ON THE BEHAVIOUR OF MARINE CRUSTACEANS IN AN ELECTRICAL FIELD OF ALTERNATING CURRENT

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The minimum flow of current essential to produce electronarcosis and fixation in marine crustaceans, *Metapenaeus affinis, Parapenaeopsis stylifera, Panulirus ornatus* and *Neptunus sanguinolentus* in an AC field of specific strength varied with the lengths of animals tested, except in case of the last one where the increase in size of animals showed no significant effect on the effective period for different reactions. *M. affinis* in interrupted AC required threshold pulses for narcosis and fixation, which varied inversely with the length of the organism. Animals subjected to current of higher effective period required longer time for recovery in interrupted AC of 50 c/s. The period for narcosis and recovery of *M. affinis* did not vary significantly with repeated stimulations on the same organism.

Introduction

Experiments using under water television showed that the performance of trawl nets depended mostly on the towing speed. Excess speed caused leap frogging of load lines over the bottom resulting in loss of probable catch while too slow speed resulted in a smaller angle of doors and decreased spread of net opening. Kreutzer and Pegalow (1949) claimed that a catchment area of ten times that covered by the trawl mouth could be obtained, if an anode was suspended from the head line of the trawl with the otter boards as cathode. In addition, fish would not flee, but would be narcotized and swept helplessly into the net. The net thus could be trawled off the bottom as the electric current forced the hidden fish to rise to the trawl mouth. Higman (1956) conducted experiments in a tank containing sea water to determine the optimal electrical conditions that would cause maximum movement of shrimp *(Penaeus duorarum)* to the positive electrode in a field of pulsed DC. Hence, an investigation on the behaviour of *P. stylifera, M. affinis, P. ornatus* and *N. sanguinolentus* in an AC field in a tank containing sea water appeared to be interesting.

Materials and methods

Studies were conducted in a glass aquarium tank, 200 x 50 x 70 cm^3, fitted in

wooden frame. Two zinc plate electrodes of 50 x 25 cm^2 were fixed vertically to each end of the tank at a distance of 200cm. The tank was then filled with sea water to a depth of 10 cm. The electrodes were connected to AC mains of 220 V/50 c/s through a voltmeter and amperemeter to record the potential drops between the electrodes and the quantity of current drained. A thermometer suspended from a clamp recorded the temperature of water during the experiments. As a variable resistance of sufficiently high capacity was not readily available, experiments were conducted direct from A. C. mains and the behaviour of organisms was studied on exposure to electric current for different periods. Tests were also done with interrupted A. C. of 220 V through a mechanical impulse transmitter which produced fixed impulses of 37 per minute with impulse and pause durations of 0.8 second each. The resistance of water was measured by an ohm meter with silver electrodes and expressed as ohms per c. c.

The test animal after being acclimatised for 24 hrs in confined waters in the laboratory and measured for total length (the length from cephalothorax to tail) was released in the experimental aquarium to settle. The position of body axis in relation to field lines was recorded before starting the experiment and the animal exposed to an AC of 220 V. 50 to 60 amperes of current were found to be drained with potential drop of 150 V between the electrodes during the closing of circuit. The behaviour of animals in relation to the time of current exposure was recorded. A series of experiments were conducted with interrupted AC with an impulse voltage of 150, to find out the effective periods. The effect of repeated stimulation on the animals in relation to fatigue and accommodation was also studied.

Tests were carried out with *M. affinis*, *P. stylifera*, *P. ornatus* and *N. sanguinolentus* of various sizes under different conditions. Except in experiments for repeated stimulations, a fresh animal duly acclimatised was taken for each experiment. In case of *N. sanguinolentus*, the length and breadth of carapace along with total weight have been taken into consideration. The behaviours of animals were also studied in relation to the position of their body axis to the lines of current conduction. The potential drop between the head and tail of the organism in electrical field during electronarcosis and fixation was recorded. The current density of the field during experiments was expressed as ma/mm^2 and kept constant for every set of experiments.

Results and discussion

Fourteen experiments were conducted with *M. affinis* of 65 to 52 mm in an AC field of current density of 1.2 ma/mm^2 at a water temperature of 30°C. The resistance of water during the tests was 750 ohms per cc. The time required for electronarcosis and fixation of the animal depended on the potential drop between the head and tail which agin depended on its position to field lines (table-I). Potential difference between the head and tail was maximum when the animal rested with its body axis parallel to the direction of current and minimum when it lay perpendicular to the lines of force. The animal of 55 mm length required 3.2, 4, 4.8 and 8 secs for narcosis and fixation when the potential drops between their head and tail were 4.1, 3.3, 2.3, and 0 6 V respectively depending on their position in the electrical field.

