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THE USE OF ELECTRONARCOSIS AS ANAESTHETIC IN THE CICHLID, *OREOCHROMIS MOSSAMBICUS* (PETERS). III. THE EFFECTS OF CHANGING PHYSICAL AND ELECTRICAL PARAMETERS ON THE NARCOTIZING ABILITY OF HALF-WAVE RECTIFIED CURRENTS

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ABSTRACT

BARHAM, W. T., SCHOONBEE, H. J. & VISSER, J. G. J., 1989. The use of electronarcosis as anaesthetic in the cichlid, *Oreochromis mossambicus* (Peters). III: The effects of changing physical and electrical parameters on the narcotizing ability of half-wave rectified current. *Onderstepoort Journal of Veterinary Research*, 56, 67–71 (1989)

The narcotizing potential of various rectified current configuarations on *Oreochromis mossambicus* was investigated. A 50 Hz, 200 Vp. half-wave rectified current, applied for 30 s, was found to be a suitable configuration for electronarcosis.

INTRODUCTION

Electronarcosis is a possible alternative to chemical anaesthesia for stress studies and routine handling procedures in freshwater fish (Barham, Schoonbee & Visser, 1987 a,b). Although it is known that the Moore shocker, a rectified direct current unit designed for electrical fishing, induces narcosis (Moore, 1968), no detailed analysis of the narcotic effects of a half-wave rectified direct current is available. We have already reported on the narcotizing potential of alternating current (Barham *et al*, 1987b) and this study, the third in the series, evaluates the narcotizing potential of various rectified current configurations on the cichlid, *Oreochromis mossambicus*, using a modified Moore shocker.

This information is necessary in order to complete the evaluation of the relevant physical effects of electronarcosis on this freshwater fish species. A comparison of the narcotic effects of rectified current electronarcosis and alternating current electronarcosis will enable researchers to establish the most suitable narcosis procedures for their specific purposes.

MATERIALS AND METHODS

The materials and methods used in the present investigation are fully described in Part 1 of this series (Barham *et al.*, 1987b).

In this study the experimental groups of *O. mossambicus* each consisted of 8 acclimated fish and the electronarcosis unit used was a Moore type shocker (Moore, 1968), as modified by Barham *et al.* (1987b). Output voltage was controlled by varying the input voltage of the unit by means of a variable transformer. In order to study the effect of electrical frequency it was necessary to vary the input frequency of the shocker. This was achieved by using the output of the alternating current electronarcosis unit described by Barham *et al.* (1987a) as the input. Because of the output voltage limitations of the alternating current apparatus the final rectified voltage used in the frequency studies was limited to 100 Vp.

Except where otherwise stated the duration of current application was 30 s.

RESULTS

Effects of voltage

The narcosis times of fish subjected to direct current potentials (Vp) of 100, 200, 300 and 350 V increased from a mean of 60,9 s at 100 V to a maximum of 137,4 s at 200 V and then decreased somewhat at higher voltages although these decreases were not significant. The mean times at the three higher voltages were significantly (P = 0,01) or highly significantly (P = 0,001) greater than the mean time at 100 Vp. (Table 1, Fig 1). Narcosis coefficients showed similar trends.

A mean opercular recovery time of 37,4 s at 100 Vp was the shortest and a potential of 200 Vp produced the longest time of 59,6 s, although this figure was not significantly greater than that resulting from the use of higher potentials.

