A technical manual for monitoring white-clawed crayfish *Austropotamobius pallipes* in Irish lakes

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A technical manual for monitoring white-clawed crayfish *Austropotamobius pallipes* in Irish lakes

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1. INTRODUCTION

This manual has been produced for National Parks and Wildlife Service (NPWS), as a protocol for sampling and monitoring lake populations of white-clawed crayfish (*Austropotamobius pallipes*) (Lereboullet). It is based on the manual for monitoring stocks of white-clawed crayfish in Irish lakes (Reynolds, 2006), as well as the English Nature manual for white-clawed crayfish monitoring (Peay, 2003). The design of this manual is also influenced by the field experiences of the 2007 lake survey (O'Connor *et al.*, 2009), feedback from a training day for NPWS field staff at Lough Owel in Mullingar, Co. Westmeath and in cognisance of health and safety while working in/near water.

The white-clawed crayfish has been classified as vulnerable in the 2010 IUCN Red List (Nadia Dewhurst, SRLI Freshwater Invertebrate Coordinator, pers. comm.), is listed under Appendix III of the Bern Convention (82/72/EEC) and Annexes II and V of the EU Habitats Directive (92/43/EEC). Ireland is required to designate Special Areas of Conservation (SACs) for the species under Natura 2000 and furthermore to monitor the status of crayfish populations on a regular basis.

The white-clawed crayfish is Ireland's only crayfish species and healthy populations (in both rivers and lakes) remain widespread in Ireland (Reynolds, 1997). The results of a survey of 25 lakes, undertaken in 2007, confirm that some Irish lakes still contain excellent stocks of crayfish and most of the lakes where good catches were realised had a healthy range of crayfish sizes present, indicating juvenile recruitment within the population (O'Connor *et al.*, 2009). Ireland therefore, has an important role to play in the conservation of this species. There is a requirement for an agreed, standardised methodology to survey and monitor these populations.

To date, crayfish monitoring has largely been focussed on riverine populations, as opposed to lacustrine populations and Reynolds (2006) is the sole manual for lake crayfish monitoring. A key difference in this manual is an improved hand-searching method; more detail is given on the handling of crayfish; and other alterations to earlier methods, including measurements, are described. The most noteworthy alteration is an advanced hand-search methodology, using snorkelling gear. This has been found to provide increased access to sites and also results in greater catch efficiency compared to the previously used viewing boxes.

Through familiarity with the ecology, habitats, distribution and threats associated with the white-clawed crayfish, future surveyors will be able to select the best possible locations for baseline surveys and continuous monitoring of the species.

1.1 Conservation status of white-clawed crayfish in Irish lakes

The purpose of designating and managing SACs is to maintain at, or restore to, 'favourable conservation status' the habitats and species listed on Annexes I and II of the EU Habitats Directive. Table 1 gives the criteria for assigning favourable conservation status to crayfish habitats and crayfish in a lake. In contrast to the rest of Europe, white-clawed crayfish are still widespread in lakes and rivers over much of Ireland. Indeed, Ireland is now thought to hold some of the best European stocks of this species, under least threat from external factors. Therefore, Irish stocks are believed to be of substantial conservation importance (Reynolds, 1998). Furthermore, throughout its European range the white-clawed crayfish is most commonly found in first-order streams, but it finds its greatest ecological expression in Ireland, where it occurs in small and medium-sized lakes, large rivers, streams and drains wherever there is sufficient lime (Lucey & McGarrigle, 1987). The findings of the survey undertaken in 2007 (O'Connor *et al.*, 2009) indicate that more lakes need to be selected for monitoring, in order to establish a sufficient number of confirmed lakes containing crayfish for conservation status monitoring.

Table 1. Criteria for favourable conservation status of white-clawed crayfish and their lacustrine habitat (based on the EU Habitats Directive EU/92/43/EEC).

Favourable status of crayfish habitat	Favourable status of crayfish
Its natural range and areas it covers within that range are stable or increasing.	Population data indicates that lake crayfish populations are self-maintaining on a long-term basis, as a viable component of their natural habitats.
The specific structure and functions necessary for long-term maintenance exist and are likely to exist for the foreseeable future, i.e. sustained water quality, macro-invertebrate populations for juveniles and vegetation for adults.	The natural range of lake crayfish is neither being reduced nor is likely to be reduced for the foreseeable future.
The conservation status of crayfish is favourable.	There is, and will probably continue to be, a sufficiently large habitat to maintain crayfish populations on a long-term basis.

The conservation status of crayfish in Ireland is threatened by the introduction of non-native crayfish species, diseases and other non-native introductions. Other activities such as drainage maintenance have been a significant threat to crayfish populations within some SAC river corridors (i.e. Moy, Boyne and Corrib catchments) (O'Connor & McDonnell, 2008).

2. ECOLOGY OF THE WHITE-CLAWED CRAYFISH

2.1 Diet

Crayfish are large, mobile, omnivorous (predators and grazers) freshwater invertebrates. The species is largely nocturnal, although it can be seen foraging in the shallow margins of lakes as dusk approaches on warm summer evenings. White-clawed crayfish are now generally considered as a keystone species wherever they occur, rather than as a bio-indicator (Füreder & Reynolds, 2003) because of its traditional importance and its large size, longevity and dominant position in the ecosystem (Matthews & Reynolds, 1992). The grazing impacts of crayfish on aquatic macrophytes have long been known; their grazing checks primary productivity and in their absence, luxuriant macrophyte growth may occur (Reynolds, 1998).

In Irish lakes, crayfish prey on a wide variety of benthic invertebrates including snails, crustaceans and insect larvae (Reynolds, 1998). In White Lake, Co. Westmeath, sub-yearling crayfish fed chiefly on small entomostracan crustacea and insect larvae, while larger crayfish fed predominantly on stoneworts and the largest ate a significant proportion of both dead terrestrial vegetation and juvenile crayfish.

2.2 Growth, reproduction and physiology

White-clawed crayfish are slow growing compared to other astacids and reach 9cm total length and 40g in five or more years and an ultimate length of perhaps 12cm (Holdich, 2003). These crayfish can live for more than 10 years, and usually reach sexual maturity after three to four years (Holdich, 2003) when they are about 50 mm total length (25 mm carapace length). Crayfish grow by moulting their shell and increasing by about 10% in length before the new one hardens. After moulting, crayfish are soft to touch and are susceptible to predation. Immature crayfish may moult several times each year, but mature males usually moult twice, in early and late summer, while reproductive females moult only once, in late summer (Reynolds, 1998).

