Behaviour of fish after recovery.
1	2	3	4	5	6	7	8
180	Parallel	12.6	0.8	Expanded fins and mouth & lay perpendicular to field line.	No narcosis	—	—
,,	,,	,,	1.6	Expanded fins & mouth & turned to-ve electrode.	,,	—	—
,,	,,	,,	2.4	Narcotised in the same place with expanded gills & mouth and lay on side.	Near middle	9.5	No movement

(Contd .....)

1	2	3	4	5	6	7	8
,,	45° angle	9.6	4.0	Moved round the-ve electrode and narcotised with expanded fins & gills.	Near -ve electrode	339	Died after 38 minutes
175	Parallel	12.3	0.8	Expanded fins, moved to -ve electrode & stayed perpendicular to field lines	No narcosis	—	—
,,	,,	,,	1.6	Expanded fins & mouth & moved round in the same position	,,	—	—
,,	,,	,,	2.4	Narcotised with expanded fins & gills in middle perpendicular to field lines	Near middle	8	Regains original pigmentation
,,	45° angle	9.1	4.0	-do-	-do-	8	-do-
150	Parallel	10.5	0.8	Expanded fins and mouth during each pulse and move to + ve electrode when disconnected	No narcosis	—	—
,,	,,	,,	1.6	Expanded fins and mouth during each pulse and moved to + ve electrode when disconnected	No narcosis	—	—
,,	,,	,,	2.4	Moved to middle with expended fins and mouth & narcotised	Near middle	7.5	No movement
,,	45° angle	7.9	4.0	Moved voilently with expanded fins and mouth between electrodes & narcotised near —ve electrode.	Near -ve electrode	5 5	—
148	Parallel	10.3	0.8	Expanded fins & moved to middle.	No narcosis	—	—
,,	,,	,,	1.6	Expanded fins & mouth and moved to —ve electrode.	,,	—	—
,,	,,	,,	2.4	Moved with expanded fins and month to —ve electrode & narcotised.	Near —ve electrode.	7	No movement
142	Parallel	10	0.8	Expanded gills & mouth & stayed near + ve electrode.	No narcosis.	—	—
,,	,,	,,	1.6	Expended fins & mouth and stayed in the middle bending the body.	,,	—	—
,,	,,	,,	2.4	Narcotised with expanded fins & mouth and lay on side.	Near middle	7	No movement

(Concld.....)

Table 5 Effect of interrupted A. C. of 50 Hz on *Plutosus arab*

Resistance of water in ohms per cc: 550
Water temperature: 25°C

Impulse voltage: 130
Impulse frequency per minute: 38
Impulse duration in secs: 0.8
Density of current in ma/mm²: 1.2
Position of fish body axis to electrical field: Parallel

Length of fish mm.	Breadth of fish mm.	Area of body surface: sq. mm.	Potential drop between head & tail: V	Effective period of electrical stimulation in secs.	Behaviour of fish during electrical stimulation	Place of fixation of fish in electrical field.	Time required for recovery in secs
1	2	3	4	5	6	7	8
330	37	6270	19.8	0.8	Stays near middle during the impulse & move to —ve violently with jerk after stimulation.	No narcosis.	—
,,	,,	,,	,,	1.6	Moved to middle and narcotised lying on its side during impulse.	Near middle.	2.5
,,	,,	,,	,,	2.4	Moved a little forward, stunned with expanded fins & settled at bottom.	,,	26
,,	,,	,,	,,	4.0	Moved to middle, stunned with expended fins lay on side.	,,	88
,,	,,	,,	,,	5.6	Stunned near + ve electrode with expended fins and bending of body.	Near+ ve electrode.	126
312	28	5928	18.7	0.8	Sudden jerk with bending of body during each pulse and moved to + ve electrode.	No narcosis.	—
,,	,,	,,	,,	1.6	Moved to middle with jerk and narcotised with belly up.	Near middle.	5
,,	,,	,,	,,	2.4	Moved from —ve to middle and then to —ve electrode and narcotised.	,,	10
,,	,,	,,	,,	3.2	Bent the body with impulse & moved to + ve electrode and narcotised with expanded fins.	Near+ ve electrode.	18

(Contd .....)

1	2	3	4	5	6	7	8
215	25	4095	12.9	0.8	Bending of body with tremour during each pulse. Moved to + ve electrode after each pulse.	No narcosis	—
,,	,,	,,	,,	1.6	- do -	,,	—
,,	,,	,,	,,	3.2	Moved slowly to middle with bending of body, narcotised with expanded fins and lay on side.	Near+ ve electrode.	9
,,	,,	,,	,,	4.0	Moved slowly to +ve electrode with bending of body and narcotised with expanded fins.	,,	13
,,	,,	,,	,,	6.4	- do -	,,	18

Movement of fish after recovery: Nil.

(Concld.....)