Higher potential difference between head and tail induced electronarcosis and fixation of the animal earlier with the increase in length of cephalothorax. Organisms of 58, 56, 55 and 53 mm when placed parallel to the direction of flow of current,

required potential differences of 4.3, 4.2, 4.1 and 3.9 V respectively between their heads and tails and were narcotized in 1.6, 3, 3.2 and 3.2 seconds respectively.

P. stylifera under similar conditions required higher potential drop between head and tail with increase in length. The effective period for narcosis and fixation varied inversely with the body voltage between the head and tail. The shrimp of 77, 66, 60 and 45 mm length exhibited narcosis and fixation in 1.6, 2.4, 2, 4 and 3.2 seconds respectively when the voltages between their heads and tails were 5.8, 4.9, 4.5 and 3.4 (table–II). Besides the voltage tension between head and tail, the effective period (period for which the organism is exposed to the current) was also an important factor in bringing about electronarcosis. Complete narcosis occurred in *P. stylifera* of 77 mm length in 1.6 seconds when the potential difference between the head and tail was 5.8 V. But the organism in similar conditions could not exhibit narcosis when exposed to current for 0.8 seconds.

P. ornatus between 255 mm and 180 mm showed narcosis with contraction of limbs and tail with the closing of circuit and were no longer able to move of their own accord as long as the current continued to flow. The animal recovered immediately after opening of the circuit and disappearance of electrical field and exhibited backward movement towards the electrode. Narcosis and fixation of the

TABLE I EFFECT OF ALTERNATING CURRENT OF 50 CYCLES ON *M. affinis*

Cephalothorax			Potential drop between head & tail: V	Time required for electronarcosis & fixation in sec	Effect during electronarcosis & fixation.	Place of fixation in electric field.	Time required for recovery in secs.	Movement after recovery
Length mm	Breadth mm	Positio in eli. field						
65	10	Perpendicular	0.75	3.2	Jumped backward and stunned	Near electrode.	65.0	Near-electrode.
58	8	Parallel	4 3	1.6	,,	,,	2.8	,,
56	,,	45° to field lines	2.9	4.8	,,	,,	1.5	,,
,,	,,	,,	,,	,,	,,	,,	2.0	Near middle
,,	,,	Parallel	4.2	3.0	,,	,,	1.2	,,
55	,,	Perpendicular	0.6	8.0	,,	,,	2.0	Near electrode
,,	,,	30° to field lines	3.3	4.0	,,	,,	1.0	,,
,,	,,	,,	,,	,,	,,	Near middle	0.8	,,
,,	,,	45° to field lines	2.8	4.8	,,	,,	,,	,,
,,	,,	Parallel	4.1	3.2	,,	Near electrode	1.0	,,
,,	,,	,,	,,	,,	,,	Near middle	2.5	,,
,,	,,	,,	,,	,,	,,	Near electrode	0.5	,,
53	7	,,	3.9	,,	,,	,,	3.0	,,
52	6	,,	,,	,,	,,	,,	0.8	,,

TABLE II EFFECT OF ALTERNATING CURRENT OF 50 CYCLES ON *P. stylifera*

Cephalothorax Length mm	Breadth mm	Position	Potential drop between head & tail: V	Time required for electronarcosis & fixation in secs	Effeot during electro-narcosis & fixation.	Place of fixation in electric field	Time required for recovery in secs	Movement after recovery.
108	15	45° to field lines	5.6	1.6	Jumped backward	Near middle	1.5	Near electrode
105	14	Parallel	7.8	0.8	Jumped baekward. No narcosis	—	—	—
96	12	Perpendicular	0.9	,,	,,	—	—	—
93	11	Parallel	6.9	,,	,,	—	—	—
91	,,	,,	6.8	,,	,,	—	—	—
77	10	,,	5.8	,,	,,	—	—	—
,,	,,	,,	,,	1.6	Jumped backward and stunned	Near middle.	2	Near electrde
66	9	,,	4.9	2.4	,,	Near electrode	3	,,
64	,,	Perpendi-cular	0.7	,,	Jumped back-ward. No narcosis	—	—	—
62	,,	45° to field lines.	3.2	,,	Jumped back-ward & stunned.	Near electrode	1	Near electrode
60	8	Parallel	4.5	,,	,,	,,	2	,,
45	6	,,	3 4	3.2	,,	Near middle	1	,,

animal occurred when the period of exposure to electric current reached the threshold value. Animals of 255, 232,185 and 180mm were not narcotized when they were exposed to current for 6, 8, 3, 2, and 2 secs respectively at potential differences of 19.1, 17.4, 16.9, 13.8, and 13.5V between their heads and tails. But they were completely narcotized when exposed for 2.4, 3.2, 4.5 and 5.5 secs respectively under similar voltage tension between head and tail. Forward movement of the organism has been observed after the recovery from narcosis (table-3). The effective period required for narcosis of the animal increased with the decrease in size. The greater the length the lesser the time required for narcosis and fixation.

