**A burrowing population of white clawed crayfish *Austropotamobius pallipes* (Lereboullet) in a drained Irish peatland stream**



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# EXECUTIVE SUMMARY

In Ireland, the native white-clawed crayfish *Austropotamobius pallipes* is typically found in hard water streams, rivers, lakes and reservoirs with a diverse range of habitat features that provide refuge from environmental pressures. It was therefore unusual to find the species in a reach of a small, historically drained Irish peatland stream in a forested, raised bog site in County Tipperary where natural in-channel refuges were extremely limited. On close inspection, crayfish were found to have constructed numerous burrows in stable peat banks. Although burrowing has previously been reported for the species, the behaviour is not considered typical for *A. pallipes*. There has, to date, been no close investigation or detailed account of a crayfish population in Ireland that in the absence of other shelter relies almost exclusively on burrows.

Burrows were at high density, simple and apparently unbranched, excavated at various angles in peat banks, ranging from 0.08 to 0.47m in depth (average 0.24m). Burrow diameter was between 0.02 and 0.07m (average 0.04cm) with entrances wider than high. Many burrows were located above the summer water level, suggesting burrows are important refuges during winter high water levels. Juvenile crayfish were found in clusters of peaty rubble and woody debris on the open stream bed whilst larger crayfish, presumably those inhabiting burrows by day, were detected using overnight trapping. A few larger crayfish were observed at burrow entrances below the summer waterline. The current study showed that *A. pallipes*, a typically non-burrowing species, is a capable burrower in a situation where in-channel refuges are absent or limited.

This study highlights the need to seek out and record burrows when assessing instream habitat for potential presence of crayfish in Irish streams. Importantly, this very much applies to base-rich streams in drained peat landscapes, a surprisingly common habitat in the Irish midlands, where *A. pallipes* may not typically be expected to be found. In addition, potential impacts on crayfish during works near crayfish stream banks should take into account that *A. pallipes* may be present at depths of up to 0.5m into banks. The occurrence of protected white-clawed crayfish in this stream adjacent to Scohaboy Bog Natural Heritage Area (000937) increases the biodiversity value of a raised bog restoration demonstration site in the Irish midlands.

# INTRODUCTION

The white-clawed crayfish, *Austropotamobius pallipes*, is currently the only freshwater crayfish species present in Ireland. Healthy populations currently occur in hardwater streams, rivers, lakes and resevoirs over a wide geographical range (Reynolds *et al*., 2010). The species is protected in Ireland under the Wildlife Acts (1976 and 2000) and is listed under Annexes II and IV of the EU Habitats Directive (92/43/EEC). It is a qualifying interest of a number of Special Areas of Conservation (SAC) within Ireland’s Natura 2000 site network. As a large, mobile aquatic invertebrate, shelter from predators and/or hydrological stress is critical to its survival. It is rare to encounter them in habitat that lacks a local diversity of natural cover elements.

As Britain and Ireland’s only native freshwater crayfish species, the habitat requirements of *A. pallipes* have been widely documented (Holdich, 2003; Kemp *et al.,* 2003; Peay, 2000, 2003; Demers *et al*., 2003; Gallagher *et al.*, 2006). The dominant habitat type is considered to be stony bottomed waterbodies, where crayfish can shelter between and under rocks and cobble. Submerged and emergent aquatic macrophytes and woody debris are also important, especially for juveniles. Undercut banks, tree-roots and bedrock or manmade structures with cracks and crevices (in concrete and stonework) such as bridges and bank reinforcements make excellent refuges. It is now accepted that *A. pallipes* also commonly occurs in muddy habitats (Holdich *et al*., 2006; Peay *et al*., 2006), usually in association with aquatic vegetation.

Evidence of burrowing by *A. pallipes* has been reported in England (e.g., Huxley, 1879; Tero *et al*., 2003; Gerrard *et al*., 2003) but details on burrow morphology for the species are limited. Only brief or anecdotal reports of *A. pallipes* burrow characteristics have been reported in the literature and only for English rivers (Holdich & Sibley, 2003). This author has observed a few scattered crayfish burrows in clay banks at other Irish sites, usually in the presence of additional characteristic cover elements in close proximity, such as instream vegetation and/or rock and cobble substrates. Burrows are routinely listed as habitat features for Irish crayfish, but there has to date been no close investigation or detailed account of a predominantly burrowing population in particular reported in Ireland.