Table 6 Effect of interrupted A. C. of 50 Hz on *Chiloscyllium indicum*

Impulse voltage: 130
Impulse frequency per minute: 38
Impulse duration in secs: 0.8
Density of current in ma/mm^2: 1.2
Position of fish body axis to electrical field: Parallel.

Resistance of water in ohms per cc: 800
Water temperature: 26°C

Length of fish: mm.	Breadth of fish: mm.	Area of body surface of fish: sq mm.	Potential drop between head and tail: V	Effective period of electrical stimulation. : secs.	Behaviour of fish during electrical stimulation	Place of fixation of fish in electrical field.	Time required for recovery in secs.	Movement of fish after recovery.
1	2	3	4	5	6	7	8	9
450	65	13950	27	0.8	Sudden jerk with impulse and moved to + ve electrode quickly.	No narcosis.	—	—
,,	,,	,,	,,	3.2	Moved to + ve electrode with jerk during each pulse.	Near + ve electrode.	23	Moved between electrodes.
,,	,,	,,	,,	4.0	Moved from + ve electrode to middle of the field with jerk during each pulse.	Near middle,	36	,,

(Contd .....)

1	2	3	4	5	6	7	8	9
448	65	13888	,,	0.8	Sudden jerk with impulse and moved to —ve electrode slowly.	No narcosis.	—	—
,,	,,	,,	,,	3.2	Moved from middle of the field to +ve electrode with jerk during each pulse.	Near +ve electrode.	91	No movement.
440	62	13800	26	0.8	Sudden jerk with impulse, turned back and moved to —ve electrode.	No narcosis.	—	—
,,	,,	,,	,,	3.2	Moved from middle to + ve electrode with jerk during each pulse.	,,	—	—
,,	,,	,,	,,	4.0	- do -	Near+ ve electrode.	47	No movement
,,	,,	,,	,,	5.6	Move from —ve electrode to + ve electrode with jerk during each pulse.	Near-+ ve electrode.	59	No movement.
420	55	13180	25	0.8	Moved between electrodes with sudden jerk during each pulse.	No narcosis.	—	—
,,	,,	,,	,,	1.6	Moved to —ve electrode with sudden jerk during each pulse.	,,	—	—
,,	,,	,,	,,	4.0	Moved from + ve electrode to the —ve electroqe with jerk during each pulse.	,,	—	—
,,	,,	,,	,,	4.8	Moved between the electrodes with jerk during each pulse.	Near—ve electrode.	38	No movement.
,,	,,	,,	,,	5.6	Moved from —ve electrode to + ve electrode with jerk during each pulse.	Near +ve electrode.	55	,,
415	52	13025	,,	0.8	Sudden jerk with the pulse and moved slowly to + ve electrode.	No narcosis.	—	—
,,	,,	,,	,,	4.0	Sudden jerk with each pulse and moved slowly to—ve elctrode.	,,	—	—
,,	,,	,,	,,	5.6	Moved from—ve electrode to + ve electrode with jerk during each pulse.	Near+ ve electrode.	32	No movement.
,,	,,	,,	,,	6.4	Moved from middle to + ve electrode with jerk during each pulse.	,,	54	,,
,,	,,	,,	,,	7.2	Moved between electrodes with jerk during each pulse & ultimately stayed near —ve electrode.	Near—ve electrode.	75	,,
400	45	12808	24	4.8	Moved between electrodes with jerk during each pulse with body bending.	No narcosis.	—	—
,,	,,	,,	,,	5.6	Moved to middle with bending of body like arch during each pulse.	Near middle	11	No movement.

(Concld.....)

Table 7 Effect of interrupted A. C. of 50 Hz on fishes of different varieties

Resistance of water in ohms per cc: 300
Water temperature: 27°C

Impulse voltage: 130
Impulse frequency per minute: 38
Impulse duration in secs: 0.8
Density of current in ma/mm²: 1.2
Movement of fish after recovery: Nil.

Length of fish: mm.	Breadth of fish: mm.	Area of body surface of fish: sq mm.	Position of fish body axis to electrical field.	Potential drop between head and tail: V	Effective period of electrical stimulation in secs	Behaviour of fish during electrical stimulation	Place of fixation of fish in electrical field.	Time required for recovery in secs.
1	2	3	4	5	6	7	8	9
Muraena undulata:								
500	50	12200	Parallel	30	0.8	Moved violently to + ve and —ve electrodes.	No narcosis.	—
,,	,,	,,	,,	,,	2.4	Moved violently to + ve electrode, then to middle & narcotised.	Near middle.	1.2
,,	,,	,,	,,	,,	4.0	Moved to middle and narcotised bending body & lay on side.	Near middle.	2
,,	,,	,,	,,	,,	5.6	Moved to middle and then to —ve and lay on side & narcotised.	Near —ve electrode.	2.8
,,	,,	,,	,,	,,	7.2	Moved from middle to + ve electrode and narcotised with body bending like arch.	Near middle.	3.8
423	35	9306	,,	25	2.4	Moved to + ve electrode violently and stayed near it.	No narcosis.	—
,,	,,	,,	,,	,,	3.2	Moved to middle, narcotised & lay on side.	Near middle	4.6
,,	,,	,,	,,	,,	4.8	Moved towards + ve electrode, narcotised near middle and lay on side.	,,	13

(Contd.....)

