A RADIO TELEMETRY STUDY OF MOVEMENT IN THE GIANT TASMANIAN FRESHWATER CRAYFISH, *ASTACOPSIS GOULDI.*

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ABSTRACT

The movements of eight adult Tasmanian giant crayfish, *Astacopsis gouldi,* (carapace lengths: 120-191 mm) were recorded using radio telemetry. Transmitters were attached to the animals' carapaces and their positions were fixed at least daily. Tracking durations varied from 14-144 days, depending on the life span of the transmitters. All animals showed substantial periods of inactivity, lasting from 1 to 10 days; in one animal, inactivity appeared to be related to brooding. Activity was not strongly nocturnal, and when active, the animals moved large distances. One animal covered 700m in a single night, and the stream lengths over which animals were active during the 5-month study ranged from 90-2200m. Animals often returned to the same refuge after excursions.

Key words: telemetry, behaviour, crayfish activity.

INTRODUCTION

The giant freshwater crayfish, *Astacopsis gouldi* the largest freshwater crayfish in the world, is endemic to the rivers and streams of northern Tasmania (Hamr 1990, Growns 1993, Lynch and Bluhdorn 1997, DPIWE 2000). The species is associated with still and flowing water in all stream classes from sea level to an altitude of 400m (Horwitz 1994). Adults are reported to live in deep pools with good water quality, undercut but not eroding banks; little sediment, intact riparian vegetation and canopy cover over the steam (Lynch 1967, Lynch and Bluhdorn 1997, Hamr 1990, DPIWE 2000). *A. gouldi* is reported to build both type 1a and 1b burrows (Horwitz and Richardson 1990), and the diet of adults consists primarily of semi-decayed wood, leaves and detritus (Gould 1870, Forteath 1985).

Declines in abundance and possible local extinctions *A gouldi* have led to the listing of the species as 'Vulnerable' under both the *Commonwealth Endangered Species Protection Act 1992* and the *Tasmanian Threatened Species Protection Act 1995*, as well as being listed as a 'protected fish' under the *Inland Fisheries Act 1995* (DPIWE 2000). The causes of these declines have been primarily attributed to a combination of habitat disturbance and fishing pressure (Horwitz 1994, DPIWE 2000).

Little is known about the movement patterns and mobility of *A. gouldi.* The Recovery Plan for the species (DPIWE 2000) lists this as one of the key gaps in the knowledge required to facilitate the recovery and conservation of the species. Forteath (1987) reported movements between 60-100m over a seven day period of radio tracked *A. gouldi*, but no further information was published; and Growns (1993) reported movements of 500m over two to four weeks by two males and one berried female using mark-recapture techniques. Information on the species' movements is particularly relevant to ecological questions relating to possible barriers to movement, dispersal and colonisation, the possible upstream movement of ovigerous females, and the adequacy of current reserve sizes (DPIWE 2000).

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Several studies have investigated the movement patterns of freshwater crayfish using mark-recapture techniques (e.g. Momot 1966, Hazlett *et al.* 1974, Skurdal and Taugbol 1995). However, the data gained from these studies were limited, providing little information on individual crayfish movements between captures. Recent studies employing radio tracking have provided much more detailed information in this respect (e.g. Bohl 1999, Robinson *et al*. 2000, Gherardi and Barbaresi 2000).

The aims of this preliminary study were

- to trial the use of radio telemetry to investigate the ecology of *A. gouldi*, and
- to investigate the home range and movement patterns of *Astacopsis gouldi*.

MATERIALS AND METHODS

Studies were carried out on a 4km stretch of the Dip River, a brown water drainage surrounded by temperate rainforest in Northwest Tasmania. The river is characterised by riffle-pool sequences, with substrates ranging from cobbles to sand or exposed bedrock. The average channel width is approximately 13 m, and the deepest pools exceed 2m. Water temperatures ranged from 7^0C to 21^0C during the study, and water depths fluctuated by 40 cm.