In contrast to these tendencies, recovery time

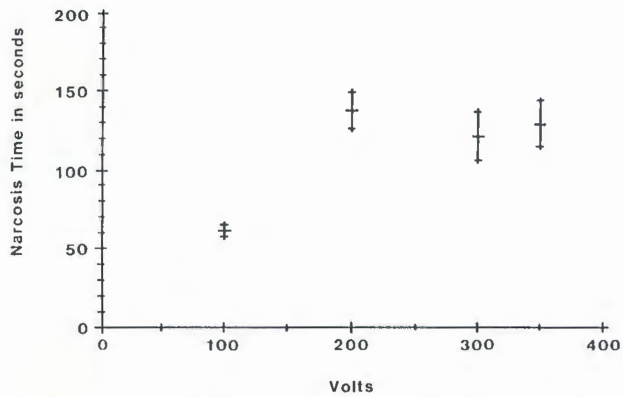

FIG. 1 The effects of different peak potentials on mean narcosis times (± SE) in *O. mossambicus* subjected to rectified current electronarcosis

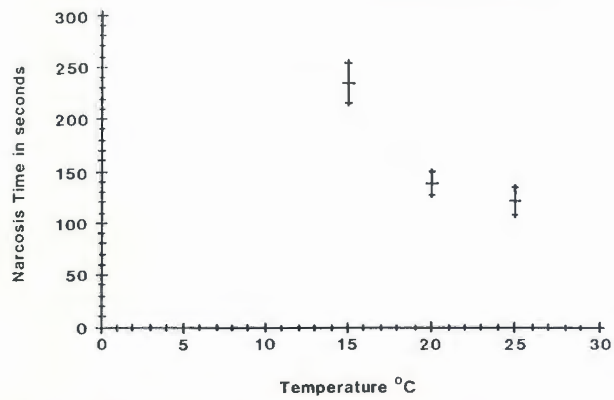

FIG. 2 The effect of water temperature on the mean narcosis time (± SE) in *O. mossambicus* subjected to rectified current electronarcosis

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TABLE 1 The effects of rectified current electronarcosis at different peak voltages on opercular recovery time, narcosis time and recovery time in *O. mossambicus*

		Length (cm)	Mass (g)	Opercular recovery time (s)	Narcosis time (s)	Recovery time (s)	Narcosis coefficient (s cm^{-1})
100 V	n =	8	8	8	8	8	8
	Minimum	21,5	155,7	25,0	49,5	20,0	1,2
	Maximum	28,1	314,2	49,2	83,1	54,9	3,5
	Range	6,6	158,5	24,2	33,6	34,9	2,3
	Mean	24,1	220,0	37,4	60,9	31,7	2,4
	Standard Dev.	2,4	57,5	8,7	11,2	11,8	0,7
	Standard Err.	0,8	20,3	3,1	3,9	4,4	0,2
200 V	n =	8	8	8	8	8	8
	Minimum	22,4	207,9	37,0	97,3	4,2	3,7
	Maximum	28,4	366,7	97,0	182,7	127,8	8,2
	Range	6,0	158,8	60,0	85,4	123,6	4,5
	Mean	25,5	275,0	59,6	137,4	58,1	5,5
	Standard Dev.	2,1	60,2	21,5	33,7	44,7	1,6
	Standard Err.	0,8	21,3	7,6	11,9	15,8	0,6
300 V	n =	8	8	8	8	8	8
	Minimum	19,7	118,4	38,0	77,5	36,3	2,6
	Maximum	29,2	419,3	63,1	188,1	145,1	7,1
	Range	9,5	300,9	25,1	110,6	108,8	4,5
	Mean	24,3	248,8	47,2	121,0	67,0	5,0
	Standard Dev.	3,1	93,8	9,2	42,1	36,8	1,7
	Standard Err.	1,1	33,2	3,3	14,9	13,0	0,6
350 V	n =	8	8	8	8	8	8
	Minimum	20,8	148,7	42,0	76,4	24,6	3,3
	Maximum	24,9	270,4	54,3	208,1	209,5	8,4
	Range	4,1	121,7	12,3	131,7	184,9	5,1
	Mean	23,2	208,2	48,8	129,0	97,5	5,6
	Standard Dev.	1,5	40,4	4,8	42,1	57,8	1,8
	Standard Err.	0,5	14,3	1,7	14,9	20,4	0,6
	100/200 (df = 14)	NS	1,869 (P=0,1)	2,707 (P=0,02)	6,098 (P=0,001)	NS	4,647 (P=0,001)
	100/300 (df = 14)	NS	NS	2,189 (P=0,05)	3,902 (P=0,01)	2,421 (P=0,05)	3,728 (P=0,01)
	100/350 (df = 14)	NS	NS	3,245 (P=0,01)	4,421 (P=0,001)	2,945 (P=0,01)	4,395 (P=0,001)
	200/300 (df = 14)	NS	NS	NS	NS	NS	NS
	200/350 (df = 14)	NS	2,606 (P=0,02)	NS	NS	NS	NS
	300/350 (df = 14)	NS	NS	NS	NS	NS	NS