1	2	3	4	5	6	7	8	9
,,	,,	,,	45° angle	19	4.8	Moved to middle, narcotised & lay on side.	Near middle.	3
,,	,,	,,	Perpendicular.	2	6.4	Moved to + ve electrode, narcotised & lay on side.	Near+ ve electrode.	2.9
415	40	9130	Parallel	25	3.2	Jumped out of water voilently & moved to +ve electrode.	No narcosis.	—
,,	,,	,,	,,	,,	4.8	Moved violently to + ve and then to —ve electrode & ultimately narcotised.	Near middle.	2.1
,,	,,	,,	,,	,,	5.6	- do -	,,	3
,,	,,	,,	Perpendicular.	2.4	,,	Moved towards middle, narcotised and lay on side.	,,	1.8
,,	,,	,,	,,	,,	16	Moved towards —ve electrode & narcotised bending body.	Near—ve electrode.	91
,,	,,	,,	,,	,,	6.4	- do -	,,	1.8
Scolopsis leucotaenia								
100	37	2500	Parallel	6	0.8	Moved to middle with small jerk and expansion of fins.	No narcosis.	—
,,	,,	,,	,,	,,	1.6	Moved to —ve electrode with expanded fins, narcotised and floated on surface with belly up.	Near—ve electrode.	3.5
,,	,,	,,	,,	,,	2.4	Moved to middle with expanded fins, narcotised & lay on side.	Near middle.	3.2
,,	,,	,,	,,	,,	3.2	Moved with expanded fins towards the bottom and narcotised.	Near+ ve electrode.	5
,,	,,	,,	,,	,,	5.6	Moved to + ve electrode with expanded fins, narcotised and lay on side.	Near+ ve electrode.	5.2
,,	,,	,,	45° angle	4.5	0.8	Moved a little with jerk and expanded fins and stayed.	No narcosis.	—

(Contd.....)

1	2	3	4	5	6	7	8	9
,,	,,	,,	,,	,,	1.6	Expansion of fins and stayed towards bottom.	,,	—
,,	,,	,,	,,	,,	2.4	- do -	,,	—
,,	,,	,,	,,	,,	3.2	Moved to —ve electrode with expanded fins and narcotised.	Near—ve electrode.	4
,,	,,	,,	Perpendicular.	2.3	4.0	Moved a little with expanded fins with jerk.	No narcosis.	—
,,	,,	,,	,,	,,	4.8	Narcotised with expanded fins and lay on side.	Near—ve electrode.	1.5
Tetradon sp:								
300	80	21200	Parallel	18	4.0	Moved to middle with expanded fins and jerk during each impulse.	No narcosis	—
,,	,,	,,	,,	,,	4.8	Moved violently to + ve electrode with expanded fins and narcotised.	Near+ ve electrode.	3.5
,,	,,	,,	,,	,,	7.2	Moved to middle and narcotised with stretching of fins and bending of body.	Near middle.	61
,,	,,	,,	,,	,,	12.8	Moved to surface, narcotised and floated with swelled abdomon.	Near—ve electrode.	86.5
100	30	7100	,,	6	4.8	Moved from surface to bottom & then to middle.	No narcosis.	—
,,	,,	,,	,,	,,	5.6	Moved to + ve electrode, narcotised & lay on side.	Near + ve electrode.	34
,,	,,	,,	,,	,,	9.6	Moved to middle and narcotised in a position perpendicular to field lines.	Near middle.	86
Apogon faciatus:								
,,	,,	2200	,,	,,	0.8	Moved to surface near —ve electrode with expended fins.	No narcosis.	—
,,	,,	,,	,,	,,	1.6	- do - & narcotised	Near—ve electrode.	1.2
,,	,,	,,	,,	,,	3.2	Narcotised in the same position with expanded fins & lay on side.	Near middle	3.5

(Contd.....)