Males develop markedly larger claws than females and have a narrower abdomen, on the first two segments of which are carried a pair of forward-pointing stylets (see Plate 1). For comparison of this trait, individuals of equal size are best examined side by side. Ripe females may show whitening at the under-edges of the abdominal segments, marking the glair glands which produce a sticky substance which cements the eggs.

Mating occurs in October to November at a water temperature of around 10°C (Reynolds, 1998). The females' abdominal appendages are more hairy than those of the male and are used to support the mass of eggs, each egg about 3 mm in diameter, which is glued to the underside of the female after laying. The number of eggs carried may range from 20 to 160, but is usually less than 100 (Holdich, 2003). Such females are described as "berried" and will over-winter with their clutch. About 50% of eggs survive to hatch in June or July at an initial length of 6-8mm (Reynolds, 1998). However, some females may lose most or all of their eggs. Brooding females in particular require undisturbed shelter over this winter-spring period. The hatchlings remain attached to the female until their second moult. The hatchlings then become independent and the female resumes active feeding (Reynolds, 1998).

O'Connor *et al.* (2009) found a significant relationship between carapace length (CL) and total length (TL) for both males and female crayfish: TL = 2.094CL + 0.779. Similarly, there was a strong correlation between carapace length and weight. In this study, the measurement of carapace length was deemed the more reliable form of measurement. In measuring the total length of crayfish, it is necessary to measure from the tip of the rostrum (as when measuring CL) to the tip of the tail. In this procedure, the crayfish may be constantly trying to move, sometimes arching itself, thereby effectively reducing its total length and resulting in an inaccurate reading. Furthermore, small hairs on the end of the tail can also affect total length measurement. Therefore, correct total length measurement can be time consuming and possibly damaging to crayfish, resulting in loss of limbs or internal damage.

Plate 1 Ventral view of female crayfish (left) and male crayfish with stylets (right).

Plate 2 Juvenile crayfish (hatchling shown here) can be easily overlooked in a sweep net among debris.

2.3 Habitats

The white-clawed crayfish typically occupies a 'refuge' which the crayfish will leave to forage. Refuges can take many forms, including large boulders and water-saturated logs, rocks and cobbles, slates, crevices in man-made walls, accumulations of fallen leaves, tree roots, holes in banks or sediment, constructions such as piers and fishing platforms and anthropogenic debris. Since rocks broadly cover any hard substrate, the various substrate particle sizes (boulder, cobble, pebble, gravel and fine) are given in Table 2. Overhanging bankside vegetation has been highlighted as an important factor in determining crayfish abundance, as this provides shade, food and cover (Holdich, 2003). The habitat type in the lake is the main factor in the selection of the survey method.

Hatchlings shelter in vegetation, gravel and among fine tree-roots, feeding chiefly on animal matter and are more reliant than adults on animal foods (Reynolds & O'Keeffe, 2005). Smaller crayfish are typically found among weed and debris in shallow water. Larger juveniles in particular may also be found among cobbles and detritus such as leaf litter.

Larger crayfish must have stones to hide under, or an earthen bank in which to burrow (Demers *et al.*, 2003). In lakes, larger crayfish prefer stony stretches of shore, but may also occur in *Chara* spp. vegetation or other aquatic weed, or at the base of emergent plants. Larger crayfish may burrow into suitable substrates, particularly in the winter months. Brooding females require undisturbed shelter over a prolonged winter-spring period.

Plate 3 A mixture of *Chara* sp. and cobble, ideal crayfish habitat in the shallows of Lough Talt, Co. Sligo. This habitat, due to the variation in substrate sizes, allows occupation by both adult and juvenile crayfish.

Table 2 Substrate particle size, adapted from the JNCC phase 1 habitat survey handbook, (JNCC, 1993).

Particle Type	Size range - diameter (mm)
Boulder	>256
Cobble	64-256
Pebble	16-64
Gravel	4-16
Fine (sand, silt, clay)	<4

Plate 4 Vegetated soft shore of Kilrooskey Lough, most suited to surveying with a sweep net. Reeds and *Chara* spp. are the main components of this soft, vegetated shoreline, ideal for crayfish requirements in that the vegetation harbours a richness of macroinvertebrates for juvenile feeding and plant matter for adults. The vegetation also provides ample cover.

2.4 Threats to the white-clawed crayfish

2.4.1 Competition and disease

The white-clawed crayfish is susceptible to predation and competition by larger, faster growing and more aggressive introduced species, particularly the North American signal crayfish (*Pacifastacus leniusculus)* (Holdich & Domaniewski, 1995). The white-clawed crayfish suffers from two main diseases: thelohaniasis, or porcelain disease (caused by *Thelohania contejeani*), and aphanomycosis, or crayfish plague (*Aphanomyces astaci*) (Alderman & Polglase, 1988).

The North American signal crayfish was introduced to Britain for aquaculture and subsequently escaped into the wild, where it has had a devastating effect on white-clawed crayfish populations. There is a real threat that this crayfish species will reach Ireland. The crayfish plague caused by the fungus *Aphanomyces astaci*, was transmitted to Europe with American crayfish species. European crayfish possess no resistance to the *Aphanomyces astaci* fungus that has the potential to eradicate complete stocks of crayfish in a matter of weeks. This fungus attaches to thin areas of cuticle as a spore and then grows through the tissues, leading to death in around two weeks. The swimming spores can then transmit directly from the infected or recently dead crayfish (Reynolds, 1998). Crayfish populations in the lakes and rivers of the Boyne catchment are thought to have been decimated by a crayfish plague outbreak during the mid 1980s (Demers *et al.,* 2005). Demers *et al.* (2005) states that the distribution of white-clawed crayfish in Ireland has declined since the mid-1980s, attributed in part to an outbreak of the crayfish plague caused by the fungus.

However, this effect is geographically isolated (Gallagher *et al.*, 2006). Large unexplained mortalities of crayfish have occurred in water bodies including Lough Owel (Demers *et al*., 2005). Crayfish were reintroduced to Lough Lene in about 1989 (Reynolds & Matthews, 1997), but disappeared again sometime after 2000 (Reynolds, 2006). They were also reintroduced to White Lake in 1999 (Reynolds *et al.*, 2000) and were confirmed breeding in 2003 (C. O'Keeffe, pers. comm.) but have not increased to the numbers expected since then (O'Connor *et al.*, 2009).