An opportunity to address this information gap arose as part of a project entitled *Demonstrating Best Practice in Raised Bog Restoration in Ireland* whereby water quality was monitored in a stream running adjacent to the Scohaboy Bog NHA (Site Code 000937). Monitoring was carried out in relation to clearfelling of Sopwell Forest Property located between Cloughjordan and Borrisokane in north County Tipperary. The project ran from 2011 to 2015 and was co-financed by the EU (LIFE+ Nature programme: LIFE09 NAT/IE/000222), Ireland’s National Parks and Wildlife Service and state owned forestry company, Coillte.

In 2011, during site selection for water quality monitoring, it was unusual to discover white clawed crayfish in a net sweep taken from the small, historically drained peatland stream adjacent to the bog restoration site. It had the appearance of a sluggish drainage ditch (1.5m wide) with substrates of peat and silt. There was no instream vegetation and no immediately notable features that typically characterise crayfish habitat. There was a broad riparian zone (5-10m on both banks) which was not planted with conifers. Natural, semi-mature riparian broadleaf trees and scrub had established in this zone providing dappled shade to the stream. On close investigation, the stable peat banks of the stream were found to be riddled with crayfish burrows.

The stream at Sopwell offered a rare opportunity to study a population of white clawed crayfish in unusual habitat where burrowing was the only source of refuge for larger crayfish. This study both investigates crayfish population density and addresses an information gap concerning the physical characteristics of *A. pallipes* burrows in an Irish stream.

# METHODOLOGY

*Study Area*

The site investigated was on a first order stream running through the Sopwell forest property just inside the eastern and north-eastern boundary of the Scohaboy Bog NHA (Site Code 000937). It is a headwater tributary of the Ballyfinboy River which drains into Lough Derg within Ireland’s Shannon River Basin District. The reach of stream within the forest property was approximately 650m in total linear length. The entire reach within the forest property was walked, and about 70m was closely investigated for the purpose of this study.

The stream within the Sopwell Forest Property was generally 1.0-1.5m in width and averaged 0.15m depth during summer. Banks were peaty and bed substrates were a combination of fine mineral and peaty silt with isolated patches of fine and medium-coarse woody debris. The left bank, possessing the majority of crayfish burrows, was stable, almost vertical and 30-50cm high. The right bank was more sloping, unstable and generally lacked burrows. There were no hard stream substrates (rock/cobble) within the forest property, but they were present upstream and downstream of the 650m reach.

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| **Plate 1:** General physical nature of the Sopwell stream. The channel was historically drained and had soft silt/peat substrates, peat banks and a regenerating natural woodland riparian zone. | **Plate 2**: Numerous crayfish burrows in peat banks plus patches of fine woody debris and small peat cobbles within the Sopwell Forest Property stream. |

Water was very clear, slow flowing, base-rich (>300mg/l CaCO3) and of circumneutral-to-slightly alkaline pH (7.8-8.1). Biological water quality was Q3 to Q3-4 (Poor/Moderate status) which is known to be conducive to crayfish survival in Ireland (Demers *et al*., 2005; Gallagher *et al.,* 2006). The stream was historically drained, most likely during planting of the conifer forest on adjacent raised bog circa 1975 (Plate 1). The regeneration of natural woodland in a 5-10m riparian buffer zone on each bank suggested the stream had not been disturbed for the 40 years over which the conifer forest grew to maturity. This conifer forest was felled in 2011 as part of the raised bog restoration project, leaving the native woodland riparian vegetation and the stream undisturbed.

*Crayfish Sampling*

All crayfish surveys were conducted under licence to the National Parks and Wildlife Service (NPWS) of the Department of Arts, Heritage and the Gaeltacht (DAHG) of Ireland. Overnight trapping was carried out using Swedish Trappy® traps (cylindrical and polyhedral shaped with cone-shaped funnel jowls at each end and 20mm diamond-shaped mesh) baited with cat-food. Trapping was conducted for 3 nights in total - 1 night each year in August of 2013, 2014 and 2015. Traps were placed at approximately 5m intervals along the small channel, targeting areas in proximity to bank reaches with greatest burrow densities. A total of 12 traps were deployed on each occasion, equating to 36 trap-nights covering approximately 70m of the channel in total. Broadly the same reach of channel was trapped on each occasion. Traps were set in water depths ranging from 15 to 30cm. Substrates were all comprised of sticky silt and peaty debris. There was no instream vegetation, but isolated patches of peat cobble and woody debris were present.

 In 2015, a 30-minute manual search covering 40m of linear channel length was also conducted on the day after traps were removed. Small patches of woody debris, leaf litter and small clumps of peat were the only instream substrates determined in the search.

