THE HOME RANGE OF SIGNAL CRAYFISH IN A BRITISH LOWLAND RIVER

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Introduction

The signal crayfish *Pacifastacus leniusculus* (Dana), a native of north-western North America, is now a common resident in some British fresh waters following its introduction to England in 1976 (Lowery & Holdich 1988). In 1984, signal crayfish were introduced into the River Great Ouse, the major lowland river in southern central England, where they have established a large breeding population, with a mean density of 15 per m^2 in riffles during summer and 2 per m^2 in pools. By the summer of 1994, they had occupied an 11.4 km section of river (Guan 1995).

The unexpected burrowing behaviour of signal crayfish in the river was reported by Guan (1994). Signal crayfish not only take natural shelters but they also dig extensive burrows in the mud banks of the river. They are typically nocturnal. In this study we have investigated crayfish movements and addressed two questions: (1), how large is the home range? [Burt's (1943) definition of home range was adopted here, i.e., "The area traversed by the individual in its normal activities of food gathering, mating, and caring for young"]; and (2), does the home range vary between sexes and crayfish of different sizes?

Study sites

Two sites near Thornborough Weir (map reference: OS 738355) were chosen for study. Site 1, about 30 m downstream from the weir, is 15 m wide, 60 m long, shallow on the south side (10 to 20 cm deep) and deeper on the north side (80 cm) with many crayfish burrows (5.6 per m of bank) in the clay bank. The bottom is compact and consists of sand, gravel, pebbles and cobbles. Site 2, about 50 m behind the weir, is 360 m long, 14 to 16 m wide and 1.5 to 2.0 m deep at midstream. The bottom is sand, gravel and clay. Macrophytes (mainly *Phragmites* spp.) are abundant along both clay banks. Water flow is much slower than that in Site 1. The section at Site 2 is straight and rather uniform in width and depth; both banks are full of crayfish burrows with a mean of 21 per m of bank.

Measuring the home range of signal crayfish

Several methods have been developed for the measurement and description of home range (see the review in Seber 1973), but none were useful in the present situation. Therefore, a new eletronic microchip system and a modified capture-mark-recapture method were employed in this study for Sites 1 and 2 respectively. In Site 1, the trapped crayfish were tagged with a microchip implant (Wiles & Guan 1993), released in the same locations where they were trapped, and detected with a probe (25 cm long and 1.5 cm in diameter). The probe was bound at one end of a bamboo stick which was waved over a crayfish detected in the light of an underwater torch.

In Site 2, sampling to study population dynamics was also designed to estimate crayfish movements. The width (15 m) of the site was assumed to be well within the home range of signal crayfish, as the distance of movement for the smaller cave crayfish *Orconectes inermis inermis* was estimated to be between 35.5 m and 67.4 m in a cave passage in the USA (Hobbs 1978). Thus only two dimensions of crayfish movement - upstream and downstream - needed to be considered. Site 2 was divided into eight locations (1 to 8 in upstream order) at intervals of 45 m, and preliminary weekly sampling by one trap in each location for one night was conducted from May to August 1992. Then a bimonthly sampling with two traps in each location for three consecutive nights was done from October 1992 to April 1994 (December 1992 was missed). The traps were cylindrical (50 cm long and 20 cm in diameter), plastic, and covered with polyethylene nets of 4 x 4 mm mesh, including inverted entry cones at both ends, to prevent small crayfish from escaping. Traps, baited with fish heads, were set in the late afternoon and emptied early in the following morning. Trapped crayfish were measured for their carapace length, and marked with a unique combined code (Guan 1997) by punching holes in the telson and uropods and by clipping the pleuron; they were released at the end of each sampling period in the locations where they were trapped. The distance of crayfish movement was then determined from the difference between the location of first capture and that of recapture, i.e. 22.5 m (half interval between locations) for crayfish recaptured in the release locations, 67.5 m (45 + 22.5 m) for crayfish recaptured at one location away from the release location, and so on.