Nine single stage radio transmitters (6 Sirtrack, 3 Telonics) were available with frequencies ranging from 150.1500 MHz to 151.1125 MHz. The frequencies of transmitters were spaced by a minimum of 50 kHz. CE386 batteries powered Sirtrack transmitters and 3.5V 200mah batteries powered Telonics transmitters. Transmitters were fitted with whip antennas and weighed from 35 to 50 gram. The smallest crayfish used was 120 mm CPL, which, according to Hamr (1996), would weigh approximately 500 g. Therefore the tag weight: body weight ratio was lower than in similar radio telemetry studies of other freshwater and marine crayfish (Robinson *et al* 2000, *Austropotamobius pallipes* Lereboullet, Smith *et al* 1998, *Homarus gammarus*). Each transmitter had a predicted working life of 4.5-5.5 months.

Crayfish were captured using ring nets baited with fish; animals used in the study ranged in size from 120-191 mm CPL. Due to the small number of transmitters available only sexually mature adults were investigated (5 females, 3 males). Two of the females were carrying eggs, but the transmitter on one of these berried females had to be replaced during the study due to battery failure.

Transmitters were attached to the carapace of crayfish using 5 min Araldite™. They were positioned so that the crayfish had full movement of the pereopods, and the transmitters were considered to be sufficiently small so as not to restrict mobility. Crayfish were held in a milk crate for 30-45 minutes while the transmitters were attached and subsequently released at the point of capture. Stress on each animal was reduced by keeping handling time to minimum and holding the animal in shaded shallow water whilst the glue dried.

Locations were gained using a Model CE 12 radio receiver (Custom Electronics, Urbana Inc.) and an AR1500 Wide Range Monitor. To determine the error factor associated with each radiolocation, trials were conducted by placing transmitters in the stream and testing the accuracy of the equipment. Transmitters could be located to within 60 cm., but further into the study it became apparent that in some situations accuracy decreased considerably, probably due to interference when animals were located in burrows or log piles. Consequently, a conservative estimate of locating accuracy was used. Animals were considered to be within a 1.5 m radius buffer around each point location (see Rettie and McLoughlin 1999), so apparent movements of less than 1.5 m were ignored.

RESULTS

Individual crayfish were tracked for periods of between 14 and 144 days (Table I). One crayfish (F5) could not be located following release, presumably due to transmitter failure. Compromises in relation to tracking precision (i.e. the time between radio locations) were necessary as a single observer conducted the study. During the first 11 days locations were gained approximately every 3 hours. From the 3/12/00 to the 23/2/01 three locations (approx. 8 hrs apart) were gained every 24 hours. For the remainder of the study one to two daily locations were obtained. Due to the time required to gain a single fix for two crayfish that made large movements (F4 and M3), these animals were only located every two to three days.

TABLE I

Tracking duration (number of days between attachment of transmitter and final location recorded), sex, size (CPL) and range of radio tracked crayfish.

Crayfish	CPL (mm)	Attachment date	Tracking duration (days)	Range (m)
F5	132	11/2/01	0	--
F1*	140	22/11/00	14	90
F3	175	14/12/00	43	240
F4	126	3/2/01	67	2065
M2	191	22/11/00	94	505
M3	120	22/12/00	110	2202
F2*	179	23/11/00, 14/2/01**	142	122
M1	165	21/11/00	144	870

* Berried female.

** When a new transmitter was attached to F2 on 14/2/01 she was no longer carrying eggs or young.

The movements of tracked crayfish were characterised by dispersal over both short and large distances, interspersed with stationary phases or periods of relative inactivity. All crayfish showed a high degree of residential behaviour and were found in a specific location or local area for extended periods. Periods of apparent inactivity lasting between one and 10 days occurred in all animals. Figure 1 shows the number of days between recorded movements for animals M1, M2, F2 and F3. Only tracking periods with at least 3 locations every 24 hours were used.