Plate 5 Excessive algal growth on the north shore of Lough Ennel, Co. Westmeath.

2.4.2 Pollution

White-clawed crayfish are vulnerable to pollution incidents, particularly those involving biocides and silage effluent. White-clawed crayfish are not usually found inhabiting substrates covered in mud or

silt, although they may cross such areas while foraging (Holdich, 2000). The delicate gills of crayfish are easily clogged by sediment and this may cause physio-pathological changes in the long term (Peay, 2000).

As with fish, suspended solids also have the potential to significantly impact on white-clawed crayfish. They can physically abrade and mechanically disrupt the respiratory epithelia of larvae. Crayfish, particularly 'berried' females are also particularly vulnerable to suspended solids.

2.4.3 Predators

The white-clawed crayfish is preyed upon by a large number of predators, including fish (pike, perch, chub, trout and eel), mammals (mink, rat and otter) and birds (heron and crow). In addition, juveniles may be preyed upon by insect larvae, including that of dragonfly (Hogger, 1988) and by large crayfish (Reynolds & O'Keeffe, 2005).

3. DISTRIBUTION OF WHITE CLAWED CRAYFISH

3.1 General distribution

The white-clawed crayfish was previously widespread in mainland Europe, Great Britain and Ireland, but its distribution and abundance has declined in recent years due to habitat destruction, pollution (Holdich, 1991) and the introduction of exotic crayfish (Holdich, 1998; Holdich & Gherardi, 1999). Figure 1 gives the distribution range of crayfish in Ireland, where it occurs mainly in streams, rivers and smaller lakes.

3.2 Distribution in Irish lakes

Demers (2005) reported that white-clawed crayfish are still widespread in the rivers of the Irish midlands, where the geology is predominantly limestone. Freshwater crayfish require relatively hard water with high calcium levels, due to their requirement for sufficient calcium to harden their exoskeletons following moulting (Gallagher *et al.*, 2006). The Erne catchment is the most important system for crayfish in the country. Elsewhere, crayfish lakes are limited to a handful of catchments, chiefly the Boyne, Shannon, Corrib, Moy, Bonet and the Blessington Reservoir on the River Liffey. Crayfish are generally limited to smaller lakes (up to 100 ha), although in medium-sized lakes (Upper Erne, Ramor, Owel and Ennell) they may occur in suitable shallows, and they have been recorded in large lakes (Derg, Ree, Lower Erne, Corrib and Mask) adjacent to inflowing streams (Reynolds, 2006).

O'Connor *et al*., (2009) found that crayfish were present in only 50% of the lakes surveyed from a subset of lakes for which crayfish populations had previously been confirmed and only nominal populations were indicated in some of the lakes where crayfish occurred. They suggested that an evaluation of the accuracy of some of the existing historical/anecdotal records should be undertaken.

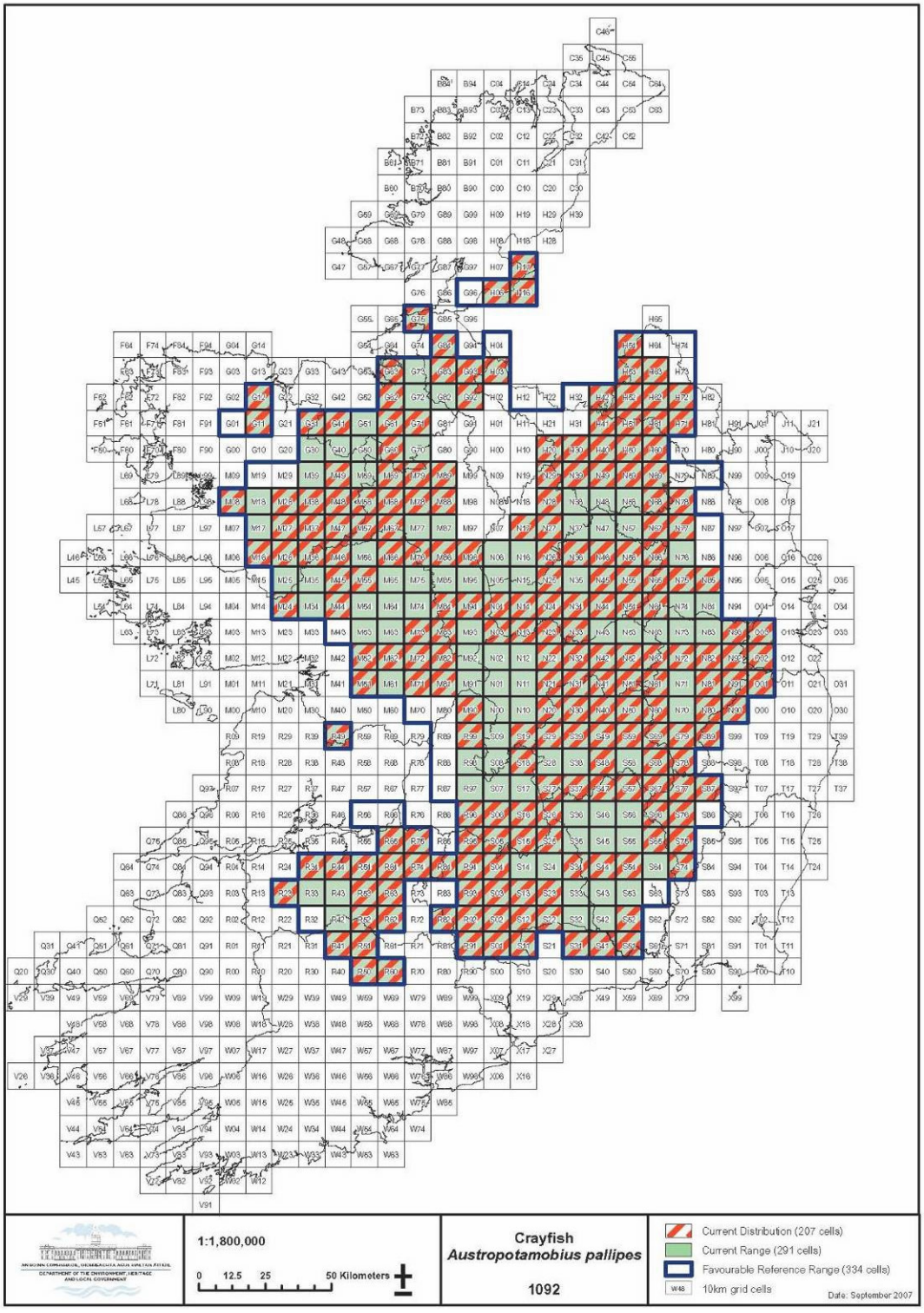

Figure 1 Distribution of crayfish in Ireland (source NPWS 2008).