Because of the relatively large size (13 x 2 mm) of the microchips used in this study and the size selectivity of trapping, only the movement of large crayfish (carapace length greater than 35 mm) was studied. Most of the small crayfish live in shallow riffles and hide in crevices between stones. At night they emerge and wander about, but immediately hide in the nearest crevice if disturbed. These small crayfish may have a very small home range or, possibly, they may not have a specific home and home range, as Burt (1943) considered for young animals.

The detection of signal crayfish tagged with implanted microchips, and their home range in Site 1

In September 1993, 414 crayfish were trapped in Site 1 and 398 (201 males and 197 females) were released in the same section of river after tagging with microchip implants. On release, some crayfish were seen to head immediately to a deep pool upstream just in front of Thornborough Weir, while some walked to the north bank and selected a burrow. Others just wandered into the relatively deep water on the north side and took a shelter under or by the stones on the bottom.

In the summer of 1994, four night visits to Site 1 from sunset to midnight were made to detect the tagged crayfish, by moving the probe over or near crayfish seen on the river bed. The codes of 23 crayfish tagged with implanted microchips, and the times and locations where they were found, were recorded. Most of these crayfish were repeatedly detected within Site 1 during 3 to 4 h of searching with the probe. During the same season, of 198 crayfish trapped from the adjacent pool upstream, six were tagged, whereas none of the 256 crayfish trapped from the pool about 100 m downstream was tagged. This suggests that few of the tagged crayfish went far downstream and the ranges of activity of the majority of crayfish are within the 190-m section between Thornborough Weir and an adjacent pool downstream.

In September 1994, one year after tagging and release, continuous trapping was done for a 2-week period to recover tagged crayfish. The results showed that 25 of 856 crayfish trapped from Site 1 were tagged, while only 9 of 1565 crayfish trapped from the upstream pool were tagged. This indicated that most of the tagged crayfish lived in Site 1.

The home range of signal crayfish in Site 2, estimated by capture-mark-recapture

In Site 2, 8,195 crayfish were trapped, of which 7,500 (4,771 males and 2,729 females) were marked on the telson, uropods and pleuron (see the section on measurement), and then released. 1,309 (973 males and 336 females) marked crayfish were subsequently recaptured. The percentages of repeatedly recaptured crayfish range from 0 to 2% in each sample, indicating there were few trap-addicted crayfish and sampling can be regarded as more or less random.

Laboratory experiments showed that some crayfish change their burrows or dig new burrows while others occupy the same burrows for several months (Guan 1994). Similarly, the lobster *Homarus americanus*, a close marine relative of crayfish, showed similar behaviour in field observations (Karnofsky et al. 1989). In our study, sampling covered a period of almost 2 years, many tagged crayfish were recaptured a long time (up to 23 months)

after their first capture, and some of these crayfish may have either relocated nearby or moved far away from their original burrows in the period between two captures. If crayfish in fact gradually moved away from their burrows, then one would expect that crayfish recaptured after a relatively long time interval would be further away from the site of first capture than those recaptured after a relatively short time.

This hypothesis was tested by comparing the frequencies and percentages of recaptures at locations in and away from the release locations, for two groups of crayfish recaptured at different intervals of time (Fig. 1). Crayfish in Group 1 were recaptured within 71 days of release, with a mean of 57 days for 244 males and 44 days for 106 females. Crayfish in Group 2 were recaptured at intervals between 71 days and 2 years, with a mean of 234 days for 729 males and 264 days for 230 females. Most of the Group 1 crayfish were recaptured in their release locations and those close by, whereas more of the Group 2 crayfish were recaptured far from their release locations (Fig. 1). A few recaptures of Group 1 crayfish far from their release locations appear to be due to occasional long-distance excursions.

The distance of crayfish movement in Group 2 was significantly greater ($p < 0.001$ for males and $p < 0.02$ for females; Chi-squared test on the frequencies of recaptures in each location) than that in Group 1, suggesting that a significant number of crayfish in Group 2 changed or shifted their home locations during the interval between two captures.

The data from Group 1 was then used for further estimates of the differences in crayfish movement between seasons and crayfish of different sizes, and the home range of crayfish.