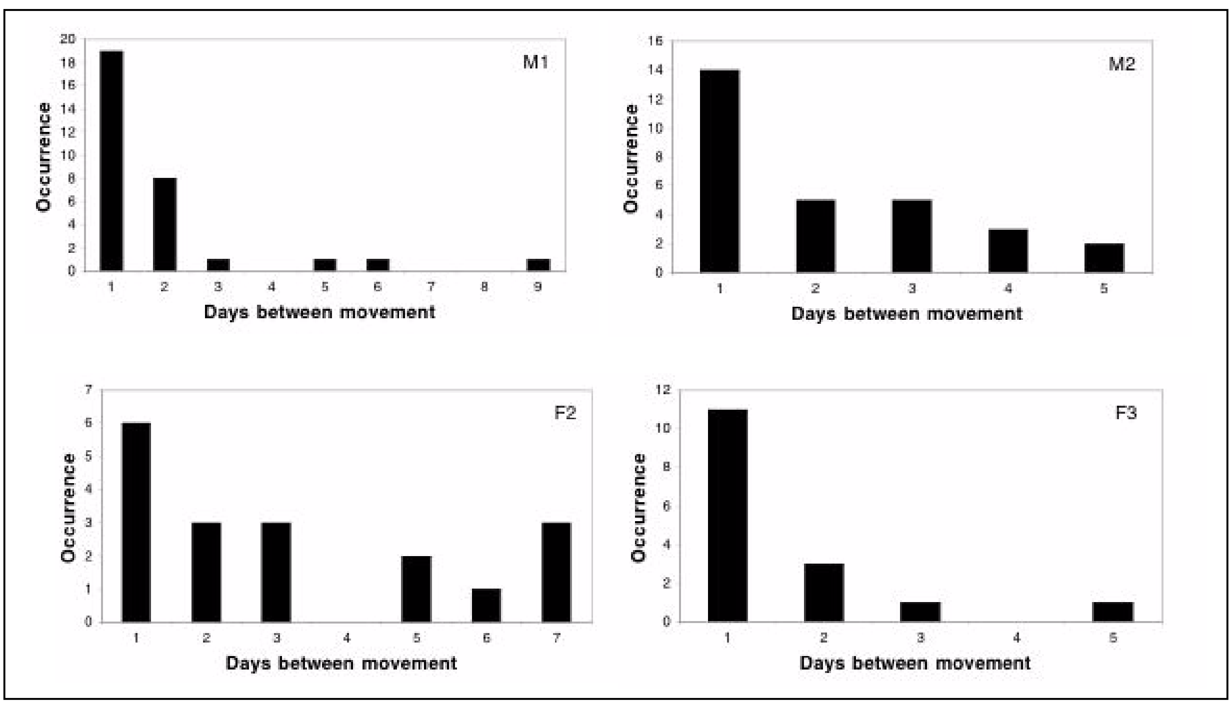


Figure 1. Number of days between recorded movements of four radio-tracked giant crayfish.

Patterns of upstream and downstream movements using the last location gained each day for an animal are shown in Figure 2a & b. During periods of high activity movements varied from several small-scale movements to large-scale excursions of up to 700 m in one night. Some small-scale movements are not well represented in Figure 2, either due to the scale required for the graph or because the animal made cross-channel movements. Furthermore, a 90 m downstream excursion made by a berried female (F1) is not shown in Figure 2a because the animal returned to the point of departure within during the same day.

Movements were often very localised (5-20m) and animals usually returned to the point of departure after making short excursions. This small-scale homing behaviour was recorded for all crayfish except F4. Following a period of residency, all crayfish except the two smallest animals (F4 and M3) made at least one large-scale excursion (>50 m), after which they returned either to the immediate point of departure, the same habitat patch or the same pool (Figure 2). Return times varied from 2 hrs-4 days. Animals F2 and M1 made several large-scale movements of this nature (<300 m), visiting several of the same sites during each excursion. After large-scale movements (>2 km) upstream and downstream by M3 and F4 respectively, neither animal moved back towards the point of departure (Figure 2b.).

Table 1 shows individual linear ranges in relation to carapace length (CPL) and tracking duration. There was considerable variation in the length of stream (i.e. range) used by different crayfish during the study (90 m – 2200 m). After making initial downstream movements all males increased their range in an upstream direction. No males were located again below the point of capture. Females tended either to increase their range in a downstream direction or remain in the same general area (Figure 2).

