Translocation of a Population of Great Crested Newts (*Triturus cristatus*): A Scottish Case Study

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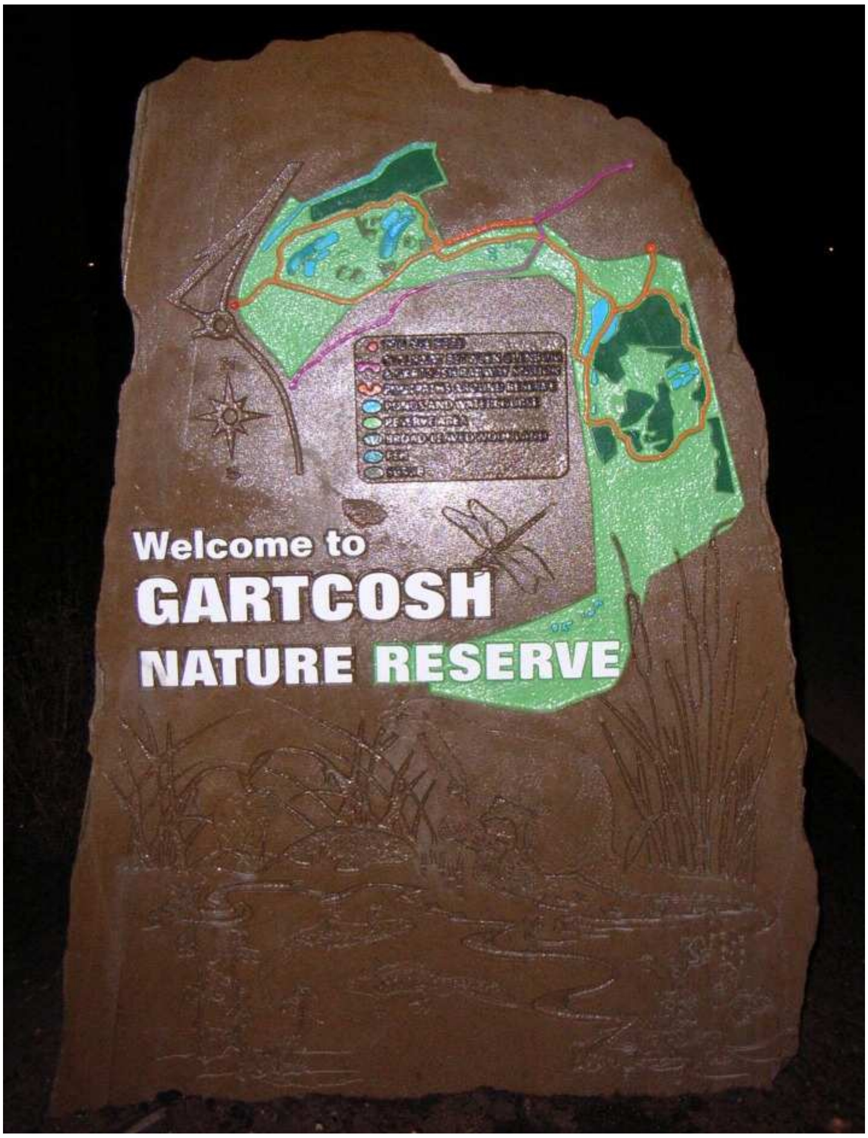

Abstract

In the UK, translocation is increasingly being used to resolve conflict between great crested newt (*Triturus cristatus)* conservation and land development. Due to a lack of objective study on the translocation procedure, there remains little evidence of the success of employing this strategy despite widespread implementation. Reviews of translocations highlight the need for case studies that include longer term pre and post translocation monitoring. To allow redevelopment of the Gartcosh Industrial Site, the decision was taken to translocate the resident great crested newt population to the purpose built Gartcosh Nature Reserve around the periphery. This provided an opportunity for in-depth analysis of the largest project of its kind in Scotland.

This project was designed to test the effectiveness of translocation in producing a self-sustaining, viable population. The key aims were: to ascertain if the population was successfully re-established in the receptor site at a level comparable with the donor site; to assess whether the newly created habitat was suitable for supporting a population of great crested newts; to determine what constitutes a successful translocation and how best to achieve this within the Scottish context. The following points summarise the projects findings:

- Simple counts of adults are being maintained at a level comparable to or greater than pre translocation counts.

- The favourable status of the adult population is supported by a capture-mark-recapture study. Population estimates are on a par with numbers of adults translocated to the Gartcosh Nature Reserve.

- Juvenile lifestages indicate declines. Further monitoring is required to determine if this is an effect of the translocation or a natural fluctuation.

- Survival rate of adults is measured at 43%.

- There is significant recruitment of ‘new’ adults.

- Good quality terrestrial and aquatic habitat has been produced, with an overall loss of land and pond surface area but increased number of ponds.

- Increased individual growth rates of adults are indicative of a habitat capable of meeting adult resource requirements.

- The nature reserve is internally fragmented into zones preventing movement through the site and is isolated within the wider landscape. For the population to be viable, connectivity requires improvement.

- To ascertain long-term success of the Gartcosh translocation it is recommended that post monitoring extends beyond simple adult counts and continues capture-mark-recapture study specifically within the Railway Junction area.

- Guidelines have been produced detailing best practice in translocation, monitoring and habitat creation.

Table of Contents

List of Figures

List of Tables

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Abbreviations

ACA	Amphibian Conservation Area
BB	Bothlin Burn
GCN	great crested newts
GNR	Gartcosh Nature Reserve
GQH	Garnqueen Hill
HEL	Heritage Environmental Limited
HSI	Habitat Suitability Index
met	metamorph
NLC	North Lanarkshire Council
PSYM	Predictive System of Metrics
RJ	Railway Junction
sa	sub-adult
SS	Stepping Stone
SNH	Scottish Natural Heritage
TWINSPAN	Two-way Indicator Species Analysis

1 Thesis Introduction

1.1 Global Amphibian Decline

Amphibians are declining on a global scale. Of the 6000+ known species, 165 are believed to be extinct with a further 1,896 species threatened (Stuart et al., 2008). Concern about amphibians is partly due to their value as indicators of environmental health (Blaustein, 1994; Blaustein & Wake, 1995). Significant threats to population viability include habitat loss and degradation, pollution, exclusion by invasive species and commercial trade (refs in IUCN, 2005). The recent global emergence of chytrid fungal disease is having a devastating impact on infected populations. It has recently been identified in Great Britain (Garner et al., 2005) in all native species except great crested newts (Cunningham & Minting, 2008). The failure of amphibians to respond to infection suggests these are new pathogens or that the immune response is being compromised (Carey et al., 1999). UV-B exposure can result in significant mortality in exposed eggs (Blaustein et al., 1994; Blaustein & Wake, 1995; Belden & Blaustein, 2002) and xenobiotics may impact growth and development of young amphibians (Carey & Bryant, 1995).

Climate change can drive population declines through a number of mechanisms. Lower water levels may increase an embryo's exposure to UV-B or pathogens, increasing mortality rates (Kiesecker et al. 2001). Global warming caused population declines in *Bufo bufo* by increasing female mortality and decreasing body size in surviving females, therefore leading to reduced egg production (Reading, 2007). Mass amphibian extinctions may be caused by temperature increases shifting conditions into the range favoured by *Batrachochytrium dendrobatidis (*Pounds et al., 2006), although Daszak et al. (2005) described declines as more likely caused by the effects of decreased rainfall over a number of years than by chytrid outbreaks.

Research has focused on single causes of declines. However, different species and geographically distinct populations of the same species will respond to threats in varying ways. Factors may work in combination, resulting in declines in previously unaffected species (Blaustein & Kiesecker, 2002). In English *Rana* *temporaria* populations, iridovirus outbreaks have frequently correlated to regions with significant levels of human disturbance (Cunningham et al., 1996). UV-B, pathogens and chemicals may act synergistically, producing sub-lethal effects in amphibians (Kiesecker & Blaustein, 1995). Worryingly, a number of species are declining with no obvious cause (Stuart et al., 2008). Declines are of particular cause for concern among amphibian populations due to limited dispersal and poor colonisation capabilities (Petranka et al., 1993).