df = degree of freedom; P = two-tailed probability; NS = not significant

TABLE 2 The effects of water temperature on opercular recovery time, narcosis time and recovery time in *O. mossambicus* subjected to rectified current electronarcosis at 200 Vp

		Length (cm)	Mass (g)	Opercular recovery time (s)	Narcosis time (s)	Recovery time (s)	Narcosis coefficient (s cm^{-1})
15 °C	n =	8	8	8	8	8	8
	Minimum	24,2	265,4	66,3	171,0	76,7	6,4
	Maximum	28,8	432,3	263,7	296,4	264,3	12,2
	Range	4,6	166,9	197,4	125,4	187,6	5,8
	Mean	26,4	324,5	117,8	234,4	170,4	9,0
	Standard Dev.	1,8	63,9	72,9	46,6	65,3	2,2
	Standard Err.	0,7	26,1	29,7	19,0	26,6	0,9
20 °C	n =	8	8	8	8	8	8
	Minimum	22,4	207,9	37,0	97,3	4,2	3,9
	Maximum	28,4	366,7	97,0	182,7	127,8	8,2
	Range	6,0	158,8	60,0	85,4	123,6	4,3
	Mean	25,5	275,0	59,6	137,4	58,1	5,5
	Standard Dev.	2,1	60,2	21,5	33,7	44,7	1,6
	Standard Err.	0,8	21,3	7,6	11,9	15,8	0,6
25 °C	n =	8	8	8	8	8	8
	Minimum	23,0	199,9	37,8	67,8	12,5	2,9
	Maximum	28,5	369,0	103,6	179,5	107,9	7,5
	Range	5,5	169,1	65,8	111,7	95,4	4,6
	Mean	24,7	247,4	61,0	121,0	65,9	4,9
	Standard Dev.	2,0	67,8	19,5	36,2	33,3	1,4
	Standard Err.	0,7	24,0	6,9	12,8	11,8	0,5
	't' Values (df)						
	15/20 (14)	NS	NS	2,140 (P=0,05)	4,777 (P=0,001)	4,014 (P=0,001)	3,639 (P=0,01)
	15/25 (14)	1,787 (P=0,01)	2,341 (P=0,05)	2,129 (P=0,1)	5,440 (P=0,001)	4,032 (P=0,01)	4,447 (P=0,001)
	20/25 (14)	NS	NS	NS	NS	NS	NS

appeared to follow a set pattern, with 100 Vp producing the fastest recovery at 31,7 s and 350 V the slowest at 97,5 s. Optimum narcosis time was at 200 Vp and this potential, therefore, was used in further investigations on the narcotizing effects of rectified currents on the experimental fish.