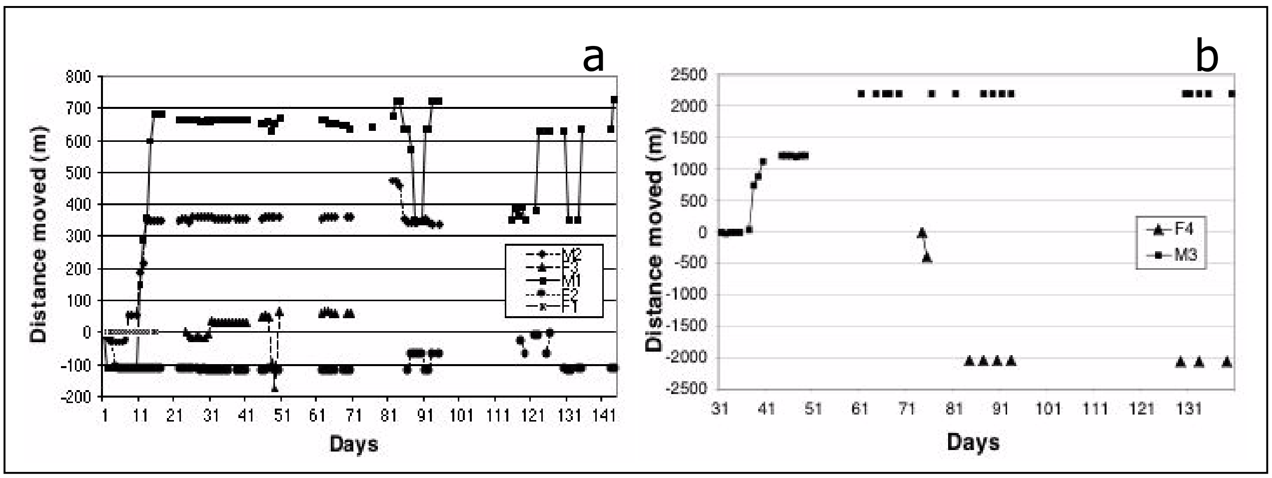
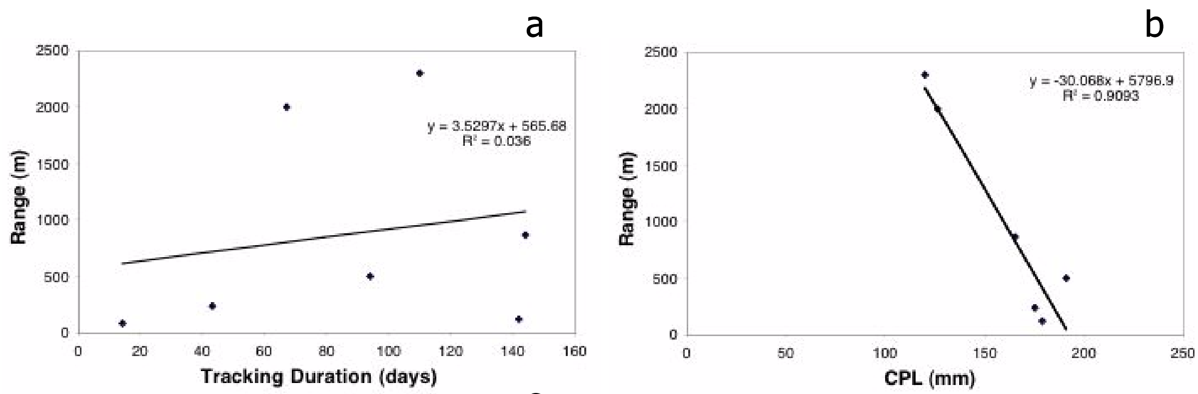


Figure 2. Patterns of daily upstream and downstream movements of radio-tracked giant crayfish. The spaces between unconnected points represent periods when no daily locations were obtained. Note the greater range of distances travelled in **b**.