1.2 Great Crested Newt Decline

The *Triturus cristatus* superspecies contains four separate species; great crested newt (GCN) *T. cristatus* (Northern crested newt), *T. dobrogicus* (Danube crested newt), *T. karelinii* (Southern crested newt) and *T. carnifex* (Italian crested newt) (IUCN, 2010). GCN are widely distributed throughout northern France, southern Scandinavia, central Europe and Western Siberia. In the UK, GCN are widespread, but localised in mainland Britain (Fig 1-1). Populations are scarce in the uplands and Scotland and are absent from Ireland.

A study in the 1980’s identified 2,000 GCN breeding sites and then calculated there to be an estimated 18,000 populations across Britain (UKBAP, 1995; Swan & Oldham, 1989). There has been significant decline in British GCN populations (Langton et al., 2001), with a yearly downturn estimated at 0.5% (Corbett, 1994) to 2% (Swan & Oldham, 1989). In Scotland, populations have declined across their range (SNH Trends, 2004). GCN populations are declining at a faster rate than other common amphibian species throughout their European range (AmphibiaWeb, 2008). The Biodiversity Action Reporting System reported 23,500 sites/populations in the UK in 2005 (Watson, 2008) and currently reports an estimate of 71,000 sites/populations (BARS, 2009) while acknowledging that this is not precise due to deficiencies in the data. It is often only as a development or other land-use project begins that a GCN population is discovered. This has negative consequences for conservation efforts as it is likely to result in a ‘rescue’ with minimal monitoring and surveying. Ongoing survey efforts by SNH and ARC should provide a better Scottish population estimate. The 2009 estimate is 25% lower than 100,000 populations set as necessary to maintain favourable status (JNCC, 2007).

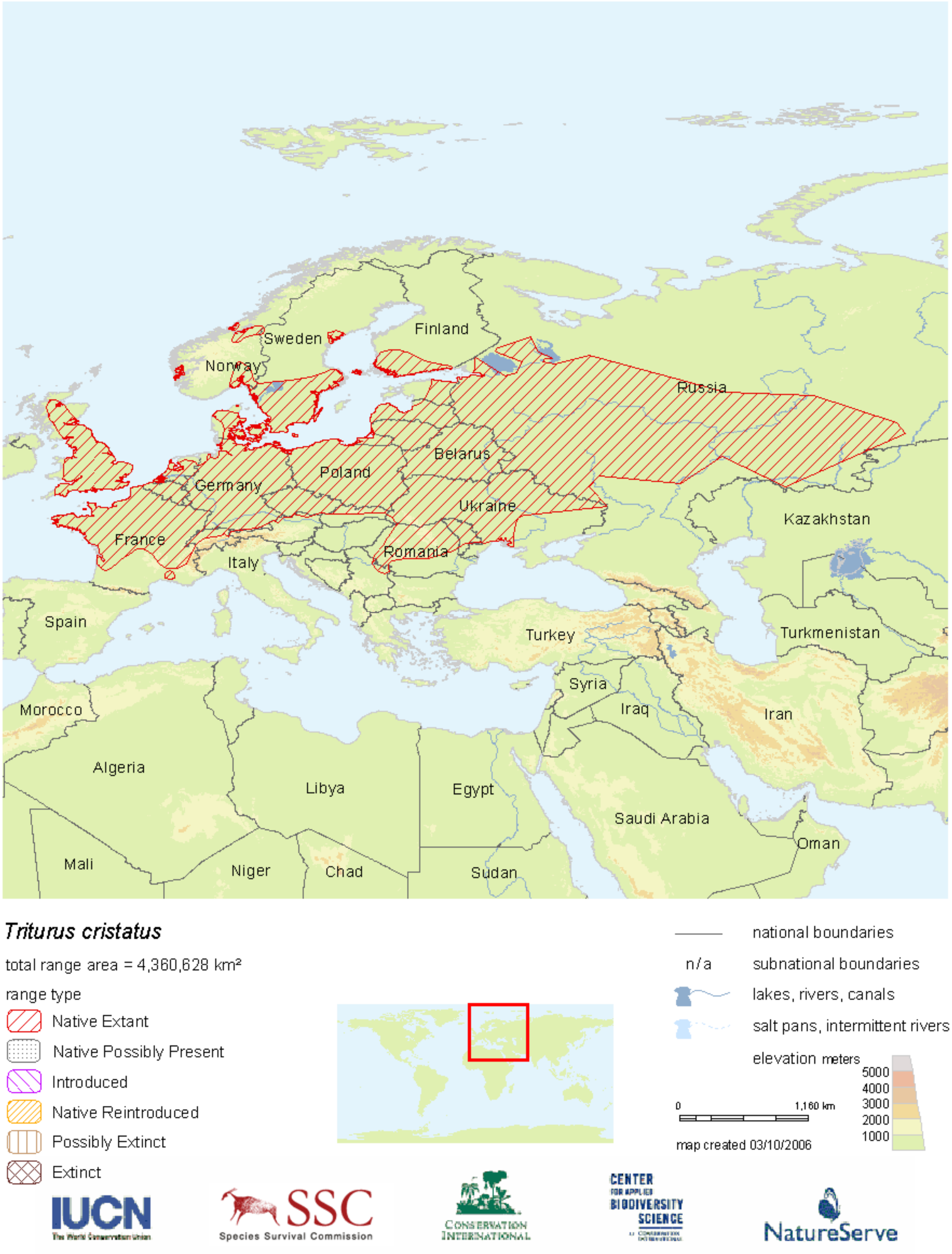

Figure 1-1: Distribution of *Triturus cristatus* throughout Europe.
Map Source: Global Amphibian Assessment. http://www.globalamphibians.org/

Threats to GCN populations are similar to the threats faced by amphibians world-wide, as described above. GCN are more at risk than other amphibian species to marked declines or possible local extinctions following the introduction of predatory fish (Beebee, 1997). This is likely due to the nektonic behaviour of larvae. Habitat degradation or destruction has the most significant impact due to reliance of GCN on both good quality terrestrial and aquatic habitat. Terrestrial habitat is threatened by development, urbanisation and other land usage change. Resulting fragmented populations are generally smaller, more isolated and at greater risk from extinction (Hanski & Gilpin, 1997; Hitchings & Beebee, 1997; 1998).

The British pondscape is in danger from deliberate destruction, lack of management and natural succession. Increased water demand has resulted in a lowering of the water table in some areas. Poor management practices such as pond deepening can shift conditions in favour of invertebrate predators. As GCN are reliant on aquatic habitat for breeding, recorded population declines are linked to pond loss and degradation. Palmate and smooth newts are less vulnerable due to their ability to utilise smaller water bodies such as garden ponds (Langton et al., 2001). However, this was contradicted by Oldham et al., (1991) in their review of translocation. There were indications of success in the usage of gardens ponds as GCN receptor sites, but they were likely able to support only small, unstable populations.

In Sussex, intensive farming practices made dewponds (ponds for livestock) a redundant feature in the landscape. Between 1950 and 1977, 70% of all dewponds were lost (Beebee, 1997). In Cheshire, 60% of ponds were lost between 1870 and 1960 (English Nature, 2001). Despite pond creation and restoration efforts, net pond loss occurred in both instances. A number of regions surveyed between 1970s and 1980s revealed a total decrease (lost or rendered unsuitable for GCN) of 50 to 55% (Corbett, 1994). Across England, it is estimated that 40,000 possible GCN breeding ponds were lost with a corresponding population decline of between 0.5 to 4% a year during 1960s to 1990s (English Nature, 2001). In order to maintain favourable conservation status of GCN the decline in suitable ponds and associated population loss must be addressed.

It is estimated that there are between 228,900 and 400,000 ponds in Britain today not including seasonal ponds garden ponds and woodland ponds (Williams et al., 1998; Biggs et al., 2005; Oertli et al., 2005) and around 140-000 and 150,000 of these are found in Scotland (Biggs et al., 2000; refs in SNH Trends, 2002). This is likely to be underestimated by approximately 30-50% as seasonal, urban, bog and woodland ponds were not included (refs in SNH Trends, 2002). The number of ponds in Scotland has declined by 7% from 1950s to1980s. No further significant losses were recorded during a survey in 1990 to 1998 (refs in SNH Trends, 2004). Another survey of Scottish ponds in 1996 revealed only 83 GCN breeding ponds (Alexander, 1997).