Unlike shrimp and lobster, crab (N. sanguinolentus) behaved differently in electrical field of similar conditions. The period required for hypnosis and fixation of the animal did not vary with the size of animal as observed in case of shrimp and lobster. Crabs of 116 mm carapace length exhibited narcosis in 3 seconds when crabs of 120 mm and 106mm were narcotised in 4.2 seconds. Even crabs of similar size (106mm carpace length) under similar voltage tension of 7.9V between the extremities of carapace, took 1.8 to 4.2 seconds for their narcosis and fixation (table-4). Meyer-Waarden (1954) reported death of all Chinese crabs within 24 hours when they were exposed to impulse current with loss of all their legs in 80% of animals and partly in 20%. Twenty percent of *N. sanguinolentus* lost their limbs from their joints in the present tests.

TABLE III EFFECT OF ALTERNATING CURRENT OF 50 CYCLES ON *P. ornatus*

Cephalothorax			Potential drop between head & tail: V.	Time reqd. for electro-narcosis & fixation in secs	Effect during electro-narcosis & fixation.	Place of fixation in electrical field.	Time reqd. for recovery in secs	Movement after recovery.
Length mm	Breadth mm	Position						
1	2	3	4	5	6	7	8	9
255	65	Parallel	19.1	0.6	Stunned with contraction of limbs & tail.	Near middle.	0	Backward to electrode
,,	,,	45°to field lines	13.3	1.2	,,	,,	,,	,,
,,	,,	Parallel	19.1	2.4	Narcotised completely.	Near electrode.	23	Moved forward
232	60	,,	17.4	0.8	Stunned with contraction of limbs and tail	,,	0	Backward to electrode
,,	,,	45°to field lines	12.1	1.6	,,	,,	,,	Backward towards the surface of water & settled at bottom
,,	,,	Perpendicular.	4.2	,,	,,	,,	,,	Turned round & settled
,,	,,	Parallel	17.4	3.2	Narcotised completely	,,	62	,,
,,	,,	Perpendicular	4.2	,,	,,	Near middle	8	,,
225	58	Parallel	16.9	2.0	No narcosis	—	—	—
,,	,,	,,	,,	3.0	Stunned with contraction of limbs & tail	Near electrode	0	Baekward to electrode.
,,	,,	45°to field lines	11.8	,,	,,	,,	,,	,,
,,	,,	Parallel	16.9	4.0	Narcotised completely & lay on its side.	,,	135	Moved forward
185	55	,,	13.8	2.0	Stunned with contraction of limbs and tail	,,	0	Moved backward with jerks
,,	,,	45° to field line	9.7	3.0	,,	,,	,,	,,
,,	,,	Perpendicular	4.1	4.0	,,	,,	,,	,,
,,	,,	Parallel	13.8	5.0	Narcotised completely	Near middle	4	Moved forward
180	52	,,	13.5	2.0	Stunned with contraction of llmbs and tail.	,,	0	Moved backward with violent jerks

(contd....)

1	2	3	4	5	6	7	8	9
,,	,,	45° to field lines	9.4	4.0	Stunned with contractions of limbs and tail.	Near electrode.	0	Moved backward with violent jerks.
,,	,,	Parallel	13.5	5.5	Nartotised & lay upside down.	Near middle	18	Moved forward