TABLE 3 The effects of duration of current flow on opercular recovery time, narcosis time and recovery time in *O. mossambicus* subjected to rectified current electronarcosis at 200 Vp

		Length (cm)	Mass (g)	Opercular recovery time (s)	Narcosis time (s)	Recovery time (s)	Narcosis coefficient (s cm^{-1})
15 s	n =	8	8	8	8	8	8
	Minimum	21,6	187,9	24,9	44,4	11,8	1,8
	Maximum	27,4	312,6	35,8	101,1	87,6	4,5
	Range	5,8	124,7	10,9	56,7	75,8	2,7
	Mean	24,4	241,6	31,3	65,4	35,3	2,7
	Standard Dev.	2,3	51,6	3,9	21,6	25,3	1,1
	Standard Err.	0,8	18,2	1,4	7,6	8,9	0,4
30 s	n =	8	8	8	8	8	8
	Minimum	22,4	207,9	37,0	97,3	4,2	3,9
	Maximum	28,4	366,7	97,0	182,7	127,8	8,2
	Range	6,0	158,8	60,0	85,4	123,6	4,3
	Mean	25,5	275,0	59,6	137,4	58,1	5,5
	Standard Dev.	2,1	60,2	21,5	33,7	44,7	1,6
	Standard Err.	0,8	21,3	7,6	11,9	15,8	0,6
45 s	n =	8	8	8	8	8	8
	Minimum	22,8	187,6	42,9	115,2	22,2	5,0
	Maximum	25,8	277,2	70,6	224,4	177,5	9,5
	Range	3,0	89,6	27,7	109,2	155,3	4,5
	Mean	23,7	225,3	57,8	161,6	76,1	6,8
	Standard Dev.	0,9	25,2	12,1	37,2	53,9	1,5
	Standard Err.	0,3	8,9	4,3	13,1	19,0	0,5
60 s	n =	8	8	8	8	8	8
	Minimum	21,4	159,8	45,6	77,6	35,6	3,4
	Maximum	28,1	317,1	69,3	157,1	146,6	5,8
	Range	6,7	157,3	23,7	79,5	111,0	2,4
	Mean	24,7	241,8	58,1	112,6	89,8	4,6
	Standard Dev.	2,5	63,5	9,0	26,7	38,7	1,1
	Standard Err.	0,9	22,4	3,2	9,4	13,7	0,4
75 s	n =	8	8	8	8	8	8
	Minimum	20,8	159,2	53,3	121,6	47,3	5,9
	Maximum	27,0	323,4	140,1	274,6	196,2	10,6
	Range	6,2	164,2	86,8	153,0	148,9	4,7
	Mean	23,9	236,7	98,9	193,1	94,1	8,0
	Standard Dev.	2,2	57,1	33,4	50,4	52,7	1,7
	Standard Err.	0,8	20,2	11,8	17,8	18,6	0,6
90 s	n =	8	8	8	8	8	8
	Minimum	24,0	192,7	76,3	181,1	36,1	6,6
	Maximum	27,3	321,7	114,0	284,5	165,4	11,8
	Range	3,3	129,0	37,7	103,4	129,3	5,2
	Mean	25,1	248,3	98,4	223,3	119,5	8,9
	Standard Dev.	1,1	39,0	13,7	32,9	43,5	1,6
	Standard Err.	0,4	13,8	4,8	11,6	15,4	0,6
	15/30 (df = 14)	NS	NS	3,663 (P=0,01)	5,087 (P=0,001)	NS	4,079 (P=0,001)
	15/45 (df = 14)	NS	NS	5,896 (P=0,001)	6,325 (P=0,001)	1,938 (P=0,1)	6,234 (P=0,001)
	15/60 (df = 14)	NS	NS	7,728 (P=0,001)	3,887 (P=0,01)	3,334 (P=0,01)	3,454 (P=0,01)
	15/75 (df = 14)	NS	NS	5,686 (P=0,001)	6,587 (P=0,001)	2,845 (P=0,02)	7,403 (P=0,001)
	15/90 (df = 14)	NS	NS	13,324 (P=0,001)	11,348 (P=0,001)	4,732 (P=0,001)	9,032 (P=0,001)
	30/45 (df = 14)	2,228 (P=0,05)	2,154 (P=0,05)	NS	NS	NS	NS
	30/60 (df = 14)	NS	NS	NS	NS	NS	NS
	30/75 (df = 14)	NS	NS	2,798 (P=0,02)	2,598 (P=0,05)	NS	3,029 (P=0,01)
	30/90 (df = 14)	NS	NS	4,305 (P=0,001)	5,159 (P=0,001)	2,784 (P=0,02)	4,250 (P=0,001)
	45/60 (df = 14)	NS	NS	NS	3,027 (P=0,01)	NS	3,345 (P=0,01)
	45/75 (df = 14)	NS	NS	3,272 (P=0,01)	NS	NS	NS
	45/90 (df = 14)	2,786 (P=0,02)	NS	6,282 (P=0,001)	3,514 (P=0,01)	1,772 (P=0,1)	2,708 (P=0,02)
	60/75 (df = 14)	NS	NS	3,336 (P=0,01)	3,992 (P=0,01)	NS	4,749 (P=0,001)
	60/90 (df = 14)	NS	NS	6,954 (P=0,001)	7,390 (P=0,001)	NS	6,264 (P=0,001)
	75/90 (df = 14)	NS	NS	NS	NS	NS	NS