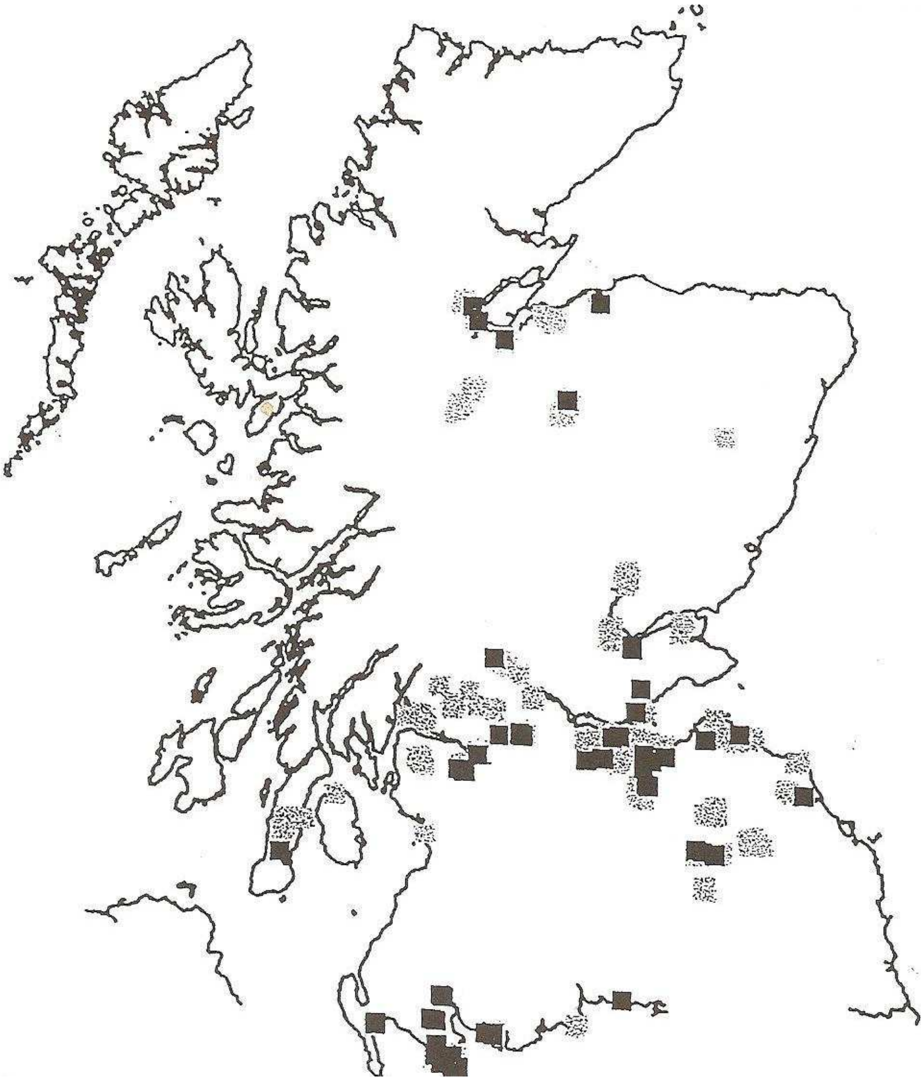

Figure 1-2: T. cristatus ponds in Scotland identified during surveys undertaken in 1995-96 including those described in Alexander (1997) and SNH (1997). Grey boxes = assessed sites. Black boxes = confirmed GCN sites.

Estimates of Scottish GCN populations are of extremely poor quality. It is often quoted that there are approximately 1000 adult GCN in Scotland (e.g. Edgar & Bird, 2005). Yet there are 1,012 breeding adults alone in the Gartcosh population that forms the basis of this research (Kellett & Bates, 2006). A survey of 42 Scottish GCN breeding ponds produced a mean of 41.6 to 138.8 adult newts per occupied pond (Bates & Hutcheon, 1999). Assuming a minimum of 83 GCN breeding ponds (Alexander, 1997), this suggests that the adult population of GCN in Scotland may range between 3,500 and 11,500 adult newts.

1.3 Legislation, conservation and licensing

1.3.1 Legislation protecting great crested newts

GCN are an internationally important species listed on Annexes II and IV of the *EC Habitats Directive*, Appendix II of the *Bern Convention* and in the 2001 International Union for Conservation of Nature (IUCN) Red List of Threatened Animals as ‘Least Concern’ (populations are in decline but still relatively widespread in their distribution). In the UK GCN are protected under Schedule 2 of the Conservation *(Natural Habitats etc.)* Regulations, 1994.

The protection afforded to great crested newts means that killing, injuring, taking, taking or damaging eggs, certain forms of disturbance (for instance at a breeding pond or during hibernation), and possession and sale are prohibited. It is also an offence to damage or destroy breeding or resting places of newts.

1.3.2 Conservation of great crested newts

Areas with particularly important populations of great crested newts may also be designated as Sites of Special Scientific Interest (SSSI) or, where populations are important in a European context, as Special Areas of Conservation (SAC). In addition to the protection afforded to GCN by the legislation described above, designation of these sites affords further protection aimed at protecting populations and preventing operations that could damage them as well as encouraging sympathetic management of their habitats.

A European action plan for the Triturus cristatus superspecies was produced in 2005, with the overall aim of maintaining viable crested newt populations across Europe (Edgar & Bird, 2005). The UK Biodiversity Action Plan includes a GCN Species Action Plan (SAP). This is adopted by Councils or the appropriate local governing body. In general, the aim is to identify and monitor populations, maintain existing ranges and increase populations through recolonisation. The

North Lanarkshire SAP sets out the objectives for the region of this project. Specific objectives include the expansion of populations within North Lanarkshire and to protect and improve habitats of all known GCN sites. Pond surveying will focus initially on ponds in areas know to support GCN populations. Implementation of the SAP is dependant on allocation of appropriate resources.

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1.3.3 Licensing

The legislation protecting great crested newts includes provision for licences to be granted for specific purposes to allow actions that would otherwise constitute offences. Licences can only be granted for specific purposes, where there is no satisfactory alternative, and where granting the licence will not be detrimental to the maintenance of the species at a ‘favourable conservation status’.

Licences can therefore be granted to permit some developments that could affect great crested newts or the habitats that they use. At one end of the scale this might mean the loss of a small area of foraging habitat in the vicinity of a known newt pond, and at the other it could mean the destruction of multiple breeding ponds and surrounding habitats.

It is expected that any licence application will describe these impacts on great crested newts. Following this they should provide a plan of mitigation to ensure that impacts on individual newts, populations and habitats is minimised and, if appropriate, where compensatory habitat is created or existing habitats enhanced for the benefit of GCN.

Where breeding ponds or significant areas of suitable habitat are to be lost to development under licence it is sometimes necessary to permit the capture of newts form areas proposed for development and their release to areas of suitable habitat outwith the development boundary.

1.4 Translocation Overview

1.4.1 Translocation as a Mitigation Method

Definitions

For the purposes of this research, translocation will be described according to the definition proposed by English Nature (2001):

> *'Any activity that involves the capture and movement of newts. This embraces both in-situ mitigation projects where newts may be moved only a few metres to contain them within the same site, as well as ex-situ projects where newts are moved off-site to a different area'.*

With mitigation defined as:

> *'Practices which reduce or remove damage (e.g. by changing the layout of a scheme or by capturing newts to avoid killing)' (English Nature, 2001).*

In-situ:

> *'Receptor sites managed for GCN that are located less than 500 m from the original development site and not separated by any major newt dispersal barriers, usually within the site boundaries or in an immediately adjacent area' (Edgar et al., 2005).*

Ex-situ:

> *'Sites receiving newts that are greater than 500 m from the original development site, or are situated on the far side of a newt dispersal barrier, such as a major road' (Edgar et al, 2005).*

Translocation has been employed with a range of motives including conservation, animal welfare, scientific research, stock enhancement and aesthetic purposes (Lindburg, 1992; Fischer & Lindenmayer, 2000). This review will focus on conservation-based translocations with aims varying from the introduction of a new population in a previously unoccupied site, reintroduction of extinct populations within historic ranges (Wilson & Stanley Price, 1994), supplementation of declining populations, investigation into the cause of declines (Fellers et al., 2007), lessening extinction risk from catastrophic events by creating metapopulations (Cooke, 2001a) and reducing bottle-necking by increasing genetic variation (Griffiths et al., 1989).