1	2	3	4	5	6	7	8	9
Platax teira:								
160	130	16700	Parallel	9.6	0.8	Expansion of fins & moved to middle with jerk.	No narcosis.	—
,,	,,	,,	,,	,,	1.6	Moved to + ve electrode, narcotised & lay on side with expanded fins.	Near+e electrode.	5
,,	,,	,,	,,	,,	2.4	- do -	,,	5.8
100	100	11100	,,	6	1.6	Moved from +ve electrode to —ve with each pulse.	No narcosis.	—
,,	,,	,,	,,	,,	2.4	Moved to middle, narcotised & lay on side.	Near middle	6
,,	,,	,,	,,	,,	3.2	- do -	,,	6
Siganus vermiculatus:								
260	93	15400	,,	21.6	0.8	Expansion of fins & moved violently to + ve electrode.	No narcosis.	—
,,	,,	,,	,,	,,	1.6	Jumped to + ve electrode with expanded fins & narcotised.	Near+ ve electrode.	2.5
,,	,,	,,	,,	,,	3.2	Moved violently from —ve electrode to + ve & narcotised.	,,	6.5
,,	,,	,,	Perpendicular	5.6	5.6	Moved to middle with expanded fins & narcotised.	Near middle	8.2
Crysophus burda.								
420	100	19460	Parallel	25.2	1.6	Moved violently to + ve electrode with expanded fins.	No narcosis.	—
,,	,,	,,	,,	,,	2.4	Moved round the +ve electrode, narcotised & lay on side.	Near+ ve electrode.	2
,,	,,	,,	,,	,,	4.0	Moved violently to the —ve electrode with expanded fins and narcotised.	Near—ve electrode.	42
Lates calcarifer.								
370	100	24500	,,	22.2	1.6	Moved forward with jerk and expanded fins and operculum.	No narcosis.	—
,,	,,	,,	,,	,,	2.4	Moved to middle with expanded fins & gills & narcotised.	Near middle.	4.5

(Contd.....)

1	2	3	4	5	6	7	8	9
,,	,,	—	,,	,,	3.2	Moved to + ve electrode with expanded fins & gills & narcotised.	Near + ve electrode.	50 (Died after 10 minutes).
Megalops cypernoides:								
350	125	—	Parallel	21	0.8	Expansion of gills & move to + ve electrode.	No narcosis.	—
,,	,,	—	,,	,,	1.6	Moved violently to + ve electrode, narcotised with belly up & floated on surface.	Near + ve electrode.	180
,,	,,	—	,,	,,	2.4	Moved violently with expanded gills & fins & bending of body and narcotised.	- do -	252
337	120	—	,,	20.2	0.8	Moved violently to + ve electrode with bending of body & expansion of gills & fins.	No narcosis.	—
,,	,,	—	,,	,,	1.6	-do-	Near + ve electrode.	6.5
,,	,,	—	,,	,,	2.4	Moved violently to middle with bending of body, expansion of fins & gills & narcotised.	Near middle	8
Hactodon ollaris:								
100	67	—	,,	6	,,	Expansion of fins during each pulse.	No narcosis.	—
,,	,,	—	,,	,,	3.2	Moved to middle with expansion of fins, head down.	Near middle.	3.5
,,	,,	—	,,	,,	4.0	-do-	-do-	4.5
,,	,,	—	,,	,,	4.8	Moved towards + ve electrode, narcotised & lay on side.	,,	7
,,	,,	—	Perpendicular.	4	,,	Moved round + ve electrode with expanded fins & narcotised.	Near + ve electrode.	4

(Contd.....)

1	2	3	4	5	6	7	8	9
33	20	—	Parallel	2	3.2	Moved little with jerk and expansion of fins during pulse.	No narcosis.	—
,,	,,	—	,,	,,	4 0	Narcotised with expansion of fins during each impulse.	Near middle.	2.6
,,	,,	—	Perpendicular.	1.2	6.4	-do-	,,	1.5
,,	,,	—	Parallel	2	,,	Moved to —ve electrode in an elliptical path & expanded fins & narcotised	Near-ve electrode.	3.8
Heniochus macrolepidotus:								
60	40	—	,,	3.6	4.0	Expansion of fins during each pulse & tremour of body	No narcosis.	—
,,	,,	—	,,	,,	4.8	Moved to + ve electrode with expanded fins, narcotised & lay on side.	Near+ ve electrode.	3.8
,,	,,	—	Perpendicular.	2.4	7.2	Moved to -ve electrode with expanded fins and jerks, narcotised & lay on side.	Near-ve electrode	6.5
,,	,,	—	,,	,,	9.6	Moved to + ve electrode with expanded fins, narcotised & lay on side.	Near+ ve electrode.	8
,,	,,	—	,,	,,	10.4	Moved to -ve electrode with expanded fins, narcotised & lay on side.	Near-ve electrode.	10
Epinephelus pantherinus:								
570	140		Parallel	34.2	1.6	Moved to + ve electrode violently with expanded fins.	No narcosis.	—
,,	,,	—	,,	,,	2.4	Moved to + ve electrode with expanded fins and narcotised.	Near+ ve electrode.	11
,,	,,	—	,,	,,	3.2	-do-	-do-	13
,,	,,	—	45°angle	25.7	,,	Moved to -ve electrode with expanded fins & narcotised.	Near-ve electrode.	12

(Contd.....)