df = degree of freedom; P = two-tailed probability; NS = not significant

Effects of temperature

The physical effects of electronarcosis at different water temperatures on the fish are presented in Table 2 and illustrated in Fig. 2. Although there were significant differences in mean length and mean mass between the fish used in the 15 °C experiment and those used at 25 °C, these differences were only 1,7 cm and 77,1 g, respectively and at the calculated narcosis coefficient values for the fish at the two temperatures the length difference represents a maximum effect on narcosis time of 15.3 s and a minimum effect of 8.3 s. It is clear that these differences could not have had appreciable effects on the results obtained. Mean opercular recovery time at 15 °C was somewhat longer than at higher temperatures but there was no significant differences between mean opercular time at 20 °C and that at 25 °C. The fish at 15 °C remained narcotized for periods highly significantly longer (P = 0,001) than did fish at the two higher temperatures. At the higher temperatures there was no significant difference in narcosis times.

There was a highly significant difference (P = 0,001) between the mean narcosis coefficients of fish kept at 15 °C and those held at 25 °C. The mean narcosis coefficient at 15 °C was also significantly greater (P = 0,01) than

TABLE 4 The effects of 100 Vp rectified current electronarcosis at different frequencies on opercular recovery time, narcosis time and recovery time in *O. mossambicus*

		Length (cm)	Mass (g)	Opercular recovery time (s)	Narcosis time (s)	Recovery time (s)	Narcosis coefficient (s cm^{-1})
59 Hz	n =	8	8	8	8	8	8
	Minimum	21,5	155,7	25,0	49,5	20,0	1,2
	Maximum	28,1	314,2	49,2	83,1	54,9	3,5
	Range	6,6	158,4	24,2	33,6	35,0	2,2
	Mean	24,1	220,0	37,4	60,9	31,7	2,4
	Standard Dev.	2,4	57,5	8,7	11,2	11,8	0,7
	Standard Err.	0,8	20,3	3,1	3,9	4,4	0,2
100 Hz	n =	8	8	8	8	8	8
	Minimum	21,0	155,0	17,2	69,9	11,6	2,9
	Maximum	27,7	355,3	48,6	169,0	64,9	7,6
	Range	6,7	200,3	31,4	99,1	53,3	4,7
	Mean	23,8	231,2	30,3	95,3	39,8	4,0
	Standard Dev.	2,5	69,8	12,1	32,9	20,1	1,5
	Standard Err.	0,9	24,7	4,3	11,6	7,1	0,5
200 Hz	n =	8	8	8	8	8	8
	Minimum	19,3	111,8	15,6	35,8	15,6	1,4
	Maximum	27,5	323,4	31,8	108,4	207,4	4,4
	Range	8,2	211,6	16,2	72,6	191,8	3,0
	Mean	24,5	245,0	26,4	54,8	90,2	2,2
	Standard Dev.	2,3	60,2	7,0	25,6	63,2	1,0
	Standard Err.	0,8	21,2	2,5	9,0	22,4	0,3
	't' Values (df)						
	50/100 (14)	NS	NS	NS	2,800 (P=0,02)	NS	2,510 (P=0,05)
	50/200 (14)	NS	NS	2,786 (P=0,02)	NS	2,574 (P=0,05)	NS
	100/200 (14)	NS	NS	NS	2,748 (P=0,02)	2,149 (P=0,05)	2,824 (P=0,02)