4. SURVEY METHODS

4.1 Comparison of different survey methods

Survey methods for the white-clawed crayfish in lakes, outlined in Table 3, are based on Reynolds (2006) and Peay (2003). The main factor to be considered when selecting the survey method is the crayfish habitat type and characteristics of the lake in question. A guide to selection of survey method based on habitat is also provided in Table 3.

Examples of recent results for different survey methods are given for various lakes during a crayfish survey undertaken in 2007 (O'Connor *et al.*, 2009). The efficiencies of the various survey methods employed were found to vary greatly between habitats. For example, in Kilrooskey Lough, with its heavily vegetated margins and soft substrate, only 7 crayfish were caught during a hand search (100 refuges), in contrast to 35 caught by sweep netting (20 sweeps) and 39 by trapping (20 traps). Conversely, on the generally stony substrate of Lough Labe, 39 crayfish were caught by hand searching (100 refuges), 8 were caught by trapping (10 traps), and one by sweep-netting (20 sweeps).

For lake monitoring at regular intervals, the most suitable method should be selected and used at the same sites and under the same conditions (seasonality, weather conditions, water conditions), to get comparable results (Reynolds, 2006). Trapping should be considered where other methods are unsuitable. The 2007 lake survey (O'Connor *et al.*, 2009) was undertaken during a very wet summer, mostly under suboptimal conditions with high water levels. Hatchlings were not detected by any method and this was deemed to be due to the prevailing conditions. Many lakes were revisited in early autumn whereupon crayfish were found at sites not recorded during the summer. This highlights the need for surveying under favourable conditions. Electrical fishing efficiency was found to be influenced by lake conductivity and was deemed too burdensome for crayfish survey. However, electrical fishing may be used to quickly indicate the presence of crayfish in high conductivity lakes such as Lough Owel.

Plate 6 Otter spraints found on a rock along the shoreline of Lough Doon, indicating the presence of crayfish.

4.2 Trapping

Trapping has traditionally been the method used to assess lake crayfish stocks; however the process is time-consuming, requiring separate visits to set and lift traps, combined with safety considerations

and risks of interference by the public. A large string of standard traps will yield repeatable catch levels, when standardized by season, weather and phase of the moon (Reynolds, 2006). Such trap data exist for some Irish lake stocks of white-clawed crayfish, e.g. 1.95 and 0.8 CPUE [catch per unit effort] for Kilrooskey Lough (Monaghan) and Lough Labe (Sligo) in October 2007 (O'Connor *et al.*, 2009). Traps modified with 10mm mesh were found to be far more effective at retaining juveniles and therefore resulted in a higher CPUE.

Because of the disadvantages of trapping, alternative methods were assessed in a pilot study of six lakes (Reynolds, 2006). These methods include hand search, modified from the JNCC selective manual survey protocol for streams (Peay, 2003), sweep-netting and night search.

Table 3 Summary of methods for surveying crayfish in Irish lakes with equipment required, suitable locations, advantages and disadvantages of each method.

Method	Equipment Required	Lake characteristics where the method is suitable	Advantages	Limitations / Disadvantages
Snorkelling Hand Search (SHS)	Wet suit or dry suit, snorkelling mask, small fish net (those used for aquarium fish are ideal), snorkelling boots, bucket, towel, disinfectant. Snorkelling hood and gloves provide extra insulation.	Shallow and deep stretches, easily disturbed substrate, lakes that shelve off abruptly, lakes with marshy / unstable margins, stony shores.	Closer to the target species, increased buoyancy in deeper water, ability to survey deeper (up to 1 m), can use both hands, crayfish easily seen / wide field of view / fewer escapees, less disturbance of the substrate, zero glare, wind and rain doesn't significantly impair ability to survey.	Time consuming changing into snorkelling gear, need clear water, drying out time / disinfecting of equipment prior to entering a different water body, can be difficult in very shallow water, overcast conditions can reduce visibility somewhat. Requires experience to identify appropriate habitats and for searching.
Hand Search	Waders, perspex bottomed bucket or small plastic aquarium, small net, disinfectant.	Shallow stretch of stony or firm-bottomed shorelines.	Fast, little equipment needed, can easily survey under rocks and stones.	Depth limited by need to reach down into water to turn over stones. Stirred-up silt can be a problem. Can be difficult to catch fast swimming crayfish.

Method	Equipment Required	Lake characteristics where the method is suitable	Advantages	Limitations / Disadvantages
Sweep Netting (SN)	Sweep net, waders, lifejacket, disinfectant.	Vegetated lakes, lakes with a substratum of silt, sand or gravel.	Fast, little equipment needed, smaller crayfish (hatchlings, juveniles) are easily caught, water clarity not an issue. Can survey to depths according to the length of the net handle and waterproof gear. Easy to disinfect the equipment used.	Method not suited to shores of larger substrate size (cobbles, rocks, boulders).
Trapping (T)	Crayfish traps, bait, rope, cable ties or alternative for attaching traps to rope, disinfectant, life jacket, tinned liver cat food.	Deep lakes, lakes with lots of vegetation and limited visibility.	Weather independent, water clarity not an issue, can be deployed any time of year to any depth (may require a boat).	Have to return to lake to retrieve traps, smaller crayfish can escape from traps especially if not modified, traps could be interfered with, time consuming.
Night Search (NS)	LED security torch with a narrow beam, spare batteries, waders, lifejacket.	All lake types with easy access.	Least labour intensive method as crayfish are only counted, quick way to assess the presence of crayfish in a waterbody. No risk to non-target species.	Survey area needs to be visited during daylight hours prior to night searching, calm conditions, required for observation of crayfish, crayfish characteristics not recorded. Smaller crayfish can be easily missed. Dependent on good water clarity.