TABLE IV EFFECT OF ALTERNATING CURREFT OF 50 CYCLES ON *N. sanguinolentus*

Length of carapace in mm.	Breadth of carapace in mm.	Total wt. of organism in g.	Position of lengitudinal axis of carapace in electric field	Potential drop between extremities of carapace in volts.	Time reqd. for fixation in secs.	Effect during electronarcosis & fixation.	Place of fixation in electrical fiald.	Time required for recovery in secs.
125	82	225	Parallel	9.4	4.2	contrction of limbs & claws, stunned with expanded claws & limbs	Bottom	268
,,	,,	,,	45°to field lines	6.5	,,	,,	,,	38
,,	,,	,,	Perpendicular	6.1	4.8	,,	,,	12
,,	,,	,,	,,	,,	5.4	,,	,,	18
120	78	210	Parallel	9.0	4.2	,,	,,	82
,,	,,	,,	45°to field lines	6.3	3.6	Limbs broken from joint.	,,	147
,,	,,	,,	,,	,,	,,	,,	,,	9
,,	,,	,,	Parallel	9.0	1.8	,,	,,	6
116	75	195	,,	8.7	3.0	Contraction of limbs & claws, stunned with expanded claws and limbs.	,,	131
,,	,,	,,	,,	7.7	2.4	,,	,,	62
,,	,,	,,	45°to field lines	6.1	3.0	,,	,,	83
,,	,,	,,	,,	,,	,,	,,	,,	61
106	65	175	Parallel	7.9	4.2	,,	,,	40
,,	,,	,,	,,	,,	3.0	,,	,,	243
,,	,,	,,	,,	,,	1.8	,,	,,	105
,,	,,	,,	45°to field lines	5.5	3 0	,,	,,	31
95	58	150	Parallel	7.1	3.6	,,	,,	216
,,	,,	,,	,,	,,	4.8	,,	,,	199
,,	,,	,,	45°to field lines	5.0	5.4	,,	,,	79
,,	,,	,,	Perpendicular.	4.4	6.0	,,	,,	19

TABLE VI EFFECT OF FATIGUE AND ACCOMMODATION OF NERVES IN *M. affinis* ON THE EFFECTIVE PERIOD FOR FIXATION AND RECOVERY IN A. C. OF 50 c/s

Water temperature : 35°c Resistance of water in ohms per cc — 500 Current density in ma/mm² — 1.2

Length of cephalothorax in mm.	Breath of cephalo therax in mm	Potential drop between head & tail: V	Effective peaiod for fixation in secs for stimulations:					Period required for recovery in secs after stimulations				
			1st.	2nd.	3rd.	4th	5th.	1st	2nd.	3rd.	4th.	5th
105	14	7.9	0.8	2.4	1.6	1.0	0 8	No narcosis	2.0	2.0	2.5	1
,,	,,	,,	1.6	0.8	0.8	1.6	1.6	15	1.0	2.5	1.2	1
96	12	7.2	0.8	1.6	1.6	,,	,,	No narcosis	3.5	3 0	4.5	133
93	11	6.9	,,	,,	,,	,,	,,	,,	1.0	2.5	2.5	2
91	,,	6.8	,,	,,	,,	,,	,,	,,	,,	3.0	3.0	2.5
77	10	5.8	,,	2.4	,,	,,	2.4	,,	2.0	1.5	1.0	3
76	,,	5.7	,,	1.6	0.8	,,	1.6	,,	1.5	1.0	2.0	2
66	9	4.9	1.6	,,	2.4	,,	,,	3	99.0	17.0	9.0	3
,,	,,	,,	2.4	,,	1.6	,,	,,	67	6.5	4.5	6.5	10
62	,,	4.6	1.6	3.2	,,	,,	2.4	1	2.0	1.2	1.0	1.2
60	8	4.5	2.4	2.4	,,	,,	4.8	2	1.5	55.0	1.0	2
55	7	4.1	0.8	0.8	,,	,,	2.4	No narcosis	No narcosis	2.0	3.5	1.2
,,	,,	,,	1.6	1.6	,,	,,	1.6	4	5.0	3.2	4 0	6.6
47	6	3.5	,,	,,	2.4	,,	,,	6	2.6	7.5	13.0	11
45	,,	3.4	3.2	2.4	,,	3.2	2.4	1	1.5	0.5	1.0	1

TABLE 5 EFFECT OF INTERRUPTED

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

Longth of cephalothorax in mm.	Breadth of cephalothorax in mm.	No. of experiments conducted.	Position of cephalothorax in electrical field	Potential drop between head & tail in volts	Effect in 1 — 0.8 I	1 — 0.8 II	2 — 1.6 I	2 — 1.6 II
132	25	7	Perpendicular	1.9	0.8	No narcosis	1.6	No narcosis
130	24	5	45° to field lines	6.8	—	—	,,	,,
128	22	,,	Parallel	9.6	0.8	No narcosis	—	—
125	20	4	Perpendicuar	1.5	,,	,,	1.6	,,
120	18	6	45°to field lines	6.3	,,	,,	,,	,,
115	15	3	Parallel	8.6	—	—	,,	,,
112	14	5	Perpendicular	1.1	0.8	,,	—	—
110	,,	4	45°to field lines	5.8	,,	,,	1.6	,,
108	12	5	Parallel	8.1	,,	,,	,,	,,
105	,,	4	Perpendicular	0 9	—	—	,,	,,
102	10	3	45°to field lines	5.3	0.8	,,	—	—
100	,,	6	Parallel	7.5	,,	,,	1.6	,,
98	8	5	Perpendicular	0.6	—	—	,,	,,
95	,,	4	45°to field lines	5.1	0.8	,,	,,	,,
92	7	6	Parallel	6.9	,,	,,	,,	,,
90	,,	4	,,	6.7	,,	,,	—	—