Conservation programmes for a large range of species have utilised translocation; birds and mammals (see references in Griffiths et al., 1989; Stanley Price, 1991; Wolf et al., 1996; Fischer & Lindenmayer, 2000), plants (Maunder, 1994; Balcombe et al. 2005), invertebrates (see references in Cullen & Wheater, 1993; Bullock, 1998), amphibians (see references in Szafoni et al., 1999; Fellers et al., 2007), reptiles (Platenberg & Griffiths, 1999) and habitats (see references in Worthington & Helliwell, 1987; Byrne, 1990; Cullen & Wheater, 1993; Bullock, 1998).

In the UK, translocation is frequently used as mitigation between wildlife and development. However, there remains little evidence of the success of employing this strategy despite its widespread implementation and use as a conservation strategy. Fischer & Lindenmayer (2000) reviewed 180 case studies of animal relocations undertaken over a 20 year period (116 reintroductions, 48 supplementations and 36 translocations) and found that translocations designed to solve conflict between humans and animals generally failed. This lack of success was reflected in a review of bird and mammal translocation undertaken by Griffith et al. (1989) and updated by Wolf et al. (1996). I will focus on amphibian translocation, specifically on the translocation of great crested newts within the UK.

During a review on amphibian population dynamics, Marsh & Trenham (2001) commented that translocation could be necessary to promote the survival of amphibian populations. This was strongly contested by Seigel & Dodd (2002). In an extensive review of amphibian and reptile translocation, Dodd & Seigel (1991) stated that despite evidence of breeding, no project resulted in the establishment of a self-sustaining population of snakes, turtles, frogs or salamanders. They argued that translocation was not a proven management technique and that evaluating the success of a translocation requires long-term population studies but that this is generally rare. Trenham & Marsh (2002) contended that translocation has been proven successful in some cases, quoting a study on the natterjack toad by Denton et al. (1997) and may be useful in instances where dispersal barriers act to prevent colonisation of suitable habitat. They believe translocation could potentially play an important role in amphibian conservation but should only be attempted if failure is acceptable. Burke (1991) agreed with the recommendations outlined in Dodd & Seigel (1991) but questioned the evidence used in support. It is possible that amphibians and reptiles are simply not suitable species to translocate and that it was flawed to group projects involving different species and techniques, as this assumes that all species have a similar chance of success. Burke included an extensive list of what he believes to be examples of successful relocations, repatriations and translocations of amphibians and reptiles (see references in Burke, 1991).

1.4.2 GCN Translocation

Nearly 100 GCN translocation attempts in the late 1980's were reviewed by Oldham et al. (1991) and proved inconclusive due to lack of monitoring. Oldham et al. (1991) reviewed records of all translocation procedures held by English Nature up to 1990 and could not conclusively determine whether the procedure was successful. Of 86 cases studied only 29% were sufficiently monitored to produce meaningful results, with a breeding population established in only one case. A follow up study from 1990 to 1995 was again inconclusive (Oldham & Humphries, 2000). The incidence of post-translocation monitoring increased to 64% but with no consistency in data recording. The majority of post-monitoring looked only to presence of adults, which is not indicative of a self-sustaining population. There were obvious deficiencies in translocation methods in the significant proportion of projects that failed completely. An unpublished study by May (1996) looked at translocations from 1990-1994, finding little consistency between translocation procedures and monitoring methods used (described in Edgar & Griffiths, 2004).

The question as to whether or not translocation is an effective mitigation method remained unanswered. In an attempt to redress this, Edgar & Griffiths (2004) and Edgar et al. (2005) reviewed all existing examples up until 2001, including for analysis only 72 projects where translocation was used specifically to resolve conflict arising from development pressures. Criteria examined include the fate of newt populations, gain or loss of newt habitat, efforts and costs. Only one project had attempted a detailed population estimate of newts on-site prior to mitigation. As a result, it was unknown what proportion of the population was translocated during the vast majority of studied projects. Furthermore, any future analysis of translocation success would lack the necessary comparisons to assess whether a viable population had been established, comparable with the original. Post-translocation monitoring did not happen at all in 36% of the sites and only three were monitored for a period of five years. Perhaps the most worrying aspect of the review was that considering it is a legal requirement to report licensed work on GCN, 55.3% of all licences issued had no returns. Valuable data that could be used to draw conclusions on translocation success are therefore either missing or remain unpublished, held in reports between the consultant and client.

Lewis et al. (2007) revisited 13 mitigation sites included in the Edgar & Griffiths (2004) review at least three years after translocation took place. Their findings lead to the conclusion that translocated populations can be maintained but the long-term viability needs to be assessed. They recommended mark recapture methods for population estimates over presence/absence or simple counts. Furthermore, ponds were isolated by development, highlighting the need to focus on habitat connectivity.

1.4.3 Successful Translocation

Comprehensive guidelines exist to promote good practice. In 1987, the IUCN published their position statement on introductions, re-introductions and re-stocking of living organisms. In 1991, Herpetofauna International Ltd proposed guidelines specifically for GCN translocations. English Nature (2001) mitigation guidelines were designed to provide advice on how to proceed on a project involving conflict with development. This document builds upon English Nature

(1996). Gent & Gibson (1998) is a valuable tool for undertaking the logistics of translocation. They included useful information on legislation, ecology, survey techniques, survey standards, impact assessments and information on how to plan and undertake a mitigation project.

Habitat

Great crested newts require good quality aquatic and terrestrial habitats to thrive. This would be defined by plentiful food, availability of refugia, sustainable competition for resources and reduced predation, particularly fish predation of newt larvae (Baker, 1999). The receptor site may require habitat enhancement to improve existing ponds and surrounding land or the creation of new habitat. On-going management may be required to maintain standards. It is preferable that the translocated animals are moved to an area with no pre-existing population (genetic implications discussed later) and that the chosen receptor site is within the historical range of the species. A population is more likely to survive and thrive if the donor population is large and the receptor site is not restricted to a single, isolated pond in a fragmented landscape. The existence of a metapopulation, within a connected pondscape supporting immigration and emigration, will reduce the likelihood of extinction events.

Edgar & Griffiths (2004) described an increase in the application for mitigation licences from 10 to over 80 per year during the period of 1990 to 2001, with Griffiths (2004) depicting an ‘exponential rise’. From a positive perspective, this could mean increased effort in mitigation against the impacts of development. Conversely, it could reflect a significant increase in development with only relatively small gains in mitigation effort. It is common in translocation projects for the receptor site to have either fewer ponds or a reduced surface area of water due to smaller ponds than the donor sites (Horton & Branscombe, 1994; Edgar & Griffiths, 2004). With the number of mitigation projects likely to continue to rise, net habitat loss could have a serious impact on the UK pondscape, already suffering from significant losses through reasons described earlier.

Translocation could be planned in a manner providing conservation gain. Objectives should include a reduction in habitat loss through well planned pond creation and restoration and increased numbers of populations within a metapopulation structure (Clemons, 1997). In Cambridgeshire, Cooke (2001a) translocated a failing populations to a new pond. This was successful in achieving the aims of creating a new and larger colony. However, the single, isolated pond is vulnerable to extinction events. An additional two ponds were created to reduce the threat. *In-situ* translocation is preferable to *ex-situ* and more consideration needs to be given to projects whereby it would be possible to maintain the existing newt habitat within the proposed development site. Beebee (1990) described a road development where there need not have been any conflict. Development could have proceeded as required with the pond remaining untouched.