All animals traversed the majority of their range within 31 days of having a transmitter attached (Figure 2). Range length was not correlated with the number of days tracked (Spearman's rank correlation n = 7, $r_s = 0.393$, $P > 0.05$) (Figure 3a.), suggesting that the study period was long enough to gain a good estimate of range size.

Figure 3b shows a strong correlation between carapace length and range size. Although there was no correlation between range length and tracking duration, to remove the temporal aspect associated with variations in tracking duration, range size was divided by the number of tracking days (i.e. range per day) for each animal (Figure 3c.). Carapace length and range per day also shows a strong correlation (Spearman's rank correlation n = 7, r_s = -0.929, $P < 0.01$).

Animals did not appear to follow any diel rhythm in their activity patterns. Small scale and large-scale movements were recorded during the day and at night, and periods of high activity or inactivity often spanned day and night. One crayfish (F4) was located only during daylight hours.



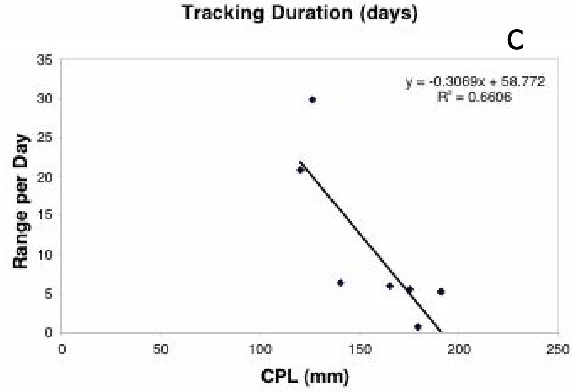


Figure 3. a) Apparent range size of 7 giant freshwater crayfish plotted against tracking duration; b) Apparent range size of 7 giant freshwater crayfish plotted against carapace length; c) Apparent daily range of 7 giant freshwater crayfish plotted against carapace length.

DISCUSSION

The large distances moved by several animals during the study are remarkable. The movements of some of the crayfish are among the largest recorded for any stream-dwelling freshwater crayfish. The apparent ability of animals to home to specific sites following large displacements is also quite striking.

In general, adult *A. gouldi* appear have two patterns in their movement and behaviour:

- residential periods, when animals may be inactive, or undertake small-scale movements, usually returning to specific "home site"; and
- less common large-scale movements, after which an animal takes up residence in a new "home site" or pool, or returns to its initial "home site".

During the first 11 days of the study (while the locating frequency was 3 hrs) it became apparent that *A. gouldi* might undergo extended periods of inactivity or at least restricted movement. Although it was not possible to maintain this locating frequency for the remainder of the study, subsequent data supported this initial finding. Figure 1 shows that *A. gouldi* may remain inactive for up to 9 days. These data were taken only from periods with consecutive days tracking and it is likely that some of these inactive periods extended into periods when no locations were gained. Some small-scale homing excursions may have gone undetected; however, these data contrast with active periods, when animals were found in a different location each day, and often several locations within 24 hours.

This pattern of active and inactive phases may be related to a number of potential variables (e.g. reproductive state, moulting, appetite and environmental conditions). There is evidence that some crayfish follow seasonal patterns in activity (e.*g. Pacifasticus leniusculus* Dana: Flint 1977, *A. pallipes*: Barbaresi and Gherardi 2001); and the marked increase in large scale movements by M1, M2 and F2 around day 80 of the study (Figure 2a), suggests that seasonal changes in environmental variables (eg. generally decreasing water temperatures and increasing flows) may influence the movement of *A. gouldi*. Animals M3 and F4 did not follow this same trend (Figure 2b), but the locating frequency was lower for these two animals.

The homing behaviour observed in most crayfish over small and large distances suggests that individuals have a preference for specific "home sites" to meet certain requirements. Furthermore, F2 and M1 were found to visit specific sites and pools during their large excursions before returning to their "home sites".