4.3 Hand searching

Hand-searching using snorkelling gear was found to be the most successful method overall and is recommended as the monitoring method of choice for many of the lakes assessed during the 2007 lake survey (O'Connor *et al.*, 2009). While the survey technique remains similar to that outlined in Reynolds (2006), the main advantages of the use of snorkel gear was the comfort of surveying and the increased visibility. The fact that the surveyor is submerged also means that he/she is nearer to the crayfish with the advantage of better visibility and efficiency of catch. Manoeuvrability and careful displacement of potential refuges is also made easier. This method allowed deeper or more inaccessible areas to be searched, as the surveyor is often swimming over the area being surveyed, as opposed to standing in it. Moreover, the use of snorkel gear helps reduce the amount of soft debris disturbed from the lake bed. With this method, one can search actual refuges and catch juveniles. Selective manual searching is generally the best method for preliminary surveys while whole reach surveys are more suited to baseline and monitoring studies (Peay, 2003).

A CPUE of 0.5 (crayfish in half of all refuges) was achieved in Lough Owel in June 2007 under optimal conditions using this method (O'Connor *et al.*, 2009).

4.4 Sweep netting

Sweep-netting can be carried out in soft substrate or heavily vegetated lakes. This method was found to be inconsistent, especially in stretches of shore containing rocky areas. However, in Kilrooskey Lough sweep-net sampling was found to be a highly effective method of surveying soft and vegetated areas. As mentioned above, it is likely that the high lake levels, which persisted during the summer of 2007, affected the efficiency of this method.

Sweep-netting in Kilrooskey Lough in October 2007 produced an average of 1.75 crayfish per sweep (CPUE = 1.75), while the same method yielded a CPUE of 0 for many lakes in that same year.

4.5 Night searching, lake shore evidence

Night-searching was found to be useful as a means of assessing the presence/absence of crayfish in lakes, but in some instances may not be practical, due to safety considerations. The presence/absence of crayfish along a stretch of lake can often be ascertained by looking for otter scats with crayfish remains or other signs of crayfish presence.

On a night search of Kilrooskey Lough, an average of 1.2 crayfish was recorded per 3m length of shoreline (CPUE = 1.2) (O'Connor *et al.*, 2009).

5. METHODOLOGY FOR SURVEYING LAKE CRAYFISH

5.1 Licensing

A licence under section 23 of the Wildlife Act to catch or disturb crayfish must be obtained from the NPWS before fieldwork commences. See NPWS website for details: http://www.npws.ie/en/WildlifePlanningtheLaw/Licences/CaptureKillingofWildAnimalsforResearch/

5.2 Health & Safety

All field survey work should adhere to health and safety procedures. Health and safety risks associated with crayfish surveying in lakes, as well as control measures are detailed in Table 4. Consider the risks associated with individual sites in advance and on arrival. If in doubt about safety at a site, do not carry out the survey. Record details on access and safety for future surveys. Useful information would include parking locations, route and ease of access to the site and any particular hazards one could encounter. If using information from a previous site assessment, be aware that conditions may have changed since the last survey.

5.3 Preparation & Location

As part of preparation, one should be aware of the habitat requirements of crayfish and know the habitat definitions, so that information for baseline surveys can be accurately recorded. Information on substrate particle size (boulder, rock, cobble) is given in Table 2 to aid in accurately completing field sheets (see Appendix 1).

The following points should be regarded before commencing fieldwork:

1. Seasonality - white-clawed crayfish are most active between June and November and are best surveyed during this period. Avoid surveying during periods of high water, winds and heavy rain.

2. Databases and maps - potentially suitable sites can be deduced from aspect and topography; rivers flowing into the lake often provide preferred habitat and possible access can also be determined. At this stage, time spent in good ordination will benefit no end. Ordnance Survey (OS) maps are recommended.
3. Lake-shore character - monitoring is easiest on gently sloping stony shores facing prevailing winds (generally the eastern shore), as these are relatively free from mud and provide ample refuges for crayfish. It is important to select the best possible sites. Larger crayfish prefer stony shores, but access may determine which sites are available to survey. Distribution of crayfish may not be homogeneous within a lake.
4. Permission - landowner(s) permission for access to the lake should be obtained in advance of surveying.
5. Materials – these depend on survey plan. See Table 3 for material requirements for each survey type.
6. Contact local NPWS Conservation Ranger and local Fisheries Officer to inform them of your work plan and carry your crayfish survey license or a letter from NPWS stating the nature of the survey.
7. Ensure that all gear and equipment that could potentially be in contact with water is sterile, either by disinfecting or by drying thoroughly.

Sometimes the lake may not be suited to the type of survey you had planned or there may be unforeseen difficulties with access, equipment etc. This may result in having to re-plan the survey; the key issue is to avoid compromising safety of personnel or to compromise monitoring results by inappropriate field survey methods.

5.4 Initial procedure at the lake

When you arrive at the lake, you should follow this procedure:

- Check access and examine the available substrate at the lake shore.
- Estimate the extent of most suitable habitat.
- Look for 'surrogate' information – cast shells/carapaces, remains in otter spraints, etc. Where vertical banks are visible, look for burrows with flattened oval entrances about 5-10 cm across – these may not be visible if you are surveying under conditions of high water.
- Take digital photos and GPS readings for sites where crayfish are particularly abundant, or where patches are widely spaced along the shore, to facilitate repeat surveying.
- Make biological observations on the crayfish catch from each defined sample (patch, sweep or trap) separately.

5.5 Survey methods

The basic survey methodology from the '*Monitoring of white-clawed crayfish manual*' (Reynolds, 2006) is utilised here, this includes aspects such as patch selection, replacement of refuges, biological observations, etc. The principal difference between this manual and that of Reynolds is a variation in the hand-searching method, with a more advanced method described in this manual. The modified hand-searching method has been found to be more efficient in lakes with a shallow shore, as well as those with deeper and higher gradient shores. The terminology used in describing lake crayfish habitats is given in Table 5, while standard patch definitions for each type of survey are given in Table 6.

Table 4 Health and safety risks associated with crayfish surveying in lakes.