Monitoring

It is recommended that a good project begins with pre-translocation monitoring, to provide reasonable population estimates. This will be used to inform the scope and method of intercepting the donor population and what proportion of the population has been moved. Often, the existence of a population only becomes known once development has begun. In a translocation in East Sussex, Beebee (1990) had only one week to catch as many GCN as possible before the pond was pumped dry and in-filled. Only bottle traps proved effective capture methods, with netting and torching revealing no GCN at all. During pond draining, the same numbers of newts were caught again, revealing inefficiencies in the capture method. During a translocation in Salzburg of six amphibian and four reptile species, Kyek et al. (2007) had ten months pre-monitoring but found that more than 7.5 times the number of pre-study recordings were actually captured and moved. Short monitoring periods are problematic as amphibian population estimates can fluctuate greatly from year to year. In addition, the captured population will include only adults breeding in the pond at that time. Adults skipping a breeding season and juveniles would not be captured. Rescue projects with short capture durations like Beebee (1990) will additionally suffer by excluding early and late arrivals.

The aim of translocation is the establishment of a viable, self-sustaining population. Whether this has been achieved can only be ascertained through long-term, post-translocation monitoring. The translocation by Horton &

Branscombe (1994) involved three years pre-monitoring followed by a three year period during which time interception, translocation and monitoring of the receptor site took place. This was considered a success based on high capture rates of adults with healthy body masses and the production of metamorphs within this translocation period. Post-monitoring after completion was not mentioned nor was any work undertaken with regards recruitment of the metamorphs into the adult population.

The duration of post translocation monitoring will often be dictated by the availability of funds, but how long is it necessary to monitor to ascertain whether the translocation has been a success or failure? The majority of projects with monitoring (e.g. Horton & Branscombe, 1994; Langton et al., 1994; Oldham & Humphries, 2000) were only monitored for a few years. After six years monitoring, a translocation in Cambridgeshire by Cooke (2001c) would have appeared to have failed with few adults and progeny observed. However, after eight years, signs of success were apparent with increased counts. Both Dodd & Seigel (1991) and Cooke (1997) advocate monitoring for a minimum of ten years. It may have been that the post-translocation fluctuation was similar to pre-translocation fluctuations, but we rarely have long-term pre-monitoring.

Duration of post-monitoring should be dictated by the life-history characteristics of the animal being translocated. It takes a GCN two to three years to mature into a breeding adult. Therefore, monitoring should be undertaken for a minimum of six years (two generations) to confidently claim that adults are breeding, larvae and metamorphs are surviving and being recruited into the breeding adult population. The presence of new adults should be monitored for. Herpetofauna Conservation Ltd (1991) described a scenario where a project could be considered a success due to the occurrence of egg-laying and larval metamorphoses. However, if the surrounding land habitat is unsuitable for young GCN and translocated adults live upwards of ten years, it may be only after this period that population declines are observed. Post-monitoring protocols should be standardised to allow for comparisons between projects. Fischer & Lindenmayer (2000) suggest monitoring not just for population size, but adult sex ratios and adult to juvenile ratios. They advocate on-going assessment of threats to the population.

Lifestage for Translocation Success

This research is focusing on 'rescue' mitigation whereby a population is threatened by some form of land use change and the objective is to capture and move as many of the animals as possible. For translocations with other objectives, the possibility of success may be increased by moving non-adult life stages. This serves two additional purposes. It is likely to have less of an impact on the donor site than the removal of adults and solves the site fidelity issue, whereby adults leave the receptor site to locate their original ponds. Oldham (1994) reported 50% of translocated GCN adults were faithful to their site of origin. Oldham & Humphries (2000) found that up to 70% tried to return to their native ponds. Semlitsch (2002) favours eggs or larvae for amphibian translocations as the adults produced will be philopatric to the translocated site.

Reinert (1991) refers to a number of examples of success achieved by the movement of early developmental stages (eggs, larvae, neonates). A six year study by Cooke & Oldham (1995) attempted to establish populations of common frogs (*Rana temporaria)* by translocating spawn, and common toad (*Bufo bufo)* by spawn and adults. Adult toads suffered heavy losses either due to mortalities or emigration. Transfer of spawn was believed to have been more effective.

Semlitsch (2002) attempted to quantify the number of translocated eggs and larvae of *Ambystoma* required to achieve the minimum viable breeding population size of 100 as described in Shaffer (1981). Estimates based on natural populations are; larvae surviving to metamorphosis: 1 – 5% (Berven, 1990), survival to first reproduction: 6 - 26% (mean approx. 20%) (Berven, 1990). This equates to an egg or larval translocation figure of 10,000 to 50,000.

For GCN, Arntzen & Teunis (1993) found juvenile survival to be 7 – 45% (mean of 22%). Oldham (1994) combined data with Arntzen & Teunis (1993) to produce a survivorship curve for GCN, estimating juvenile survival at 0.2 and adult survival at 0.68.

Species range could be increased or populations re-established in historical sites with the creation or restoration of ponds and the translocation of 'spare' eggs and larvae from successful colonies.

1.4.4 Potential Problems with Translocation

Disease

The emergence of infectious diseases in amphibians (Daszak et al., 1999) and the potential transmission of disease between populations and from captive to wild populations (Dodd & Seigel, 1991; Cunningham et al., 1996) is a very real threat associated with translocation. Garner et al. (2005) described the surfacing of the chytrid fungus disease in Europe in introduced American bullfrogs. A national survey of chytrid infection was undertaken in spring and summer 2008, with nearly 6,000 amphibians in 121 ponds tested across the UK. Chytrid was confirmed in all native species with the exception of GCN (Cunningham & Minting, 2008) although there are unconfirmed reports that chytrid has been located in wild GCN populations in other sites (*pers. comm. John McKinnell, SNH*). Best practice for disease control needs to be disseminated among relevant people to avoid translocations furthering the spread of this or any other pathogen.

Genetics

Translocation may have a significant impact on the genetic pool of a population (see Reinert, 1991; Dodd & Seigel, 1991; Storfer, 1999; Semlitsch, 2002; Trenham & Marsh, 2002). Mixing populations could result in the loss of local adaptations. This may limit a population's ability to evolve and adapt to change, causing a reduction in fitness. If populations are to be mixed, it may be preferable to select animals with similar genetic backgrounds where possible. Alternatively, Semlitsch (2002) suggested maximising genetic diversity of the donor individuals by selecting a small number of animals from a large number of colonies. Conversely, gene flow through translocation could aid genetic variation, preventing inbreeding depression. This may be particularly applicable to small, localised populations of amphibians in fragmented landscapes with limited dispersal capabilities.

Cost

There is very little information freely available in the literature with regards the true costs of mitigation. Often, the project work is carried out by private consultants and financial information is considered commercially sensitive. Edgar et al. (2005) approximated spending on GCN mitigation projects in England at £1.5 million per year. Average spend per project was estimated at £15,000 to £20,000 (Edgar & Griffiths, 2004). Tattersfield (1994) reported a mitigation costing £200,000. Langton (1994) mentioned five cases where total costs per project were in excess of £1,000,000. A recent project in Wales described a housing development mitigation project, where £140,000 was spent but only two adult GCN were caught and moved (www.metro.co.uk, 2007). Such negative press is detrimental to conservation efforts throughout the UK. The question remains as to whether or not translocation is a cost-effective method of maintaining a favourable GCN status. Would the money perhaps be better spent surveying to identify a greater proportion of the as-yet unknown colonies, protecting and maintaining existing pondscapes or developing new habitat? In the wider context, this question needs serious consideration. In terms of mitigation for development conflicts, costs should be met by the developers, therefore not absorbing monies from the public purse. Research on the cost of translocations compared with other conservation methods is currently being undertaken as a PhD project by B. Lewis at DICE (B. Lewis, *pers. comm.*).

1.4.5 Conclusion

Despite extensive reviews of the literature, it remains unclear whether translocation of GCN and indeed, translocation in general is effective as a conservation method. The vast majority of the information which could help answer this question is held by private consultants and not published in peer-reviewed scientific journals. Simberloff et al. (1992) made the valid point that 'there are few, if any, proven management techniques'. The examples used were road underpasses and habitat corridors. However, when translocation is being used to resolve a case of development conflict, the potential impacts of this particular management technique are likely to be much higher. The original habitat is destroyed and population displaced.