df = degree of freedom; P = two-tailed probability; NS = not significant

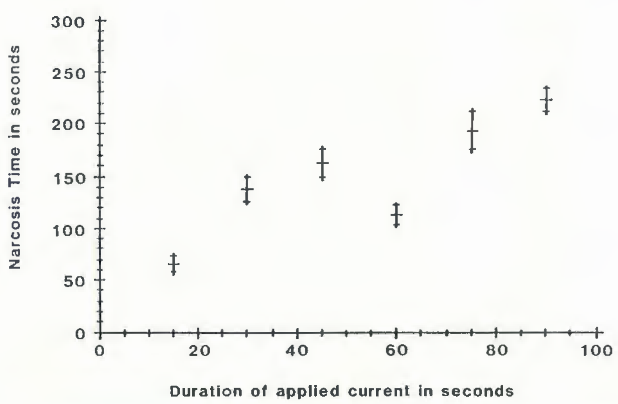

FIG. 3 The effect of duration of current flow on the mean narcosis time (± SE) in *O. mossambicus* subjected to rectified current electronarcosis

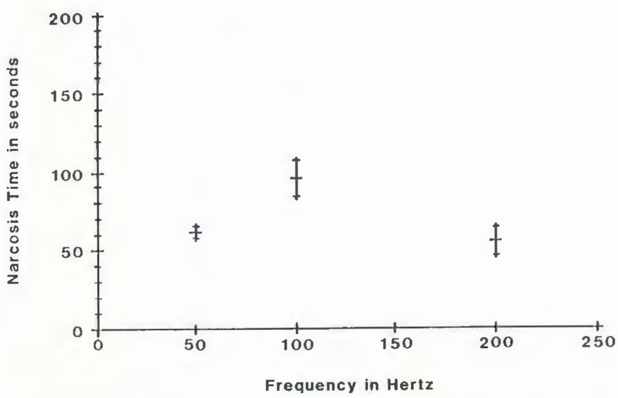

FIG. 4 The effect of 100 Vp rectified current electronarcosis at different frequencies on the mean narcosis time (± SE) in *O. mossambicus*

that at 20 °C. This suggests that the relatively small difference in mean lengths, as well as in the difference in mean mass, were probably not important factors in determining the different narcotizing effects observed at the two higher temperatures. Recovery times also followed a similar pattern with fish at the lowest temperature taking the longest time to recover. It must be noted that the optimum mean narcosis time was at 15 °C. This phenomenon can perhaps be related to the fact that this fish is a warm water species.

Effect of duration of application

The results of an experiment to evaluate the effects of duration of application of a rectified current on *O. mossambicus* are given in Table 3 and illustrated in Fig. 3. These results are in general agreement with the results achieved in a similar experiment using alternating current (Barham *et al.*, 1988)

Narcosis time increased with application time up to 45 s but, at 60 s application time, was significantly shorter (P = 0,01) than at 45 s. Further increases in application time up to 90 s resulted, once again, in increased narcosis time. This trend is also apparent when comparing the mean narcosis coefficients.

Although application times of 75 and 90 s produced opercular recovery times which ranged from significantly longer (P = 0,02) to highly significantly longer (P = 0,001) than shorter application times, there were no appreciable differences between opercular recovery times at application times of 30, 45 and 60 s.