For the differences in crayfish movement between October to February (winter) and March to September (growing season), only the data for males is sufficient for a Chi-squared test. Few females were recaptured, mainly due to their inactivity during the egg-hatching season, which obviously led to a narrower range of movement during this period than in the rest of the year. Nevertheless, there is no significant difference ($p > 0.05$) in the range of movements of male crayfish during these two periods (Fig. 2). Also, no significant difference ($p > 0.05$) was found in the range of movement between crayfish of different sizes (33 to 72 mm carapace length for males, and 39 to 64 mm carapace length for females) in both upstream and downstream directions.

The home range of crayfish was estimated separately for both sexes and both upstream and downstream directions. The frequencies of recaptures from one to six locations upstream from release locations 1 and 2 (recaptures at seven locations away from location 1 were omitted) were pooled to increase the data used for plotting against the distances of movement upstream (Fig. 3). Similarly, data from release locations 7 and 8 were pooled for plotting against the distances of movement upstream. When the results are fitted by

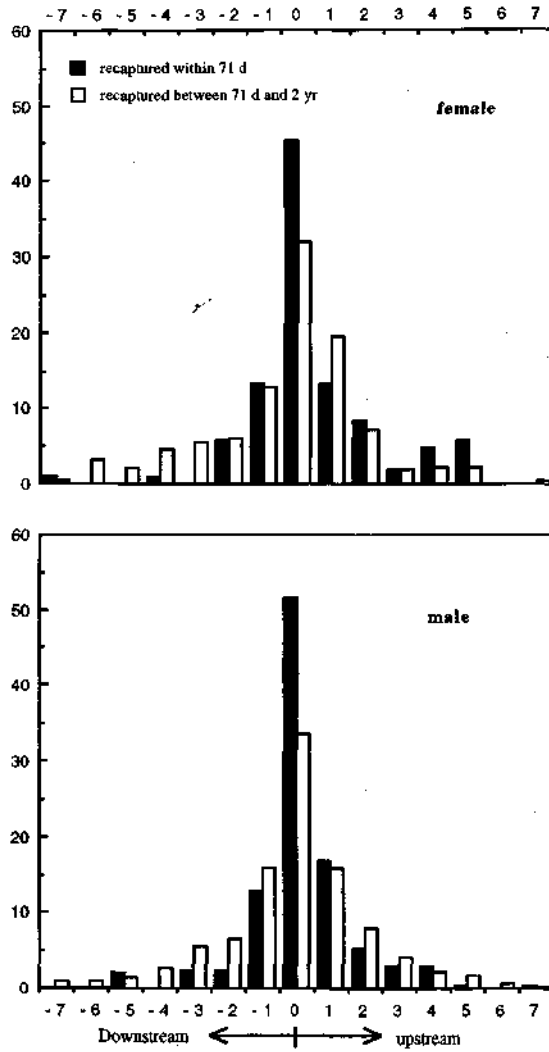

FIG. 1. Percentages of pooled recaptures of signal crayfish from equal numbers of locations upstream (1 to 7) and downstream –1 to –7 from the release location at Site 2 in the River Great Ouse. Crayfish recaptured between 71 days and 2 years after marking and release (open symbols, Group 2) are more widely spread out from their release locations ($p < 0.05$, Chi-squared test) than crayfish recaptured within 71 days (solid symbols, Group 1).