Increased identification of GCN ponds would be beneficial by informing Planning Authorities, reducing the need for poorly planned ‘rescues’. Guidelines should be used as ‘best practice’ when undertaking a translocation project. Standards on pre- and post- monitoring would allow for better comparison between the effectiveness of different projects and information on project outcomes should be made more widely available. The objectives of a translocation should be not simply to meet a legal obligation with regards preventing the death or injury of the animals, but should be planned in such a way that at the very least, there is no net conservation loss and where possible, net gain.

1.5 The Gartcosh Translocation

The combination of GCN populations being both widespread and highly protected has lead to conflict between conservationists and developers. Translocation has become increasingly popular as a method of resolution despite a lack of definitive evidence that it is a successful conservation tool.

Such a conflict arose when development of the Gartcosh former steelworks site was proposed. In 2003, the Scottish Executive granted a licence to allow the population of great crested newts, one of the largest in Scotland, to be translocated to a purpose-built reserve on the periphery of the development site. This began in 2004 and is the largest translocation project in Scotland.

1.5.1 Gartcosh Former Steelworks Site Information

The Gartcosh Former Steelworks Site is located 16 km to the east of Glasgow in North Lanarkshire and is situated 75 to 100 m above sea level (Knowles & Bates, 2003). Iron and Steel works in Gartcosh was constructed between 1858 and 1872. The rolling mill was built in 1960 and operated until 1986 when it was demolished. Associated ground remediation works occurred during the years 1986 to 1996. Anecdotal evidence from local residents suggests the newt population was in residence from 1972, possibly earlier (Archibald Laing *pers. comm.*).

A field survey undertaken in 1998 identified 13 water bodies of which seven were deemed significant for GCN breeding (see Fig. 1-3, labelled C-I). These ponds and an area of terrestrial habitat of approximately 10 hectares were designated the Amphibian Conservation Area (ACA) and surrounded by an amphibian proof wall in July 1998. The remaining site was to be subject to development. Sub-optimal ponds outside the ACA were destroyed over a period of two years to allow translocation of any captured amphibians into the ACA.

The original plans for the site had been to protect the GCN *in-situ* within the ACA, with tunnels built leading to hibernation sites and allowing migration. Eight new ponds were dug into the ACA producing a 15 pond cluster. The success of the ACA was to be monitored from 1999 to 2003 using torchlight and funnel trapping methods outlined in (Griffiths et al. 1996) and a 10 year management was put in place.

An options appraisal process was then undertaken, with three of the five options protecting the GCN *in-situ* within the ACA. However, the Gartcosh Regeneration Partnership (consisting of North Lanarkshire Council (NLC), Scottish Enterprise Lanarkshire and other public and private sector partners) supported a regeneration ‘masterplan’ that included development of the ACA and part of the existing Site of Importance for Nature Conservation. The decision was taken to build the Gartcosh Nature Reserve (GNR) around the periphery of the Gartcosh site, destroy the ACA and translocate over all captured amphibians. The ACA ‘donor’ site consisted of six extant and seven newly created ponds with a total pond surface area approximating 2500 m^2 as new pond number L & 1 were no longer being surveyed (see Fig. 1-3)

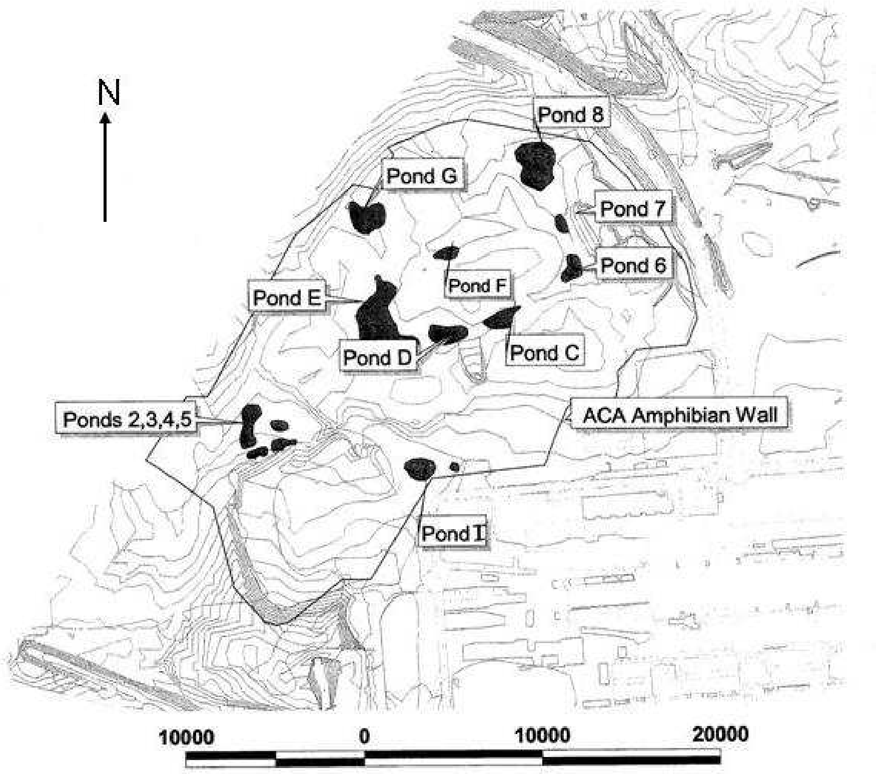

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Figure 1-3: Location of the ponds within the Amphibian Conservation Area. This formed the donor population for the translocation. Pond L is not shown on this map. Pond 1 is unlabelled, located to the right of Pond I.

Following a review of the suitability of the proposed Gartcosh Nature Reserve (GNR) as a 'receptor' site for GCN (Smith & Bates, 2000), pond creation and terrestrial habitat development was completed in 2003. The GNR encompasses a 29 hectare area. The donor and receptor site are approximately 600 m apart. A general lay-out of the GNR is shown in Fig. 1-4. More detailed maps of the different sections of the GNR are given in Chapter 2 as Fig. 2-3, 2-4 and 2-5.

Figure 1-4: Map of the Gartcosh Industrial Site. The locations of the donor Amphibian Conservation Area and the newly created Gartcosh Nature Reserve, as indicated by 'Woodland Reserve' in the key, are shown.

There are three newly created newt zones. Bothlin Burn is approximately 9.1 Ha and consists of two fields of rough pasture each containing four ponds. Garnqueen Hill is the largest zone at approximately 14.1 Ha with five ponds in the cluster. Gartcosh Railway Junction is the smallest at 5.4 Ha and contains six small ponds (Smith & Bates, 2000). This equates to a pond surface area of approximately 2400-2600 m^2, comparable in size to the donor pondscape. Three small ponds and five shallow scrapes have been built in the 'Stepping Stone' area between Bothlin Burn and Garnqueen Hill and a further two small ponds have been built at the bottom of Garnqueen Hill to aid dispersal between the three zones. Dispersal between zones was not initially possible due to the existence of temporary newt fencing surrounding individual zones. The newt fencing remains in place (2009) but during late spring 2007, two gates were positioned in Bothlin Burn and another in Garnqueen Hill. These were not covered with amphibian-proof mesh; they therefore represent a limited means for migration and immigration. In Railway Junction, there are a number of places where the amphibian fencing has collapsed, facilitating potential movement. The same was true for fences surrounding the five dispersal 'stepping stone' ponds.

1.5.2 Gartcosh Project History

Translocation was phased over three years. In 2004 (year 1), 25% of the estimated adult GCN population (sex ratio 1:1±10%) were moved to the Railway Junction zone. Translocation was permitted to continue after the minimum target criterion of 15% of translocated adults was confirmed as present. The remaining newts were moved to the Bothlin Burn, Garnqueen Hill and Stepping Stone zones in 2005 and 2006. Four other species of amphibian are present on-site, *Lissotriton helveticus* (palmate newt formerly known as *T. helveticus*), *Lissotriton vulgaris* (smooth newt formerly known as *T. vulgaris*), *Rana temporaria* (common frog) *and Bufo bufo* (common toad) and they were translocated along with the GCN. A large number of toads were translocated to the GNR but out-with the fenced zones. The belly-pattern of a great-crested newt is unique and can be used like a 'fingerprint' to identify individuals (Oldham & Humphries, 2000). All translocated adult newts had their belly-patterns photographed.