1	2	3	4	5	6	7	8	9
Therapon jarbua:								
128	45	3840	Parallel	7.7	1.6	Narcotised with expanded gills and fins.	Near middle.	16
,,	,,	,,	,,	,,	2.4	- do - with	Near +ve electrode.	26
,,	,,	,,	,,	,,	4.0	- do -	Near middle.	61
,,	,,	,,	Perpendicular	2.7	4.8	- do -	Near +ve electrode.	50
,,	,,	,,	,,	,,	8.8	- do - lay on side.	Near middle.	Death after 8 minutes
120	40	3600	Parallel	7.2	1.6	Moved to —ve electrode and narcotised with expanded gills & fins.	Near —ve electrode.	9
,,	,,	,,	,,	,,	2.4	Narcotised with expanded gills and fins.	Near middle	17
,,	,,	,,	Perpendicular	2.4	8.8	- do -	Near middle.	Death after 17 minutes.
105	30	3150	Parallel	6.3	1.6	Jumped to middle and narcotised with expanded gills & fins.	,,	7.5
,,	,,	,,	,,	,,	2.4	Moved violently to middle in a circular path and narcotised with expanded gills and fins.	,,	3
,,	,,	,,	,,	,,	3.2	Narcotised with expanded gills and fins.	,,	4
,,	,,	,,	Perpendicular	1.8	11.2	- do -	Near +ve electrode	Death after 10 minutes.
103	30	3090	Parallel	6.15	1.6	Moved to +ve electrode violently and narcotised with expanded gills & fins.	,,	4

(Contd.....)

1	2	3	4	5	6	7	8	9
,,	,,	,,	,,	,,	2.4	Narcotised with belly up and expanded gills & fins.	,,	6
,,	,,	,,	,,	,,	3.2	Moved violently to + ve electrode & narcotised with belly up and expanded gills & fins.	,,	14
,,	,,	,,	45° angle	4 6	3.2	- do -	,,	8
,,	,,	,,	Perpendicular.	1.8	11.2	Narcotised with expanded gills & fins & lay on side.	Near middle.	Death after 20 minutes.
100	25	3000	Parallel	6.0	1.6	Narcotised with expanded gills & fins.	,,	2
,,	,,	,,	,,	,,	3.2	- do -	,,	3
,,	,,	,,	45° angle	4.5	3.2	- do -	,,	2
,,	,,	,,	Perpendicular	1.5	12.0	- do -	,,	Death after 7 minutes.
Dasyatis gerrardii:								
420	185	23200	Parallel	25.2	0.8	Bending of sides during impulse and no movement.	No narcosis.	Moved to + ve electrode.
,,	,,	,,	,,	,,	3.2	Bending of sides with tremour.	Near middle.	120 Moved to + ve electrode.
,,	,,	,,	,,	,,	8.0	Bending of sides with tremour during each pulse & moved to + ve electrode.	Near+ ve electrode.	139 Stayed near + ve electrode.
,,	,,	,,	45° angle	19.0	4.8	- do - Moved to —ve electrode.	Near—ve electrode.	104 Moved to + ve electrode.
,,	,,	,,	Perpendicular.	11.1	6.4	- do -	,,	75 ,,
410	180	22650	Parallel	24.6	0.8	Bending of side during impule & no movement.	No narcosis	— Moved to + ve electrode.

(Contd .....)

1	2	3	4	5	6	7	8	9
,,	,,	,,	,,	,,	3.2	– do – moved to + ve electrode.	Near+ ve electrode.	63 ,,
,,	,,	,,	,,	,,	4.0	– do – moved to middie	Near middle.	76 Moved to +ve electrode.
,,	,,	,,	45° angle	18.4	4.8	– do – narcotised.	Near—ve electrode.	58 ,,
385	165	21650	Parallel	23.1	0.8	Bending of sides with contraction of body and no movement.	No narcosis	,,
,,	,,	,,	,,	,,	4.8	Bending of sides with treamour & moved to middle & narcotised.	Near middle.	149 ,,
,,	,,	,,	,,	,,	6.4	– do –	,,	218 ,,
,,	,,	,,	45° angle	17.1	,,	Bending of sides with each pulse and narcotised.	Near—e electrode.	76 ,,
,,	,,	,,	,,	,,	11.6	– do –	Near+ e electrode.	205 ,,

(Concld .....)

