Electronarcosis of the yabby, *Cherax destructor* (Clark)

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ABSTRACT

Both chilling and chemical bath agents are inconveniently slow for anaesthesia of crayfish, generally having induction times of about an hour and recovery times of even longer. The use of electricity as a means of inducing narcosis or anaesthesia in crayfish was investigated using the yabby, *Cherax destructor*, as a test crayfish. It was found that under suitable conditions, narcosis of adult yabbies could be achieved within thirty seconds, and the duration of narcosis was about 10 minutes. The main factor limiting the application of DC electricity for narcosis was the water conductivity.

Keywords: crayfish, anaesthesia, electroanaesthesia, electronarcosis, direct current

I. INTRODUCTION

In a previous paper (McRae et al. 1999) a study of methods for inducing anaesthesia in yabbies was reported, using a bath treatment to provide an alternative to chilling and to avoid stressing the animals by handling and injection. The most promising of these were diethyl ether and clove oil or eugenol, which are non-polar agents that pass through the chitinous cuticle. However, the rate of induction of anaesthesia was slow and the recovery times were also long – the entire procedure taking several hours.

It has long been known that electricity can disrupt nerve function, and has been applied in electrofishing techniques for many years (Cowx and Lamarque 1990). The effects of electricity include electrogalvanism (muscle contractions leading to twitching or rigidity (tetany)); electrotaxis (the tendency to orient to or move within an electric field); electronarcosis or galvanonarcosis (immobility resulting from muscular relaxation); and, in the case of crayfish, electroautotomy (casting off of claws and legs, probably from severe electrogalvanism).

Electrofishing equipment is designed to produce a range of waveforms including steady direct current (DC), pulsed DC, alternating current (AC), half-wave and full-wave rectified AC and multi-phase rectified AC. In the case of both pulsed DC and AC, the frequency may be controlled, and for pulsed DC, the mark-space ratio may also be varied. Studies on finfish suggest that the most likely waveform to induce controllable electronarcosis would be DC or perhaps pulsed DC at low field levels (Cowx and Lamarque 1990). Because electrofishing equipment is intended for field application, the voltages and available power are much higher than would be required in an aquarium, so specific power supplies were needed.
This study, therefore, was an investigation of the potential for using low power DC for rapid induction of narcosis in freshwater crayfish, using the yabby, \textit{Cherax destructor} (Clark), as the test animal. An important consideration in the study was that electroautotomy should be minimised, or completely eliminated, since the objective was to develop a tool for stress-free laboratory manipulation of crayfish.

\section*{II. MATERIALS AND METHODS}

Adult \textit{Cherax destructor} (20–90 g) were obtained from a commercial source in south western Victoria (Domo’s Yabbies, Edenhope). The yabbies were sex segregated and maintained indoors in 600 L troughs at ambient temperatures (15–22 $^\circ$C) with internal biofiltration systems; they were fed a maintenance diet of commercial yabby pellets (Kinta yabby pellets, 21% protein). Excess refugia were provided. Water quality was monitored for pH, nitrite, nitrate and ammonia to verify biofilter function, and water was exchanged when nitrate concentration reached 150 mg L$^{-1}$. The light regime was 14:10 h light:dark, provided by fluorescent tubes.

Most anaesthetisation experiments were carried out on individual yabbies in glass aquaria measuring 13x22.5 cm to which 2 L of water was added (depth 6.8 cm). Two experiments were carried out with groups of yabbies in a larger aquarium (33x54x5.6 cm containing 10 L of water). The aquaria were fitted with stainless steel plate electrodes that completely covered the ends of the aquaria so that the electric field (in the absence of yabbies) would be uniform throughout the water. Plastic mesh was placed over the electrodes so that the yabbies could not make direct contact with the metal.

Direct current was applied to the electrodes from laboratory power supplies intended for vacuum tube electronics experiments (BWD Electronics P/L, Melbourne, Models 215 and 225). These provided regulated constant voltage output. A milliammeter was placed in series with the electrodes, as shown in Fig. 1.

The experimental procedure was to:

a) fill the aquarium with water from the holding trough  
b) adjust the conductivity if necessary by adding salt  
c) place a yabby in the tank and allow it to resume normal behaviour  
d) turn on the current for a controlled time, and then  
e) remove the yabby to a recovery tank.

The yabby was placed upside down in a recovery tank so that the movement of the appendages could be observed. The anaesthetisation time was defined as that time for which the yabby showed no response to touching with a probe, and no visible appendage movement. The recovery time was defined as the time it took for the yabby to right itself.
Using this general procedure, 4 different aspects of electro-anaesthetisation were investigated. These were:

a) the effect of current duration  
b) the effect of water conductivity  
c) the effect of repeated anaesthetisation, and  
d) the efficacy of simultaneous anaesthetisation.