1.5.3 Pre-Translocation Monitoring

Heritage Environmental Ltd. (HEL), the environmental consultants undertaking the translocation, carried out a base-line survey of the ACA for six years prior to the translocation, using a combination of egg searches, torch counts and funnel trapping. The peak adult numbers monitored for all five amphibian species are presented in Table. 1-1 (Knowles & Bates, 2003).

Amphibian	1998	1999	2000	2001	2002	2003
GCN	68	66	93	140	77	78
Palmate	107	100	47	148	88	107
Smooth	157	146	99	161	121	98
Frog	68	639	747	261	516	441
Toad	5	24	155	801	480	326

Table 1-1: Peak numbers of adult amphibians seen in 15 ponds of existing ACA.

A peak for all three newt species was observed in 2001, with GCN breeding adults almost a factor of two times higher than the 2003 counts. This was also a peak for toads but a poor year for frogs.

1.5.4 Translocation 2004

HEL employed a number of methods in the translocation procedure; refuge searching, temporary ring fencing with pitfall traps, pitfall trapping of the permanent ACA wall, aquatic netting, funnel trapping and egg translocation. Between 11th Feb and 31st Oct, a total of 2,624 amphibians were moved to the Railway Junction Zone. This included 260 great-crested newts: 27 male, 29 female, 135 sub-adults and 69 metamorphs. 26 egg strips were also moved (Bates & Kellet, 2004).

1.5.5 Translocation 2005

It was decided that no amphibians would be translocated into the Railway Junction zone in 2005 to prevent disrupting the previously translocated population. A total of 5,349 amphibians were captured from the ACA and moved to Bothlin Burn and Garnqueen Hill. This included 803 great-crested newts in total: 357 male, 299 female, 82 sub-adult and 65 metamorphs. Table 1-2 shows the breakdown of species numbers to each zone (Kellett & Bates, 2005).

zone	GCN	Smooth	Palmate	Frog	Toad
Bothlin Burn	436	839	633	374	531
Garnqueen Hill	367	656	662	188	300
Nature Reserve*	0	0	0	0	363*

Table 1-2: Number of amphibians translocated to each zone 2005. *363 toads were translocated into the nature reserve out-with the fenced pond clusters.

1.5.6 Translocation 2006

A total of 3,794 amphibians were captured from the ACA and moved to Bothlin Burn and Garnqueen Hill. This included 531 great-crested newts in total: 145 male, 155 female, 115 sub-adult and 116 metamorphs. Railway Junction was again excluded as a receptor site. Table 1-3 shows the breakdown of species numbers to each zone (Kellett & Bates, 2006).

zone	GCN	Smooth	Palmate	Frog	Toad
Bothlin Burn	286	394	509	204	382
Garnqueen Hill	244	339	424	137	428
Nature Reserve*	0	0	0	0	446*

Table 1-3: Number of amphibians translocated to each zone 2006.
***446 toads were translocated into the nature reserve out-with the fenced pond clusters.**

1.5.7 Translocation Summary

During the three year translocation process, a total of 11,676 amphibians were transferred to the GNR. This included 1,594 great-crested newts: 529 male, 483 female, 332 sub-adults and 250 metamorphs. Table 1-4 shows the breakdown of species numbers to each zone, with additional population detail for the GCN (Kellett & Bates, 2006).

GNR Zone	GCN				Smooth	Palm	Frog	Toad
	male	female	sa	met				
Railway Junction	27	29	135	69	571	477	597	719
Bothlin Burn	285	246	118	74	1233	1142	578	913
Garnqueen Hill	217	208	79	107	996	1086	325	727
GNR								*809
Total	529	483	332	250	2800	2705	1500	3168

Table 1-4: Total number of amphibians translocated to each zone 2004-2006.
***809 toads were translocated into the nature reserve out-with the fenced pond clusters.**

A target of 95% of the estimated GCN population had to be moved for translocation to be deemed complete. The target had been set through pitfall trap monitoring in the ACA in 2004, with a baseline population count of 405 adult GCN (95% = 385 adult GCN). This was reached and exceeded in 2005. A further condition for termination of translocation was that a nightly torchlight count in suitable conditions (5ºC and within 14 days of a minimum 5 mm rainfall) resulted in less than 5 GCN (HEL, 2003a). This was met in October 2006 with no adult catches and a peak of four sub-adult/ metamorphs. In November 2006, all ponds in the ACA were dewatered and in-filled, with only one GCN found to be overwintering in an ACA pond. This was moved to the GNR (Kellett & Bates, 2006).

1.5.8 Scottish Translocations

The Gartcosh translocation was the first undertaking of its kind in Scotland. Since 2006, 36 licenses have been granted for GCN work. Return data is either not currently available or data protected but the extent and nature of GCN work in Scotland is detailed in Table 1-5.

Year	Mitigation	Translocation	Licence
2006	7	1	1
2007	7	3	11
2008	8	1	9
2009	6	2	13
2010 (up to May)	1	1	2

Table 1-5: Number of licence applications for mitigation projects and how many of these projects were translocations. 'Licence' refers to the actual number of licences issued for working with GCN in Scotland on any project in any given year. Information provided by SNH and Scottish Government.

1.6 Project Introduction

Translocations can only be permitted under licence from ministers or statutory nature conservation organisations, such as Scottish Natural Heritage (SNH). Under the terms of the Habitats Directive, a licence will be issued only if proposed actions are not detrimental to the maintenance of the favourable conservation status of the great-crested newt population. A lack of objective study on the translocation procedure introduces an element of risk into the assessment of the impacts of any such translocation on conservation status. This project aims to add to the body of knowledge as to what constitutes success and how best to achieve that within the Scottish context.

HEL will continue to monitor the adult population counts within the GNR for the next ten years until 2015. General trends of breeding numbers in ponds will give an indication of the overall health of the populations. The long-term nature of the monitoring should allow for reasonable conclusions to be made as to the success or otherwise of this project, using simple counts. SNH and the Local Authority considered that since the Gartcosh population constituted a large proportion of the known Scottish great crested newt population and since there was no previous documentation of translocation in Scotland, that it would be valuable to undertake a more detailed study than the monitoring contracted to HEL. A major thrust of this research will be to complement this population study and examine a number of the ecological aspects that influence conditions for translocation success. SNH and North Lanarkshire Council approached the University of Glasgow and the resulting discussions lead the project reported here, funded principally by SNH with additional funds from University of Glasgow and the Glasgow Natural History Society.

The research was designed to test the effectiveness of the translocation procedure in its aim to produce a self-sustaining, viable population. Central to the project is a study of aquatic and terrestrial habitat use.

1.7 Chapter Summaries

1.7.1 Chapter 2: Early Indicators of the Successful Translocation of a Population of Great Crested Newts (Triturus cristatus)

Reviews of long term translocation success have proved inconclusive due to insufficient pre and post translocation monitoring (Dodd & Seigel, 1991; Oldham et al., 1991; May, 1996; Edgar et al., 2005; Lewis et al., 2007). The Gartcosh Former Steelworks Site presented an opportunity to undertake long-term monitoring of a population before and after a translocation event. The translocation will be considered a success if the long term monitoring reveals a population comparable with pre translocation counts. The aims of this chapter are to report on the success of the translocation in terms of counts of breeding adults, presence of eggs, presence of larvae and relative abundance of larval production.

1.7.2 Chapter 3: Monitoring Population Size, Recruitment and Morphometrics in Translocated Great Crested Newts (Triturus cristatus)

To determine the success of a translocation project, in-depth population analysis is required, yet rarely done. At Gartcosh, capture-mark-recapture methodology will utilise the unique belly pattern markings of the great crested newt to determine whether this translocation had resulted in a viable population. The principle aims of this chapter are to assess whether new adults are being recruited into the population, to assess survival of the original translocated population and to explore the effect relocation has on subsequent pond fidelity. Seasonal changes in sex ratio and body length of individuals using the ponds throughout the breeding season and annual growth rates as a proxy for provision of good habitat will also be investigated.