Risk	Control measures
Traffic accidents	Park in suitable locations away from roads. Wear high visibility clothing when walking along roads to access sites, especially at night.
Farm animals	Assess the presence of farm animals before entering fields. Do not enter fields with bulls or other potentially dangerous animals.
Falls, trips	Do not work at night in areas which have not been previously surveyed. Take care when crossing field boundaries and rough ground.
Accidental entry into water	Take extreme care when working on, over or adjacent to water. Avoid lone working – always work in pairs and maintain contact. Use relevant personal protective equipment (PPE). Limit night work to areas of the shore that have been surveyed during the day and are considered safe.
Waterborne disease (i.e. Leptospirosis, Hepatitis B, Poliomyelitus, Tetanus).	Ensure all staff have up to date vaccinations for waterborne diseases. Avoid water that is obviously contaminated. Wear PPE (i.e., wetsuit, gloves, and face mask). Limit emersion time in water Avoid water entering mouth or eyes. Wash hands as soon as possible after working around watercourses and always before touching food. Protect any cuts and grazes using dressings or gloves. Alert safety officer if you develop flu like symptoms within 3 days of working near water.
Cuts, biological and chemical pathogens	Avoid physical contact with areas where sharp items/contaminants may exist. Correct handling of crayfish.

Table 5 Definitions of crayfish habitat terminology

Term	Definition
Stretch	A lake margin with apparently suitable habitat and substrate. There may be several stretches of different extent at any one lake.
Patch	The patch description depends on the type of survey being undertaken (SHS, SN, T, NS) and definitions for each survey are given in Table 6.
Refuge	A stone, crevice, burrow, submerged tree, tyre or clump of vegetation which may shelter crayfish.

Table 6 Standard patch definition for each type of survey.

Method	Patch definition
Snorkelling hand search (SHS)	10 potential refuges
Sweep Netting (SN)	A sweep for 1 meter in one direction and a return sweep over the same area.
Trapping (T)	One trap
Night Search (NS)	3 meter stretch of lake shoreline

5.5.1 Snorkelling hand search

This method is most suitable for lakes with abundant stony cobble in the shallows. Aim to examine at least 100m of shoreline, depending on lake size. Estimate how many stretches of this habitat are available in the lake, and accessible to surveyors. Centre the stretches on known crayfish hotspots where possible. Select 10 patches of stony habitat in each stretch and ideally investigate 10 refuges per patch. If stony stretches are continuous, treat the whole lake shore as a stretch and define patches at a suitable distance apart i.e. 10m. If crayfish are found in abundance, concentrate on just one stretch per lake.

Plate 7 Snorkelling hand search method.

Equipment and method

Equipment needed for the snorkelling hand-search include a wet suit or dry suit, wetsuit boots, snorkelling mask, crayfish container, towel for drying off and disinfectant. Optional equipment includes hood and gloves, and a small fish net (those used for aquarium fish are ideal). Snorkelling boots, hood and gloves reduce heat loss and boots are useful for walking over rough ground. However, heavy gloves restrict finger movement and therefore the ability to efficiently catch crayfish, so light gloves are preferable. Prior to wetting the mask, use anti-fogging spray/gel or saliva on the inside of the visor, otherwise visibility will be reduced. Effort (CPUE) is measured as the number of crayfish per patch.

1. Work to a maximum depth of 1 meter with a partner a short distance behind to hold the crayfish container.
2. Select 10 stony patches in each stretch and investigate 10 refuge stones per patch.
3. Stones (boulder, cobble) should be flattish, and at least 10 cm long; smaller or rounded stones rarely harbour crayfish
4. Lift and turn over each stone carefully and catch any crayfish underneath by hand or using a hand-net where water is deep or conditions difficult.
5. Replace each stone carefully into the position from where it was originally displaced.
6. Place all crayfish caught in this patch into the container, make biological observations and return to where they were caught before moving on to the next patch.
7. If no crayfish are seen after 5 patches or 50 refuge stones are investigated, move to a different stretch of lake shore.
8. Try to avoid stepping on the substrate (easily achieved with the added buoyancy of a wet suit) and remove potential refuges towards your body to avoid disturbing silt in your line of view.

9. When moving larger rocks, try to lift when possible, as opposed to rolling, so as to reduce the possibility of injury to crayfish. Slow movements greatly increase the chance of crayfish capture.
10. In places where the lake shelves off quickly, work in a position facing the shore.
11. Disinfect gear with bleach spray before surveying another lake/watercourse.

When hand searching, look for a stretch of shore that has rocks and cobbles consisting of one layer only, i.e. rock and cobble not on top of other loose rock and cobble or in other words a 2 dimensional shoreline. Surveying of the latter type of shore means that crayfish cannot penetrate deeper into the 3 dimensional substrate once their refuges are disturbed resulting in the crayfish not being detected or not caught.

An alternative but less versatile method is to wear chest waders and a snorkelling mask or viewing bucket, advantageous in that one doesn't need a wet/dry suit but one cannot survey to the same depth as with a suit, as depths are restricted to an arm's length. Problems in visibility associated with silt dislodgement through trampling also limit this method. Sometimes a slight drift in the lake takes this sediment away and accordingly, one should work against the direction of this drift. This might mean moving a distance of 100 meters along the shore and moving in a direction opposite to that which was initially planned.

5.5.2 Sweep netting

Sweep-netting should be used if there are no or few stones, or the bottom is obscured by weed, algae or debris. The sweep-netting technique involves using a hand-held pond net and sweeping and re-sweeping a 1m length of shore. Each standard 1m sweep of the net is recorded as a sampling unit. Select an apparently favourable area as the patch to be sampled. Note however, that hand-searching and sweep-netting are not directly comparable; a standard sweep may often yield no crayfish, or may sometimes turn up large numbers of juvenile crayfish, particularly amongst weed. As sweeps are less predictable than hand search, aim to do a minimum of 20 sweeps per lake. Remember that hatchlings can be caught when sweep netting, so it is important to examine the contents of the sweep net thoroughly. CPUE is the number of crayfish per standard sweep.

Plate 8 Crayfish from Lough Talt.

<u>Equipment and method</u>

You will need two white trays and a sturdy, square-framed pond net (FBA or equivalent), 25 cm x 25 cm mouth with strong mesh bag. A mesh size of 1-2 mm will retain all juveniles.