Studies of other freshwater decapods have found similar general patterns of movement. Gherardi *et al.* (1988) reported movements of short distances around shelters, followed by less common long distance displacements or wandering movements by the freshwater crab, *Potamon fluviatile*. Gherardi *et al.* (1998) and Robinson *et al.* (2000) found that *Austropotamobius pallipes* individuals remained in a restricted area, and rapid large movements followed this period of sedentary behaviour to new areas. Gherardi and Barbaresi (2000) reported a similar pattern in radio tracked *Procambarus clarkii* in rice fields and found that they returned to a general area after very large displacements over 4 days; however, no records appear to exist of stream dwelling crayfish returning to home sites over such large distances (e.g. M1, M2, F2)

As with other stream-dwelling crayfish (e.g. *O. juvenalis,* Merkle 1969, *O. virilis,* Hazlett *et al.* 1974, *A. pallipes,* Robinson *et al.* 2000), the ranges of crayfish varied considerably during the study. Although the small sample size and variations in tracking durations preclude any rigorous comparisons between individuals, the strong negative correlation between CPL and range size (Figure 3b & c) indicates that the size may be an influencing factor. Larger individuals may be better able to defend home ranges or "home sites", forcing smaller individuals to travel further to met their requirements. However, it should be noted that the sample size was small and this result was strongly influenced by large distances travelled by the two smallest crayfish, F4 and M3.

The movements of berried female F2 provided no evidence to support the idea of an upstream migration of ovigerous females prior to releasing young. Unfortunately, the failure of the first transmitter attached to F2 resulted in no locations being gained for 3 weeks, during which time she released her young. F2 was then captured in the same pool as her last record, but was no longer carrying young. Following the attachment of a second transmitter, F2's activity and large-scale movements increased considerably, suggesting that reproductive state may influence activity patterns. Hazlett *et al.* (1979) also reported similar patterns in ovigerous *Orconectes virilis*.

Although further investigation is required, it became apparent during the study that *A. gouldi* is neither strictly nocturnal nor diurnal. Freshwater crayfish and other decapods are reported as being primarily nocturnal animals (e.g. *O. virilis*: Hazlett *et al.* 1974, *Astacus Astacus*: Cukerzis 1988, *P. fluvitile*: Gherardi *et al.* 1988, *A. pallipes*: Barbaresi and Gherardi 2001). Predation is well documented to affect the behavioural patterns and distribution of freshwater crayfish (e.g. Englund and Krupa 2000, Englund 1999, Stein and Magnuson), and although it has yet to be proven (Gherardi 2002), nocturnal activity is often attributed to the avoidance of diurnal predators. The diurnal activity of *A. gouldi* may be related in part to its large adult size*,* which probably frees them from the risk of predation at any time of day or night.

This preliminary investigation has shown radio tracking to be a useful tool in collecting detailed movement information on individual *A. gouldi.* This study has shown that *A. gouldi* is considerably more mobile than previously thought and may travel considerable distances; as a result, mark recapture techniques may be ineffective for the investigation of the species' movements, since extensive lengths of stream will need to be sampled to gain an adequate number of recaptures.

Although no correlation was found between tracking duration and range size, the considerable temporal variation in large scale movement patterns (Figure 2) within individuals shows the need for extended tracking periods to gain an accurate representation of its ranging behaviour. Extended periods of apparent inactivity (Figure 1) and/or localised movements, and the lack of any obvious synchronicity of movement patterns between animals, further highlight this point. For example, animal M1 ranged over 870 m of stream during tracking. However, between day 16 and 82 of the study this animal was confined to a 50 m stretch of stream (Figure 2a). Similarly, M3 travelled over 2 km upstream during the first 31 days after transmitter attachment (from day 30-61 of the study), but was not located outside a 10 m stretch of stream for the remainder of the study (Figure 2b).

The capacity of *A. gouldi* to move over such large distances highlights the need for further investigation of the species' movement patterns in order to formulate effective conservation measures. If barriers to movement exist, such as culverts or degraded stream reaches, movement patterns may be significantly curtailed. Similarly, the size of reserves adequate for this species may have to be reviewed.

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