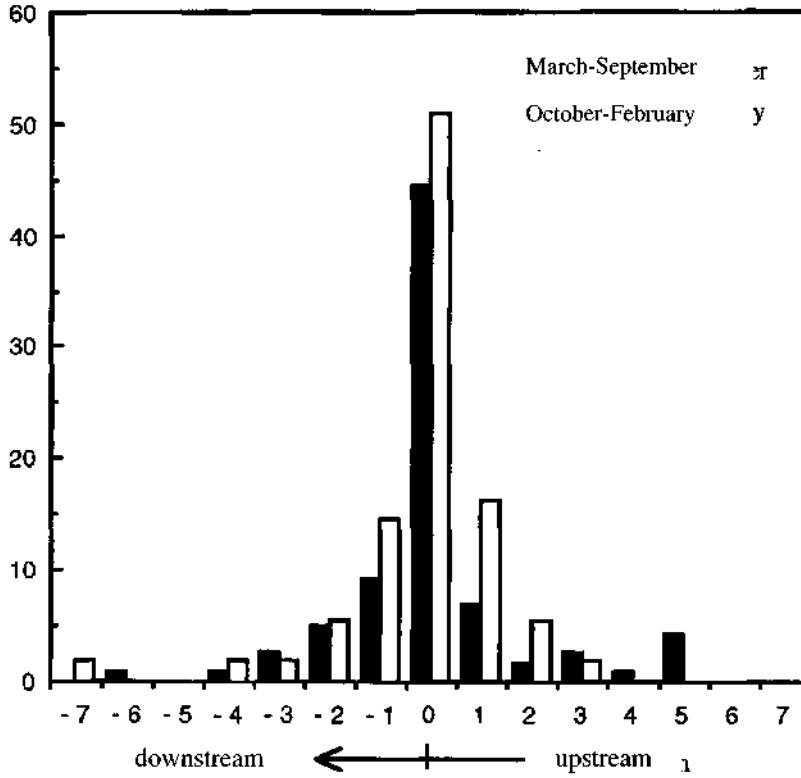

FIG. 2. Percentages of pooled recaptures of signal crayfish from equal numbers of locations upstream and downstream from the release location at Site 2 (as in Fig. 1) during October to February (open bars) and March to September (solid bars). All crayfish were recaptured within 71 days (Group 1).

logarithmic regressions, the intercepts on the abscissa are interpreted as the maximum distance of crayfish movement upstream and downstream (Fig. 3); none of the differences within and between the sexes are significant (see below).

The home range area of signal crayfish in Site 2

The home range of crayfish in rivers is often indicated by the linear distance

travelled from the release location in both upstream and downstream directions (e.g. Black 1963; Hobbs 1978), and this has been done in the sections above. However, it may be better to present the home range of crayfish in rivers in terms of the total area involved, as this may be more useful when comparing crayfish home ranges in rivers of different widths or when comparing rivers and lakes or ponds.

The home range area for upstream movements was simply estimated from the estimated (linear) distance moved, multiplied by the river width (15 m at Site 2). Similarly, the home range for downstream movements was estimated from the pooled data for release locations 7 and 8. The estimated means for linear movement are comparable to those estimated above for Site 1 and similar between males and females in both upstream (242 m for males and 252 m for females) and downstream (221 m for males and 216 for females) directions. Recaptures in each location are not signifiicantly different ($p > 0.05$) for movements in upstream and downstream directions, though movement in an upstream direction is slightly longer (10% for males and 17% for females) than movement downstream (Fig. 3), as occurs in other invertebrates (Minckley 1964; Momot 1966; Elliott 1971; Hobbs 1978).

From the above, estimates for the mean home range areas of signal crayfish in the present study are 3630 m^2 upstream and 3315 m^2 downstream for males; equivalent figures for females are 3780 m^2 and 3240 m^2. These figures are much larger than the reported figures for other North American crayfish species, e.g. *Orconectes inermis inermis* (Hobbs 1978) and *O. virilis* (Black 1963), but smaller than that for Western Australian marine crayfish *Panulirus longipes* (George 1957), and spiny lobsters *Panulirus argus* (Herrnkind *et al.* 1975).

Concluding remarks

The microchip implant used to estimate the home range of signal crayfish in the River Great Ouse in this study is new and still being developed. Though the data obtained were not sufficient to determine the range of crayfish movement because of poor detection distance by a small probe, it still provided evidence that the range of movement of the majority of crayfish was within 190 m.