1. Carry out a standard sweep by drawing the net along one metre of bottom, forward and back once along the same track, as quickly as possible. In this procedure, the substrate should be thoroughly disturbed in the first half of the sweeping cycle. The net opening should then be reversed at the end of the first cycle (1m) and re-swept over the disturbed substrate. The success of this operation will depend on how quickly it is carried out because disturbed crayfish will flee to find cover.
2. Empty contents of net into a white tray for examination, and remove all crayfish to a white container.
3. If no crayfish are encountered in the first 10 sweeps, repeat the process at a different location, to a maximum of 20 sweeps.
4. Remember to make separate biological observations for each sweep.

5.5.3 Night Search

If the edge shelves abruptly, or the bottom is soft marl or mud which may swirl up if disturbed and obscure vision, night viewing should be considered as an alternative to the other methods. Reynolds (2006) noted that an estimate of lake margin length and width viewed in each area and a count of crayfish seen will give a semi-quantitative abundance of crayfish moving around in the area. However, algal growth and unclear water may limit usefulness of this method especially at deeper locations. This method also has safety considerations, especially where access is limited or difficult. CPUE is number of crayfish seen per 3 metres of bank.

Equipment and method

Bring a torch with a narrow beam, and oily fish as bait (sardines in sunflower oil are recommended).

1. By daylight, survey the stretch to be viewed, identifying access and noting hazards. Aim to cover at least 30 metres of margin; this may be discontinuous because of access or for other reasons. Ground-baiting with oily fish by day may later attract crayfish into the open.
2. When dark, use a torch with a narrow beam to scan a strip of shore up to one metre wide. Keep the light off the water until you are ready to view, and then only illuminate an area of about one square metre at a time.
3. Remember to record numbers of crayfish seen after every 3 metres viewed.

5.5.4 Trapping

Trapping should be considered where the terrain is unsuitable for hand-searching, sweep-netting or night search. Baited traps may attract crayfish from an unknown area, probably several square metres. Since trapping is known to select for larger individuals and possibly introduce a sex-bias (Gallagher, 2006) modify all traps by the application of 10mm mesh on the outside of the trap, fixing with cable ties or otherwise. Mesh modified traps were found to be far more effective at retaining juveniles and therefore resulted in a higher CPUE (O'Connor *et al*, 2008). As a trial, juvenile crayfish caught by hand searching were placed in an unmodified trap, left overnight and had escaped the following morning. CPUE is expressed as the number of crayfish per trap.

Equipment and method

You will need 20 modified traps ('Trappy' August plastic mesh traps are recommended); set in two strings of 10 traps, dropped at different locations along the lake shore and baited with liver or fish. Traps are to be spaced four metres apart on each rope. In this way both parts of the lake will be trapped in a similar way. Upon retrieval, records are taken for each individual trap.

1. Visit the lake at least 4 hours before dusk to allow sufficient time for the baiting and setting of traps (assuming that the 20 traps are pre-assembled and all traps are mesh modified).
2. Bait traps with tinned liver cat-food, which should be contained in small plastic mesh boxes that come with the traps. A standard 400g tin of catfood is sufficient for 10 traps, i.e. approximately 40g per bait cage.
3. Attach 10 traps at 4 m intervals along each rope, either with purpose made clips that come with the traps or with cable ties. Secure one end of the head rope to the lakeshore for ease of retrieval and throw the traps into the water, so that the rope lies parallel to the shore and ideally within 5 m of it, in about 0.5-3 m water. As the traps are pre-weighted, no further anchor weights are necessary. Try to leave the traps and anchored head rope as inconspicuous as possible, to avoid public nuisance.
4. As early as possible the morning after, haul the traps onto the shore preferably by pulling the rope as you walk along the shore (the less time the trap is moving while submerged in the water the less likely smaller crayfish will be lost). Watch for any smaller crayfish that may escape through the mesh as traps are hauled.
5. Remember to record biological observations on any crayfish caught after examining each trap.

5.6 Handling, records & measurement

In order to accurately measure and examine white-clawed crayfish, it is essential to be able to handle both large and small specimens with confidence and comfort. The following is a guide to handling, but individual surveyors may find alternative ways of holding crayfish. With practice, handling of crayfish will be easy and efficient.

5.6.1 Handling

Crayfish claws can be large and are very powerful, but even the largest crayfish will not cause harm if handled properly. A crayfish claw can cause localised bruising or perhaps a small cut, often due to the softening of the hands from being immersed in water. Although the wound is not serious, broken skin can lead to infection while working with water. Should a crayfish attach to your hand, put your hand into a bucket of water so that the crayfish is immersed and it will let go; trying to pull off the crayfish will only result in the grip tightening and may injure the crayfish. In catching the crayfish, approach from the rear with one hand, as there is less chance of your hand being seen. You can move your free hand in front of the crayfish to distract it. Press down gently on the crayfish while you get a good grip on the carapace (shell on the back, behind the head). In general, the crayfish should be held between the thumb and the forefinger with claws directed away from your hand. Once caught in a comfortable position, the crayfish can then be transferred from hand to hand so that it can be moved into a position for examination. The little finger of the hand can be used to hold the tail away from the crayfish body during examination. Crayfish that have just moulted have a soft carapace and need to be handled with extra caution, as internal organs could be damaged, resulting in death or compromised mobility. Remember that smaller crayfish moult more often than adults, so the chances of encountering a recently moulted crayfish are much greater when dealing with juveniles, including hatchlings.

5.6.2 Measurement of white-clawed crayfish.

During the survey of each patch the following steps are required:

1. Record hard carapace length (CL), this is measured from the tip of the rostrum to the posterior end of the carapace. Note whether the specimen is a hatchling (2.5-7 mm CL), juvenile (7-23 mm CL) or adult (greater than 23 mm CL) and whether male or female. Sex of hatchlings will be indeterminate in the field.

2. You may see evidence of breeding status outside the normal summer sampling period; in October or November mated females will have white cement-like spermatophores at base of legs; while from November to June berried females carry eggs attached to the abdomen.
3. Note also any signs of damage or disease, then return specimen to place of capture before moving on to sample the next patch.
4. If a crayfish is seen but not caught, estimate its size and life-stage as hatchling, juvenile or adult.
5. Record all data onto the attached Recording Form (see Appendix 1); include observations on breeding and disease status etc. under 'Notes' column on the form.