Table 8 Effect of repeated stimulation on fatigue and accomadation of fishes

Impulse frequencey per minute: 38
Impulse duration in sec: 0.8
Density of current in ma/mm²: 1.2

Species	Length of fish: mm	Tempreature of water: °C	Resistance of water: ohms/cc.	Movement of gills/ minute before expt.	No of impulses given	Period of exposure: secs	Gill movements minute after expt.
Chiloscyllium indicum	450	26	800	96	14	11.2	84
-do-	440	,,	,,	84	18	14.2	80
-do-	420	,,	,,	100	19	15.2	96
-do-	415	,,	,,	88	24	19.2	84
-do-	400	,,	,,	80	26	20.8	94
Apiniphelus diacanthus	180	24	350	76	14	11.2	56
-do-	175	,,	,,	76	14	11.2	36
-do-	150	,,	,,	88	15	12.0	36
-do-	148	,,	,,	88	14	11.2	68
-do-	142	,,	,,	88	15	12.0	60
Megalops cypernoides	350	27	300	80	8	6.4	76
-do-	337	,,	,,	80	10	8.0	72
Platax teira	160	,,	,,	180	12	9.6	188
-do-	120	,,	,,	168	17	13.6	208
Haetodon ollaris	101	,,	,,	264	19	15.2	304
-do-	33	,,	,,	258	32	25.6	298
Lates calcarifer	370	,,	,,	62	16	12.8	48
Crysophus burda	420	,,	,,	96	15	12.0	112
Heniochus macrolepidotus	60	,,	,,	228	41	32.8	180
Siganus vermiculates	260	,,	,,	188	18	14.4	192
Epinephelus pantherirnus	570	,,	,,	40	26	20.8	30
Plutosus arab	330	25	550	100	17	13.6	84
-do-	312	,,	,,	100	13	10.4	88
-do-	215	,,	,,	144	19	15.2	120
Muraena undulata	500	27	375	40	36	28.8	36
-do-	425	,,	,,	64	21	16.8	56
-do-	415	,,	,,	60	49	39.2	40
Scolopsis leucotaenia	100	,,	500	180	13	10.4	200
-do-	100	,,	,,	212	15	12.0	216
-do-	100	,,	,,	200	17	13.6	216
Tetradon sp.	300	,,	,,	84	47	37.6	28
-do-	100	,,	,,	128	40	32 0	108
Apogon faciatus	103	,,	,,	132	15	12.0	I04
Therapon jarbua	128	,,	450	216	27	21.6	12
-do-	120	,,	,,	212	15	12.0	8
-do-	105	,,	,,	200	15	12.0	120
-do-	103	,,	,,	266	19	15.2	120
-do-	100	,,	,,	212	21	16.8	56
Dasyatis gerrardii	430	,,	,,	132	35	28.0	84
-do-	400	,,	,,	132	19	15.2	92
-do-	385	,,	,,	128	27	21.6	88

of current (1.2 ma/mm^2) are shown in table 3. *Apiniphelus diacanthus* of 142 to 180 mm exhibited narcosis in body voltage of 7.87 to 12.6 in 2.4 to 4 seconds. *Plutosus arab* of 215 to 312 mm were stunned in 1.6 to 3.2 seconds when the voltage drop between their head and tail were 12.9 to 18.7. *Chiloscyllium idicum* between 400 and 450 mm length were hypnotised in 2.4 to 5.6 seconds when subjected to body voltages of 23.7 to 27. Potential drops of 2.1 to 30 V brought about narcosis and fixation of *Muraena undulata* of 400 to 415 mm in 2.4 to 6.4 seconds. *Scolopsis leucotaenia* with lengths of 95 to 100 mm required a potential drop of 2.3 to 5.7 for paralysis in 1.6 to 4.8 seconds. *Tetradons* of 95 to 300 mm were narcotised in 4.8 to 7.2 seconds when subjected to body voltages of 6 to 1.8. The body voltages for narcosis and fixation varied according to length and position of the fish body in the electrical field. The fish which lay parallel to the direction of current conduction was subjected to more potential drop between head and tail than in any angle to the direction of electrical lines or perpendicular to the lines of force for a given size. *Apogon faciatus* of 95 to 100 mm, *Platax teira* of 100 to 160 mm, *Siganus vermiculatus* of 260 mm *Crysophus burda* of 410 to 420 mm, *Lates calcarifer* of 360 to 370 mm, *Megalops cypernoides* of 335 to 350 mm, *Haetodon ollaris* of 33 to 100 mm, *Heniochus macrolepidotus* of 60 mm, *Epinephelus pantherinus* of 550 to 570 mm, *Therapon jarbua* of 100 to 128 mm and *Dasyatis gerrardii* of 385 to 420 mm were narcotised in body voltages of 1.8 to 6, 6 to 9.6, 5.6 to 21.6, 18.4 to 25.2, 16.2 to 22.2, 14.8 to 21, 1.2 to 6, 2.4 to 3.6, 8.1 to 34.2, 1.5 to 7.7 and 11.1 to 25.2 volts respectively (table 3). The effective periods in the present series of experiments, for narcosis and fixation of fish were more with the decrease of potential drop between head and tail irrespective of varieties. In *Apiniphelus diacanthus* the period for narcosis was raised to 4 seconds from 2.4 when the body voltage was lowered to 7.87 from 10. Effective period of narcosis in *Muraena undulata* increased to 5.6 secs from 4.8 secs when body voltage was decreased to 2.4 from 24.9. *Scolopsis leucotaenia* of 100 mm required 4.8 seconds for stunning; when subjected to body voltage of 2.3. On increasing the body voltage to 6, the period for narcosis was reduced to 1.6 secs. Similar reduction in effective periods for narcosis has been noticed in *Siganus vermiculatus* of 260 mm, *Therapon jarbua* of 120 mm and *Dasyatis gerrardii* of 420 mm with increase of potential difference.