The Carapace Length (CL) of crayfish captured were measured using Vernier callipers, excluding hatchlings (<7mm CL) which were too delicate to handle without damaging. All crayfish were released live back to the stream.

*Burrow investigations*

In 2013, an endoscope camera was used to view inside burrows which were found to be simple and generally straight. It was hoped that crayfish could be viewed in burrows, but many were too deep to operate the camera effectively. Because burrows were generally straight, various techniques were trialled to measure burrow depth. The best method was insertion of a narrow stick as far as possible into burrows until it reached the end. Burrow depth was thus crudely measured from burrow end to burrow entrance. A total of 98 burrows were measured for depth. The diameter of the burrow tunnel (as opposed to the burrow entrance) was measured at a random selection of 20 burrows. The burrow entrance was generally wider than the tunnel further into the bank, which may be owing to hydrological impact at the entrance (Peay & Hirst, 2002). It was difficult to accurately measure burrow tunnel diameter without destroying the entrance, which limited the number of burrow tunnel diameters recorded.

# RESULTS

*Crayfish sampling*

A total of 13 crayfish with were trapped over the 36 trap-nights, equating to an average Catch Per Unit Effort (CPUE) of 0.36 crayfish per trap-night. The Carapace Length (CL) range of trapped individuals was 28-43mm, averaging 33.5mm. The sample was too low to justify analysis of population size distribution. All crayfish except one were healthy with no signs of stress or disease. One individual had been partially predated in the trap. A 30 minute search of peat cobble and woody debris patches covering 20m of linear channel revealed a total of 18 individuals: 1 adult male (30mm CL), 5 juveniles (7-15mm CL) and 12 hatchlings (<7mm CL).

*Burrow Investigations*

Burrows were simple and unbranched and were generally excavated into the bank on the horizontal plane, although they tended to be gently sloped upwards (relative to the stream bed) nearer the entrances. Some were connected with other burrows a short distance into the bank. Burrow entrances were wider than high, but burrow tunnels in the bank were roughly circular in outline. Burrow tunnels (n=20) ranged between 2.1 and 7.1cm in diameter with a mean of 4.4cm.

Burrows were only present where the bank was stable and more or less vertical, which was a feature of the true left bank which averaged 0.35m in height. The true right bank was sloping at the foot, unstable and lacked burrows.

Figure 1 – Number of burrows in specified burrow depth (cm) range.

Depth of burrows (n=98) was in the range 8 - 47cm with a mean of 23.8cm (Standard Deviation 8.7cm, Median 23cm). Figure 1 shows the distribution of burrow depths.

There was a high density of burrows, >15 burrows per linear metre of stream. Some were well above the summer water level and likely to have been excavated when water levels were higher in winter.

# DISCUSSION

The first apparent account of white clawed crayfish burrowing behaviour was by Huxley (1897) who reported *“Where the soil, through which a stream haunted by crayfishes runs, is soft and peaty, the crayfishes work their way into it in all directions, and thousands of them, of all sizes, may be dug out*”. The burrowing behaviour of *A. pallipes* was not, however, widely accepted until relatively recent accounts were reported in England (Tero *et al*. 2003; Gerrard *et al.,* 2003; Peay, 2004). It was previously assumed that only the introduced Signal crayfish (*Pacifastacus leniusculus*) made burrows in English rivers. *A. pallipes* is the only freshwater crayfish species currently present on the island of Ireland, so any burrows observed could only be made by this species.

This author has previously observed a few scattered burrows in some Irish rivers, but always in the presence of a local range of alternative natural cover options like aquatic vegetation and rocky substrates. Over a wide experience of white-clawed crayfish streams covering ten years in Ireland, this author has never observed such a high density of burrows, nor a situation where crayfish are solely burrowing for refuge because alternative in-channel refuges are absent.

Burrowing ability and burrow morphology has been investigated in some detail for other freshwater crayfish species (e.g., Horowitz & Richardson, 1986; Guan, 1994), but *A. pallipes* has largely been considered a non-burrowing species. Berrill & Chenoweth (1982) suggested, however, that all crayfish species are capable burrowers. They demonstrated that the three species of typically non-burrowing North American crayfish all burrowed with equal proficiency to typically burrowing species when put under environmental stress, i.e., receding water levels. The current study lends weight to this theory, showing that *A. pallipes* is a very capable burrower in a situation where larger in-channel refuges are absent. In addition, more, “typical” crayfish habitat, with hard substrates and aquatic plant cover was available a few hundred metres upstream and downstream of the investigation site. It would have been supposed that *A. pallipes*, a typically non-burrowing species, may be confined, or likely to migrate, to more suitable habitat rather than burrow.