For the first two aspects, randomly selected yabbies were subjected to each set of conditions. Statistically significant differences were assessed only by pairwise t-tests of differences between means at a significance level of 0.05, since the study was intended only to explore the range of experimental conditions for electronarcosis.

With the exception of the three yabbies selected for the repeated anaesthetisation experiment, no yabby was subjected to the process more than once.

III. RESULTS

General observations

When the current was turned on, the yabbies exhibited an initial escape reaction, then entered a period of convulsive tetany for a few seconds — that is, the legs and antennae jerked in an uncoordinated manner. There was normally an extension of the antennal scales, and the animal aligned itself along the electric field with the head towards the anode. During the remainder of the steady current, the yabby exhibited rigid galvanotetany which persisted for some tens of seconds after current was switched off. The body then became relatively limp, leaving the yabby in a state of galvanonarcosis. There was still some muscle tone, since the antennal scales were not retracted. In this state, the yabby could be handled, with no response to tactile stimuli.
As the effects wore off, the initial signs of recovery were beating of pleopoda and uncoordinated leg movements – if the yabby was upright, it was unable to walk properly. The last major response to return was the opening and closing of the dactyls. The recovery time could be reduced by stimulation - for example by manually manipulating the walking legs, or by permitting contact interaction with other yabbies in the recovery tank. The recovery time was generally less than anaesthesia time.

During the study, 210 yabbies were narcotised, and only one did not recover. Post mortem examination revealed that this female was on the point of spawning. One yabby lost a claw during an attempt to narcotise it in water with too high a conductivity, but no other autotomy was observed.

**Conditions required for electronarcosis**

Figure 2 shows the effect of varying the time for which the current was applied to the yabbies. The data for each induction time were obtained from 10 replicate experiments and the error bars represent the 95% confidence range for the mean electronarcosis duration. If only 10 seconds induction was used, only 50% of the yabbies became narcotised. For the experiments at 50 seconds induction time, the data are biased by the observation from one yabby which remained narcotised for 94 minutes. If this value is removed from the data set, the mean duration falls from 29 minutes to 21 minutes. (This particular yabby had a weight of only 7 g, but there is insufficient evidence to conclude any correlation of narcosis duration and yabby weight.)

Figure 3 shows the variation in electronarcosis duration for different fresh water conductivities at a constant voltage. The measured initial current was proportional to the conductivity. It is apparent that for very low conductivity, insufficient current passes through the yabby to cause any significant effect. Similarly, at the highest conductivity tested, the majority of the current passes around the yabby and therefore it is protected. The experiments were carried out on replicates of 10 yabbies, and there was no statistically significant difference in mean electronarcosis duration at water conductivities between 335 and 1100 μS cm⁻¹. At a conductivity of 2200 μS cm⁻¹, the mean duration was significantly reduced. Therefore, at an applied field of 2.44 V cm⁻¹, electronarcosis can be achieved successfully with a water conductivity of between approximately 300 and 1200 μS cm⁻¹.

**Simultaneous and repeated electronarcotisation**

The simultaneous narcotisation experiment was carried out in the larger (10 L) aquarium with 10 and 15 yabbies at a time using water with a conductivity of 470 μS cm⁻¹, a field strength of 2.78 V cm⁻¹ and an induction time of 40 seconds. All 35 yabbies used became anaesthetised, although for different periods. The mean duration was 10.3 minutes (range 1 to 32; standard deviation 7.7). The recovery times of these animals were not determined.

Three female yabbies were re-narcotised twice more at intervals of 4 weeks. The data for these are shown in Table I. The mean electronarcosis duration for the smallest female was significantly less than that for the larger specimens; however, this trend is not reflected in the data for yabbies which had only been narcotised once. This suggests that each individual has
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Figure 2. Duration of narcotic effects of direct current applied to *Cherax destructor*. Error bars show 95% confidence intervals for mean electronarcosis duration \((n = 10)\). Applied field = 2.44 V cm\(^{-1}\), water conductivity = 475 \(\mu\)S cm\(^{-1}\).

Figure 3. Effect of water conductivity on duration of electronarcosis of *Cherax destructor* induced by direct current at 2.44 V cm\(^{-1}\). Error bars show 95% confidence intervals for mean duration \((n = 10)\)."
Mature males (>35 g) ejaculated spermatophores under the influence of the current; but there were no other apparent adverse effects. On the day following the treatment, yabbies had returned to normal eating patterns. There was no apparent change in moulting behaviour. There was also no apparent adverse effect on reproductive behaviour. This was discovered accidentally, since one of the “females” had been mis-identified, and was functionally a male intersex yabby. Two of the electronarcotised females subsequently spawned and one carried the eggs to a successful hatching before the completion of the study. The electronarcosis treatment had the effect of dislodging and killing external parasites - both flatworms (Temnocephala spp.) and threadworms were dislodged and found dead on the bottom of the aquarium.