Apiniphelus diacanthus of 149 to 180 mm exhibited narcosis and fixation only when the exposure to current was for 2.4 seconds or more in body voltages of 10 to 12.6. A decrease in body voltage to 7.87 increased the effective period for narcosis to 4 seconds. Though the requirement of effective period for narcosis of fish did not vary from 2.4 seconds between 142 to 180 mm of fish length, yet the intensity of shock in large sized fishes was great and could regain senses only in 9.5 secs in case of 180 mm as against 7 secs in case of 142 mm (table 4).

Plutosus arab between 215 to 330 mm felt the impulse with sudden jerk and bending of body accompained by tremour. Movement of fishes occurred during electrotaxis and were narcotised in 1.6 to 2.4 seconds in every case at body voltages between 12.9 to to 19.8. Fishes of 215 mm required a greater effective period of 2.4 seconds while those between

312 to 330 mm were narcotised in 1.6 seconds. With the gradual increase in period of exposure to 5.6 seconds an intense effect on the fish of 330 mm was observed delaying the recovery of fish up to 126 seconds depending on the period of exposure (table 5).

The effctive periods for initiating taxis and narcosis of *Chiloscyllium indicum* varied inversely from 3.2 to 5.6 seconds with decrease of length from 450 to 400 mm in potential differences of 27 to 24 volts between their heads and tails. Movement of fish accompanied with intermittent jerks during each pulse occurred during electrotaxis. On reaching the threshold effective period, the fish underwent hypnosis. The periods of recovery from hypnosis were longer with the increase of periods of stimulation for the fish of same length (table 6).

Marine eel *(Muraena undulata)* of 415 to 500 mm showed narcosis and fixation in 2.4 to 4.8 seconds with gradual increase in effective periods with the decrease of fish length when subjected to potentital difference of 24.9 to 300 volts. Violent movements were observed prior to narcosis. The period of recovery of fish was delayed to 3.8 secs from 1.2 secs with increase of duration of shocks to 7.2 seconds from 2.4 seconds (table 7).

In a fixed density of current of 1.2 ma/mm^2, *Tetradon sp.* of 300 mm remained stunned in 4.8 seconds, while 5.6 seconds were required to narcotise a fish of 100 mm. Effective periods of 1.6, 3.2 and 4.8 seconds induced narcosis in *Scolopsis leucotaenia* of 100 mm when subjected to voltage tensions of 6, 4.5 and 2.3 respectively. Increased periods of shock intensified the effect on the fish causing delay in recovery in case of both *Scolopsis leucotaenia* and *Apogon faciatus* (table 7).

Platax teira of 160 mm were narcotised in 1.6 seconds when subjected to a body voltage of 8.6 while that of 100 mm required 2.4 seconds when the voltage tension was 6. At potential differences of 21.6, 25.2 and 22.2 volts created between the head and tail of *Siganus vermiculatus* of 260 mm, *Crysophus burda* of 420 mm and *Lates calcarifer* of 370 mm, intense effects were observed with the increase in effective periods resulting in delayed recovery of fishes (table 7).

Though *Megalops cypernoides* of both 350 mm and 337 mm required 1.6 to 2.4 seconds to exhibit narcosis in body voltage of 21 and 20.2, yet the effects on longer fishes were more prolonged than on smaller ones as the latter recovered in 6.5 to 8 seconds, while the former took 180 to 252 seconds to regain their normal positions. *Haetodon ollaris* of 100 mm were stunned in 3.2 seconds as against 4 seconds required for a fish of 33 mm. *Epinephelus pantherinus* of 570 mm, *Heniochus macrolepidotus* of 60 mm and *Haetodon ollaris* of 100 mm took longer periods for recovery with increased periods of stimulation when treated with potential differences of 34.2, 2.4 and 6 volts, respectively (table 7). Movement during taxis prior to narcosis occurred with expansion of gills, fins and tremour of the body in most of the varieties.

Therapon jarbua of 128 mm, required a higher potential of 7.7 volts than that of 100 mm (6 volts) for narcosis. The effective period for narcosis however remained 1.6 seconds irrespective of variation in length of fish. But the effect on bigger fish was so intense that it took 16 seconds for recovery, while fishes of 120 mm, 105 mm, 103 mm, and 100 mm recovered in 9, 7.5, 4, and 2 seconds

respectively (table 7), Unlike other marine species 80% of *Therapon jarbua* did not exhibit any movement during electrotaxis and were narcotised in their original places with expanded gills and fins. On prolonged exposure to the current for 8.8 to 12 seconds, *Therapon jarbua* of 100 to 128 mm did not recover from the shock and died within 7 to 20 minutes after the exposure. The periods of narcosis were also prolonged with increase in effective periods and fishes of 128 mm, 120 mm, 103 mm and 100 mm recovered in 61, 17, 14, and 3 seconds respectively when subjected to electric shocks of 4, 2 4, 3.2, and 3.2 seconds (table 7).