The estimation of home range from the capture-mark-recapture method used in this study was not new but the design of the sampling locations and methods of analysis are new (Guan 1995, 1997), providing several advantages. Firstly, data for estimating the home range of crayfish from the capture-mark-recapture method can also be used for estimating population densities when a section of river is divided into several equidistant linear "locations". Secondly, a larger number of recaptures from several release and recapture locations (eight in this study) can be obtained, compared with the

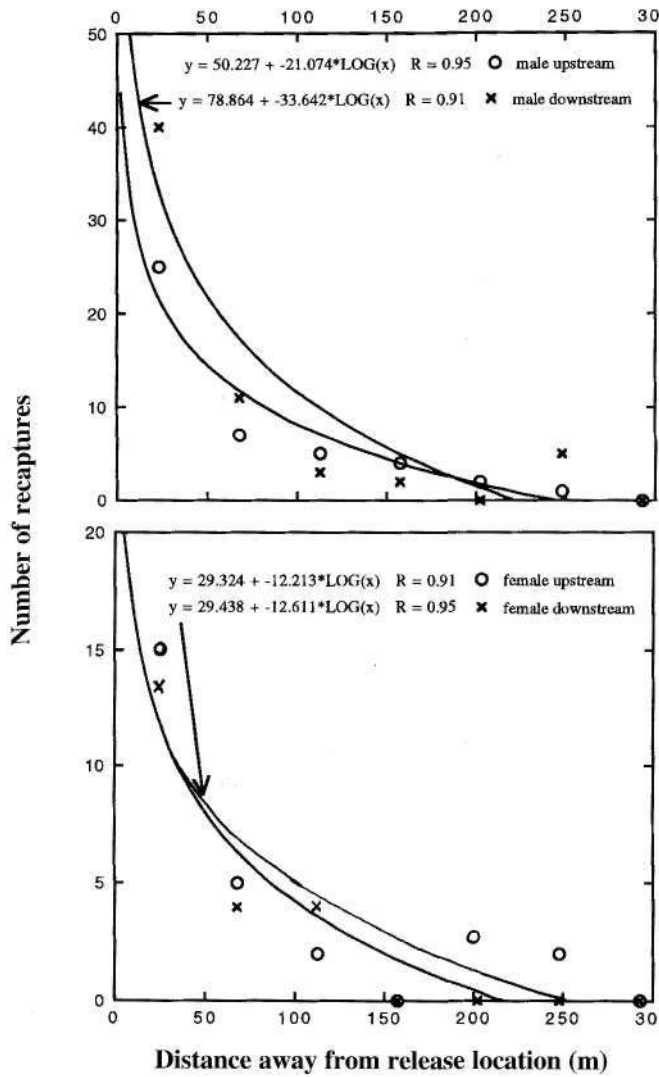

FIG. 3. Estimated distances for movement of signal crayfish in a stretch of the River Great Ouse. The number of $\log_{10}$ recaptures is significantly correlated ($p < 0.05$, *t*-test on the correlation coefficients) with $\log_{10}$ distance from the release location. *Upper figure:* males; the arrow points to the regression for distances moved downstream after release (crosses). *Lower figure:* females; the arrow points to the regression for distances moved upstream after release (open circles).

number obtainable from a single release location and the same number of recapture locations. Moreover it is often impossible to capture large numbers of crayfish in a single location. Finally, the pooled data of the distance of movement from several locations reduces the error due to local variations in the study section of river.

We do not know whether the few Group 1 crayfish that made long-distance movements did this in order to relocate in a new home area, or simply made occasional excursions away from a home area. Obviously, the estimated mean distance for crayfish movement will be less if the data for recaptures from more than three locations (i.e. >192.5 m in Fig. 3) away from the release locations are omitted (assuming they were from relocated crayfish). On the other hand the inclusion of relocated (dispersal) crayfish in estimates of the mean distances moved could lead to an overestimation, although this may be somewhat compensated by the possible prevention of further crayfish movements as a result of the trapping method, which produces an underestimation (Sanderson 1966). Such effects of trapping on random sampling are a cause for concern (Kikkawa 1964). In our study, the trap-addicted bias was not significant as few crayfish were repeatedly recaptured.

The attraction of baits (the smell of fish heads spreads downstream on the current) appeared to have no significant effects on the number of crayfish recaptured, as there was no significant difference in the number of recaptures upstream and downstream from the point of release. The spacing of traps at intervals of 45 m appears to be reasonable because a considerable number of marked crayfish were recaptured in sampling locations near the release location; there is then a gap in locations at which recaptures were not made, followed by distant locations where relatively long-distance travellers were recaptured.

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