### IV. DISCUSSION

The initial impetus for experiments described here was in response to increasing societal pressure concerning animal welfare. The experiments were limited to adult yabbies since much of the current laboratory research with these crayfish is concerned with reproduction for aquaculture purposes. Previous work (McRae and Mitchell 1997) had demonstrated that overnight cooling from 22 to 10 °C initiated ovarian development, and therefore interfered with experimental protocols for studying ovarian development. Chilling was also ineffective as a means of narcotising yabbies acclimated to temperatures of 10 °C. Subsequent studies determined that the only effective anaesthetic agents which could be administered without injection were low polarity or volatile substances such as diethyl ether, halothane, chloroform or eugenol. These, however, proved still quite slow to act and involved long recovery times (McRae et al. 1999). They also carried a measurable toxicity risk.

Electrofishing is a technique that provides a very rapid response and stuns fish. Correctly used, it will attract swimming fish to the anode and when the field is sufficiently high, causes galvanotaxis or galvanonarcosis, and the stunned fish can simply be collected using a dip-net. It is not, however, routinely used for harvesting crustaceans. Westman et al. (1979) have reported on the use of electrofishing techniques for surveying freshwater crayfish, and Phillips and Scolaro (1980) reported that a 50 Hz AC field of approximately 10 V m⁻¹ sustained for 5
minutes immobilised rock lobsters (*Panulirus cygnus* George) for several minutes. This result, however, was almost certainly not electronarcosis, because an even higher field was used to induce the lobsters to move out of shelter. Electrofishing is designed for field situations, and to provide the desired effectiveness and range the equipment often must provide high voltages or high currents. The critical parameter that governs the effect of electricity on a nerve is usually expressed as the electric field and is reported in V cm\(^{-1}\). However, what is probably more important in both electrofishing and in the experiments reported above is the current in the body of the crayfish or fish. Although this current is proportional to the electric field within the body of the animal, this field is not that provided by the electrofishing equipment.

The animal may be considered to be a resistor in series with a tube of water connecting the animal to the electrodes, but there is also a parallel resistor (water) which connects the electrodes directly. The electrical equivalent circuit is shown in Fig. 4. It can be deduced from the equation shown that the current \(I_a\) in the animal will be small if \(R_w\) is either very small or very large compared with \(R_a\). Thus, in freshwater, the water may be of such low conductivity as to be considered an insulator, and even though the equipment may be able to provide several thousand volts per metre, very little current flows, and therefore cannot influence the nerves in the animal. In seawater, the water is highly conductive and very large currents must flow to produce even small electric fields. The equipment used by Phillips and Scolaro (1980) required a 2.5 kVA generator to provide sufficient current.

In the laboratory, it is possible to adjust the water conductivity to facilitate control over the current in the animal. It is also possible to control the form of the electric field so that it is uniform, whereas electrofishing equipment generates a field which varies from quite low values at a distance from the anode to very high values close to the anode. Subjecting the fish or crayfish to high fields can cause serious stress and even injury to the animal. Westman et al. (1979) noted the electroautotomy induced in crayfish by electrofishing techniques. There

![Figure 4. Equivalent electrical circuit for electric fishing or electronarcotisation experiments.](image-url)
are many studies on the adverse effects of electrofishing in finfish (e.g. Burns and Lantz 1978; Hudy 1985; Sharber and Carothers 1988), including fractures of the vertebral column.

This study has made no attempt to investigate any adverse effects of DC on yabbies. However it is unlikely that they are serious under the conditions required for electronarcosis, since no autotomy was observed, nor was there any apparent disruption to feeding, reproductive or moulting behaviour. It is to be expected that some physiological changes would occur (Mitton and McDonald 1994), but since the application of the current lasts for less than a minute and the animal has returned to normal behaviour within an hour, it is likely that even these changes would be transient.

Of the effects observed in these experiments, the one that is of most concern is the convulsive galvanotetany observed when the current is initially turned on. Since this is directly attributable to the sudden rise in current, it may be possible to minimise or even eliminate the effect by controlling the initial waveform supplied by the power supply. Two options may be considered – having a slow rise time, or perhaps superimposing on the rise an alternating current component of sufficient frequency. This will be the object of future studies.

The technique described in this study provides a simple method of narcotising yabbies, with exceptional rapidity and safety. If the water conductivity is within the range of 300-1200 $\mu$S cm$^{-1}$, there is little risk of autotomy and high success rate. The duration of anaesthesia is similar to the alternative methods of chemical baths and chilling, but the recovery generally only takes about 10 minutes, so the entire procedure can be completed in less than an hour, in contrast to the several hours of the alternatives. The procedure may have some other uses in crustacean culture, such as external parasite treatment and artificial spawning.

REFERENCES

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