Mean recovery times showed a general increase with increasing application time, although there was considerable variation within a group. This intra-group variation in recovery times appears to be common to all the experiments conducted in this study.

Effects of frequency

This particular aspect of the study was limited to 100 Vp as the apparatus configuration, using the a.c. amplifier was not able to produce higher potentials in the unit.

It is interesting to note from Table 4 and Fig. 4 that, although the mean opercular recovery time is somewhat shorter at 200 Hz than at 50 Hz, this is not the case for narcosis times, where there was no significant difference between the duration of narcosis at 50 Hz and at 200 Hz. In contrast, while mean opercular recovery time at 100 Hz did not differ significantly from the time at the other frequencies, the mean narcosis time at this frequency was significantly longer (P = 0,02) than at either 50 Hz or 200 Hz. At 4,0 s cm^{-1} the narcosis coefficient for 100 Hz was also somewhat higher than for either of the other two frequencies.

DISCUSSION

In the past no clear distinction was made between narcosis induced by an electric current and paralysis caused by an electric current. In the case of paralysis a fish will swim away as soon as the current is switched off. Where true narcosis is induced the fish will remain immobilized and relaxed for a period after the current is disconnected. In the present series true narcosis was always induced by all the electrical configurations used, the fish remaining limp and unresponsive for varying periods after the current had been switched off.

The results show that a half-wave rectified current will induce narcosis in the freshwater bream *O. mossambicus* and that a potential of 200 Vp is adequate to produce a sustained narcosis for 140 s. This compares favourable with the 156,8 s produced by a 60 Vrms, 50 Hz, sine wave current (Barham *et al.*, 1988). Although a frequency of 100 Hz produced the longest narcosis times, the results achieved at 50 Hz are adequate and more practical in terms of unit design.

The effect of water temperature on narcosis times is in agreement with that obtained for alternating current (Barham *et al.*, 1988) and may perhaps be due to temperature induced changes in the cell membranes.

The decrease in mean narcosis time after 60 s of current application is in general agreement with the results observed by Barham *et al.*, (1988) for alternating current. The reason for this phenomenon is not clear. Further investigation into this aspect will no doubt prove fruitful.

This series, consisting of three parts studying the narcotic effects of electro-anaesthesia, has shown that fish length is an important consideration in determining the narcotic potential of an electrical current in the tilapiine fish *O. mossambicus*.

The narcotic coefficient derived from the ratio of narcosis time to fish length (Barham *et al.*, 1987b) can be a useful tool in predicting the duration of narcosis for a given size of fish. Further refinement of this formula involving a biological constant should make these predictions more accurate.

Variations in opercular times and recovery times for both alternating and rectified currents would not normally be major considerations in evaluating narcotic potentials. The actual period of narcosis must be the major criterion when evaluating the narcotic effects of an electric current.

In contrast to chemical anaesthesia using benzocaine hydrochloride, where recovery from aneasthesia appears traumatic, with the fish undergoing periods of violent swimming activities (personal observation), recovery from both forms of electronarcosis studied appears uneventful.

This series of investigations has clearly shown that both alternating and rectified current electronarcosis produced adequate periods of anaesthesia in *O. mossambicus* for most routine laboratory procedures. Although an elaborate alternating current unit was employed in the study, a 60 Vrms, 50 Hz or similar current can usually be be obtained in most laboratories, using the main supply and a suitable transformer. It must be emphasized in the interests of operator safety that electronarcosis units, in all instances, must be isolated from the main supply. This configuration should be within the means of most laboratories. In contrast, a rectified current electronarcosis unit requires a more elaborate system.

Thus, based on a consideration of the narcotic effects obtained and with due consideration to the circuit practicalities, alternating current electronarcosis at 60 Vrms, 50 Hz, appears to be the electronarcosis procedure of choice for *O. mossambicus*.

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