Using interrupted AC of 50 c/s, and impulse voltage of 150 and 37 impulses per minute having impulse and pause durations of 0.8 second, narcosis of animals did not occur in 2 pulses having effective period of 1.6 seconds, when subjected to potential drop of 0.6 to 9.6 volts in *M. affinis* of 132mm to 90mm. Narcosis and fixation occurred first with 3 pulses of effective period of 2.4 seconds in animals having body voltages between 6.7 to 9.6 V. With the rise of effective period of 3.2 seconds in 4 pulses animals having body voltages between 0.6 to 1.9 were not affected. All the organisms were found to be narcotised when treated with 6 pulses having effective period of 4 8 seconds irrespective of the value of potential drops between the head and tail. The animal exhibited electro narcosis and fixation in every case with the rise of effective period between 4.8 to 6.4 seconds subsequent to the increase of pulses from 6 to 8 (table-5). In a constant pulse rate of 37 per min. and current density of 1.2 ma/mm^2, 6 pulses of 4.8 seconds were found to be the optimum, when all the shrimps between 132 to 90mm were narcotised completely. No significant effect has been observed on the requirement of effective period for the narcosis and fixation of *M. affinis* with repeated stimulation. Prawns between 96 and 91 mm took 1.6 seconds to be narcotised in successive stimuations (table-6). Mitra and Biswas (1969) also observed similar effect on *Cirrhina mrigala.*

CONCLUSION

M. affinis, P. stylifera and P. ornatus exhibited electronarcosis and fixation in different times when exposed to current density of 1.2 ma mm^2 at temperature and resistance of water of 30°C and 750

A. C. OF 50 C/S ON *M. affinis*

Current density in ma/mm² — 1.2

different impulse currents : Pulse — sec.

3 — 2.4		4 — 3.2		6 — 4.8		7 — 5.6		8 — 6 4	
I	II	I	II	I	II	I	II	I	II
2.4	No narcosis	3.2	No narcosis	4.8	1.8	5.6	2.8	6.4	33.0
,,	,,	,,	8.3	—	—	,,	3.8	,,	18.0
,,	10.5	—	—	4.8	18.0	,,	28.0	,,	33.0
—	—	3.2	No narcosis	,,	2.0	—	—	—	—
2.4	No narcosis	,,	3.6	,,	17.4	—	—	6.4	14 5
—	—	,,	5.2	—	—	5.6	17.0	—	—
2.4	No narcosis	,,	No narcosis	4.8	1.4	,,	2.2	—	—
—	—	—	—	,,	8.4	—	—	6.4	11.3
2.4	4 2	3.2	4.8	—	—	5.6	14.0	—	—
—	—	,,	No narcosis	4.8	1.2	—	—	6.4	2.6
2.4	No narcosis	—	—	—	—	5;6	2.8	—	—
,,	4 0	3.2	2.5	4.8	9.5	—	—	6.4	24.0
,,	No narcosis	,,	No narcosis	,,	0.8	5.6	1.8	—	—
—	—	,,	,,	,,	1.4	—	—	—	—
2.4	3.8	,,	1.0	—	—	5.6	9.4	6.4	16.8
,,	2.8	,,	1.0	4.8	1.0	—	—	—	—

I = Period for fixation (secs.) II = Period for recovery (secs)

ohms respectively, the periods varying inversely with the length of animals. In case of *N. sanguinolentus*, however the increase in size did not have any effect on the effective periods for bringing about fixation of the animal. *M. affinis* required 3 pulses of effective period of 2.4 seconds to bring out narcosis and fixation for length between 132 to 90 mm in interrupted AC of 37 pulses per minute, when the body voltage between head and tail were 9.6 to 6.7. The effective period for narcosis and fixation of the animal varied inversely with the voltage tension between head and tail. The period for recovery of animals increased when treated with higher pulses for greater effective periods. Repeated stimulations had no marked effect in *M. affinis* on the period for narcosis and recovery except in some cases where the same period was required for fixation in 2nd to 5th stimulations, which confirmed similar findings of Mitra and Biswas *(loc. cit)* on *C. mrigala* in AC of 50 c/s.

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