Desyatis gerrardii, 285 to 420 mm, felt the electric current by bending of sides accompanied by tremour of body during taxis and were stunned in the same place without any movememet in the electrical field. Fishes of 420 mm were narcotised in 3.2 seconds, whereas those of 385 mm took 4.8 seconds for narcosis. Intensive effects of shocks have been observed with increase in effective periods irrespective of size of fishes (table 7).

Higher voltage gradients were needed to produce the minimum response in a fatigued fish than in a rested or fresh fish in an A. C. field (Bary, 1956). The effect of interrupted A. C. on the general behaviour of fish were studied. The rate of gill movement of *Platax teira*, *Haetadon ollaris*, *Crysophus burda*, *Siganus vermiculatus*, *Scolopsis leucotaenia* increased with treatment of impulse current of different effective pariods irrespective of size of fishes indicating increased respiration after shock treatment (table 8).

No significant effect was observed on the period for narcosis and recovery in relation to repeated stimulation in case of *Catla catla* and *Cirrhina mrigala* which was possibly due to the accomodation of nerves and subscquent fatigue of the fish (Biswas, 1969.)

Lowered activity was observed in case of all other species tried as shown by decreased rate of gill movements after electric shocks of different effective periods irrespective of fish length (table 8).

Conclusions

In an interrupted A. C. of 50 Hz having a fixed impulse frequency of 38/ minute and constant current density of 1.2 ma/mm^2, marine fishes exhibited electrotaxis and narcosis on reaching the optimum period of flow of current through them. The visible reactions were stretching of fins, tremour of the body and change of place accompanied by either specific movement towards the electrodes or at random in the field till the narcosis set in. Some fishes like *Therapon jarbua* and *Dasyatis gerrardii*, underwent narcosis in the same place without any movement in the electrical field. Though the requirements of minimum current flow varied from species to species it was within the range of 2 to 6.8 seconds irrespective of fish size at a fixed impulse duration of 0 8 seconds. 12.5 to 75% of 16 species moved towards increasing potential during eletrotaxis and narcosis, while 12 to 58% of 14 varieties exhibited oscillotactic reaction and placed their body axis perpendicular to lines of force. Only 8 to 50% of 8 varieties swam towards the counter pole during electrotaxis. *Crysophus burda* was narcotised in 1.6 to 4 8 seconds while *Muraena undulata* *Eipnephelus pantherinus* and *Dasyatis gerrardii*, were stunned only in 2.4 to 6.4 seconds at potential drops of 11.1 to 33 volts between their heads and tails. Similarly *Megalops cypernoides* reacted earlier

(1.6 to 2.4 seconds) than *Late calearifer* and *Dasyatis gerrardii*. *Tetradonsp* also showed narcosis in higher effective period compared with *Haetodon ollaris*, *Platax teira*, *Thearpon jarbua*, *Scolopsis leucotaenia* and *Apogon faciatus*.

The effective periods required for narcosis and fixation varied inversely with the potential drop created between the head and tail of the fish. Fishes of greater length were subjected to more voltage tension than smaller ones, causing earlier effect on large sized fish in smaller effective period. The same fish which was placed parallel to the field lines was subjected to higher potential difference between head and tail than that situated at an angle to electrical lines. With increase in angle the voltage tension between head and tail decreased and was lowest at right angles to the flow of current conduction causing the requirement of higher effective period for narcosis and fixation of fishes. The intensity of electric shock on fishes was more with increase in period of exposure to current and took longer period for recovery. Interrupted A. C. of 50 Hz affected fishes with a difference in rate of gill movements before and after shock treatment.

ACKNOWLEDGEMENT

The author is grateful to Dr. C. V. Kulkarni, Director, and Dr. H. G. Kewalrámani, Senior Scientific Officer, Maharastra Fisherises Department for all possible help in conducting these studies in Taraporevala Aquarium, Bombay.

REFERENCES.

Bary, B, 1956. *Scottish Home Deptt. Series* No. 1, 32.

Biswas K. P. 1969. *Fish Technol.*, 6 (2), 83.

Cattley, J. G. 1955. *World Fishing*, 4 (3).

Goffstown, N. H., 1958. *National Fishermen*, 39 (3), 9.

Kreutzer. C & Peglow. H, 1947 *Fishing Gazettee*, 66 (12), 52.

Meyer-Waadrden, P. F. 1955. *Elektronik*, 4 (7).