It is evident that larger adults in this stream utilise burrows (undetectable by manual searches), while juveniles and young adults are confined to patches of woody debris and peat cobble in the open channel. Demers *et al.* (2003) also observed the use of different micro-habitats by adult and juvenile crayfish within a river reach. The reasons offered were competition for shelter and intraspecific (cannibalism) and interspecific predation pressures. To avoid predation by fish, mammals and birds, larger crayfish must occupy larger refuges. When shelter is in short supply, larger crayfish exclude smaller ones from the best available shelter (Ranta & Lindstroèm, 1993).

The current study confirms that when there are no large shelters available, larger white-clawed crayfish readily construct their own. The range of burrow tunnel diameters in the current study (Ø 2.1-7.1cm) suggests that crayfish in this particular stream reach must, owing to lack of alternative large shelters, burrow (and compete for burrows) when they reach a certain size. A number of large individuals (males with big claws) were captured during trapping (>40mm CL) and these would likely be the occupants of burrows at the upper end of the burrow size range (Ø7.1cm). Juveniles, detected in abundance in the open channel, are unlikely to be able to compete for the best available refuges (burrows), but can shelter in isolated patches of fine woody debris owing to small body size. Clearly, however, there is a size at which crayfish must burrow in order to secure adequate shelter, hence the lower end of the burrow tunnel diameter range in this habitat.

In the absence of instream plants, the main food sources for crayfish in the reach are likely to be other small invertebrates, detritus, and each other (Englund & Krupa, 2000).

The question of burrow depth was raised at this stream in relation to construction of a footbridge to facilitate access to the raised bog restoration demonstration site. Huxley (1879) reported *A. pallipes* burrows could be between “*a few inches and a yard*” (0.08 – 0.91m). Holdich (2003) reported burrows “*usually about 0.3 to 0.5 m into the bank*”. The burrow depth range in the current study agreed with the lower end of Huxley’s range and the upper end of Holdich’s range, i.e., 0.08 – 0.47m.

Given the high burrow density and the abundance of juvenile and hatchling crayfish in the open channel, the low CPUE during trapping was unexpected. It is worth noting evidence of trap predation, and also the observed presence of an active otter holt/slide on the left bank near the trapping location. It is not unreasonable to suggest that strong predation pressure (by otter and fish) operates in this stream, intensified by lack of refuges in the open channel. Larger (trappable) foraging crayfish would be taking a high risk to venture out at any stage in this channel.. Their behaviour may be adapted in this environment to forage not far from burrow entrances, hence a possible explanation for low trap catch observed.

In addition, it is accepted that trapping often underestimates total crayfish populations (Peay, 2004) and favours larger adults (Matthews & Reynolds, 1995; Peay, 2004). Peay (2004) reported a study where intensive trapping (23 traps for 6 nights in a 20m reach) captured 60 adult crayfish. When the same 20m reach was dewatered for engineering works, the total population was 549 crayfish. Using fewer traps on less nights in this same habitat (10 traps for 2 nights) resulted in 9 adult crayfish being captured, representing just 2-4% of potentially trappable individuals (>23mmCL) and only 1% of the total population. Going by this example, and considering the low number of trap nights used in the current study, the population in the 70m investigated reach of the Sopwell stream could be in the order of 1,300 crayfish, i.e., >18 crayfish per linear metre. This figure would more accurately reflect the combination of: (1) high burrow density observed, e.g., 15 burrows per linear metre in places, and; (2) the abundance of juveniles amongst patches of woody debris in the open channel.

It is noted that stream water chemistry and water quality were favourable to the species in this stream. In addition, the role of natural broadleaved canopy in the riparian zone between the stream and the commercially managed forest undoubtedly contributes to the success of this population by providing dappled shade (temperature regulation, cover from aerial predators) and an essential supply of woody debris (shelter for juveniles) and detritus (food source).

This study highlights the necessity of actively seeking evidence of burrows when assessing instream habitat for potential presence of crayfish in Irish streams. Importantly, this very much applies to base-rich streams in drained peat landscapes, a surprisingly common habitat in the Irish midlands, where *A. pallipes* may not typically be expected to be found. In addition, potential impacts on crayfish during works near crayfish stream banks should take into account that *A. pallipes* may be present at depths of up to 0.5m into banks.

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