As each patch, sweep or trap is surveyed, place any captured crayfish in a bucket with sufficient lake water. Crayfish recorded from traps retrieved from the lake should be replaced as close to the point of removal as feasible. Using other survey methodologies, crayfish should be replaced on completion of each patch.

Plate 9 This picture shows how a crayfish can be held without injury by grasping the dorsal side of the carapace and holding the claws directed away from your hands. White spermatophores are visible in this photo, near the base of the legs on the underside of a female crayfish. The female's broad abdomen is suited to carrying the brood.

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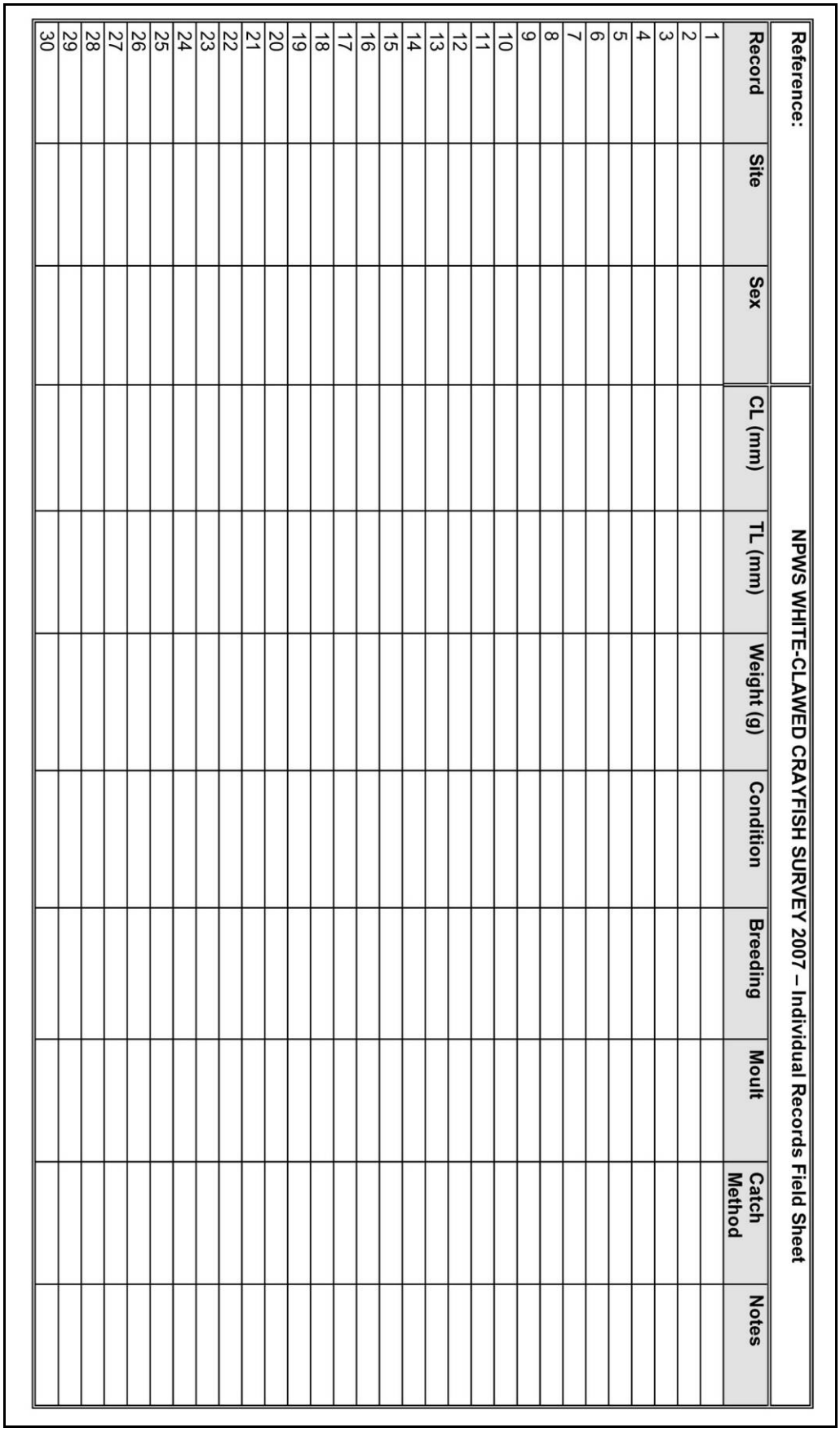
APPENDIX 1 FIELD RECORD SHEETS

NPWS WHITE-CLAWED CRAYFISH SURVEY 2007
FIELD RECORD SHEETS

Site Code:		**Date Surveyed:**		
Catchment:		**Method:**		
Lake:		**Surveyors:**		
Location:		**Lake Levels:**		
Grid Reference:		**Water Temperature:**		
Photograph Number:		**DO(%):**		
Weather Conditions:		**DO (ppm):**		
		Conductivity:		

	Patch/Site									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Location										
Surveyor										
Patch / Site Area (m^2)										
Distance from shore (m)										
Shoreline type										
Shore gradient (^{o})										
Mean depth (cm)										
Maximum depth (m)										
Substrate										
Rock (%)										
Cobble (%)										
Gravel (%)										
Sand (%)										
Clay (%)										
Silt (%)										
Vegetation Cover (%)										
Shade (%)										
Refuges Present										
Small Cobble (6.5-15cm)										
Large Cobble (15-25.6cm)										
Rock (25.6-40cm)										
Boulder (>40cm)										
Other (state)										
Woody Debris										
Urban Debris										
Tree Roots										
Moss										
Filamentous Algae										
Chara										
Other Vegetation										
Emergent Vegetation										
Search Time (mins)										
Total Number of Crayfish (n)										
Total Adult Males (n)										
Total Adult Females (n)										
Total Juveniles (n)										
Other Fish										
Crayfish Habitat Evaluation										
Notes:										

Figure A 1.1 Recording form for lake crayfish survey



Reference:

NPWS WHITE-CLAWED CRAYFISH SURVEY 2007 – Individual Records Field Sheet

Record	Site	Sex	CL (mm)	TL (mm)	Weight (g)	Condition	Breeding	Moult	Catch Method	Notes
1										
2										
3										
4										
5										
6										
7										
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Figure A 1.2 Recording form for data on individual crayfish captured during lake survey