1.7.3 Chapter 4: Assessing the Suitability of Newly Created Habitat in the Gartcosh Nature Reserve for Great Crested Newts (Triturus cristatus)

The provision of good quality aquatic and terrestrial habitat is essential to the survival of great crested newts. The mitigation efforts at Gartcosh Industrial Site led to the destruction of the original habitat and the creation of a new habitat within the Gartcosh Nature Reserve. The aim of this chapter is to investigate whether the newly created GNR provides good quality aquatic and terrestrial habitat, mitigating for the loss of the original ACA and to assess the potential for the GNR to support the long term survival of the translocated population of great crested newts.

1.7.4 Chapter 5: Terrestrial Distribution Behaviour in a Translocated Population of Great Crested Newts (Triturus cristatus), Smooth Newts (Lissotriton vulgaris and Palmate Newts (Lissotriton helveticus)

The ability of newts to disperse and colonise new ponds is essential to the long term survival of the species yet has become increasingly challenging within fragmented landscapes (Halley et al., 1996; Latham et al.,1996; Hanski & Gilpin, 1997; Hitchings & Beebee, 1997; 1998; Griffiths & Williams, 2000; Oldham et al., 2000). An understanding of dispersal direction choice could prove useful to inform the planning of wildlife corridors and identification of important habitat to support migration and the design of nature reserves. This chapter focuses on the direction of migration patterns by adults and juveniles of three species of newts upon leaving the aquatic habitat, annual changes in direction travelled and whether juveniles followed adult migrational cues. Diurnal versus nocturnal timing of migrational activity was investigated as was the effectiveness of barrier fences in combination with terrestrial vegetation searches as a resource-light survey method for counts of juvenile amphibians in the terrestrial habitat.

1.7.5 Chapter 6: Conclusions

The question central to this project was whether the translocation has been successful in achieving the aim of producing a sustainable population, viable in the long term. The aim of this chapter was to summarise the evidence to determine if this had occurred and suggest recommendations for future management of Gartcosh. Pilot studies undertaken will be described, as will suggestions for future study. A key requirement for SNH, who funded the study, was the production of a set of guidelines for uses in future translocation projects. These were based on lessons learned from the Gartcosh project and best practice as determined from relevant literature. Three documents are included; ‘Best Practice Principles in Great Crested Newt Translocations’, ‘Monitoring the Success of a Translocation’ and ‘Best Practice Principles in Habitat Creation’

2 Early Indicators of the Successful Translocation of a Population of Great Crested Newts (*Triturus cristatus)*

2.1 Abstract

Translocation is increasingly being used to resolve conflict between great crested newt conservation and land development, despite a lack of evidence to prove the method is successful. Gartcosh Steelworks was subject to a translocation, providing an opportunity to investigate the largest project of its kind in Scotland. The overall aim was to establish a population within the newly created Gartcosh Nature Reserve that was comparable with the original donor site. Post-translocation breeding adult counts were a factor of two higher than pre-translocation counts across the entire site. However, monitoring of eggs, larvae and metamorphs suggest breeding failure and an inability of the reserve to support the development and survival of juveniles through to recruitment into the breeding adult population. Declines within the breeding adult counts would only become apparent once the 'relic' population began to die off. The long term monitoring plan for the translocation only includes torchlight sampling of the breeding adults within ponds. There is a clear need for projects of this nature to factor in monitoring of all lifestages.

2.2 Introduction

The combination of Great Crested Newt (GCN) populations being both widespread and highly protected has lead to conflict between conservationists and developers. In the UK GCN are protected under Schedule 2 of the Conservation *(Natural Habitats etc.)* Regulations, 1994 and the *Wildlife and Countryside Act, 1981*. Translocation has become increasingly popular as a method of resolution, meeting legislative requirements, despite a lack of definitive evidence that it is a successful conservation tool.

Reviews of long term translocation success have proved inconclusive due to insufficient pre and post translocation monitoring (Dodd & Seigel, 1991; Oldham et al., 1991; May, 1996; Edgar et al., 2005; Lewis et al., 2007). The Gartcosh Former Steelworks Site, located 16 km to the east of Glasgow in North Lanarkshire, presented an opportunity to undertake long-term monitoring of a population before and after a translocation event. A field survey undertaken by Heritage Environmental Limited (HEL) in 1998 revealed a population of GCN within water bodies on the site. Anecdotal evidence from local residents suggests the newt population was in residence from 1972, possibly earlier (Archibald Laing *pers. comm.*). The Amphibian Conservation Area (ACA) was established in 1998 when seven ponds and ten hectares of terrestrial habitat were enclosed with an amphibian-proof wall. An additional eight new ponds were dug into the ACA (see Fig. 2-1 and Fig. 2-2). Monitoring of the cluster was carried out from 1998 to 2003 using torchlight and funnel trapping methods outlined in Griffiths et al. (1996). Ponds outwith the ACA were destroyed over a period of two years to allow for the translocation of any captured amphibians into the protected ponds.

An options appraisal process was undertaken, with three of the five options protecting the GCN *in situ* within the ACA. However, the Gartcosh Regeneration Partnership (consisting of North Lanarkshire Council (NLC), Scottish Enterprise Lanarkshire and other public and private sector partners) supported a regeneration ‘masterplan’ that included development of the ACA and part of the existing Site of Importance for Nature Conservation. The decision was taken to build the Gartcosh Nature Reserve (GNR) around the periphery of the Gartcosh development site, translocate all captured amphibians and destroy the ACA. In 2003, the Scottish Executive granted a licence to allow the population of GCN, one of the largest in Scotland, to be translocated to the GNR. Pond creation and terrestrial habitat development was completed in 2003. This was the largest translocation project in Scotland, beginning in 2004 and reaching completion in 2006. Four other species of amphibian were present on-site, *Lissotriton helveticus* (palmate newt, formerly *T. helveticus*), *Lissotriton vulgaris* (smooth newt, formerly *T. vulgaris*), *Rana temporaria* (common frog) and *Bufo bufo* (common toad) and were translocated along with the GCN. Post-translocation monitoring of the GNR began in 2006 and will continue until 2015 under the licence agreement.

The GNR encompasses a 29 hectare area and consists of three zones containing 21 newly created ponds (see Fig. 2-1 and Fig. 2-2). Bothlin Burn (BB) is 9.1 Ha and consists of two fields of rough pasture each containing four ponds. Garnqueen Hill (GQH) is the largest zone at 14.1 Ha with seven ponds. Railway Junction (RJ) is the smallest at 5.4 Ha and contains six small ponds (Smith & Bates, 2000). This equates to a pond surface area of approximately 2400-2600 m^2, comparable in size to the donor pondscape. Three small ponds and five shallow scrapes were built in the 'Stepping Stone' area between BB and GQH to aid dispersal between the three zones. Dispersal is very limited due to the existence of amphibian-proof fencing surrounding individual zones. By 2009, the fencing remained intact in BB and GQH with the exception of a small gate in each. Fencing was no longer intact around RJ and SS. The GNR was subject to management by NLC during January 2008, including extensive vegetation clearing in BB using a mechanical digger.

The translocation will be considered a success if the long term monitoring reveals a population comparable with pre translocation counts. GCN are a long-lived species with recorded longevity in natural conditions of 14 years (Francillon-Veillot et al., 1990) to 16 years (Hagstrom, 1979) although the majority may only survive a few years after reaching sexual maturity (English Nature, 2001). This can mean that adults may continue to use breeding sites although the sites themselves may have ceased to produce metamorphs (Arntzen & Teunis, 1993). These 'sink' ponds or sites may happen if conditions are unfavourable for the survival of eggs, larvae or sub-adults e.g. high predation and/or limited prey items, resulting in a ‘relic’ population. The aims of this chapter are to report on the success of the translocation in terms of counts of breeding adults, presence of eggs, presence of larvae and relative abundance of larval production.

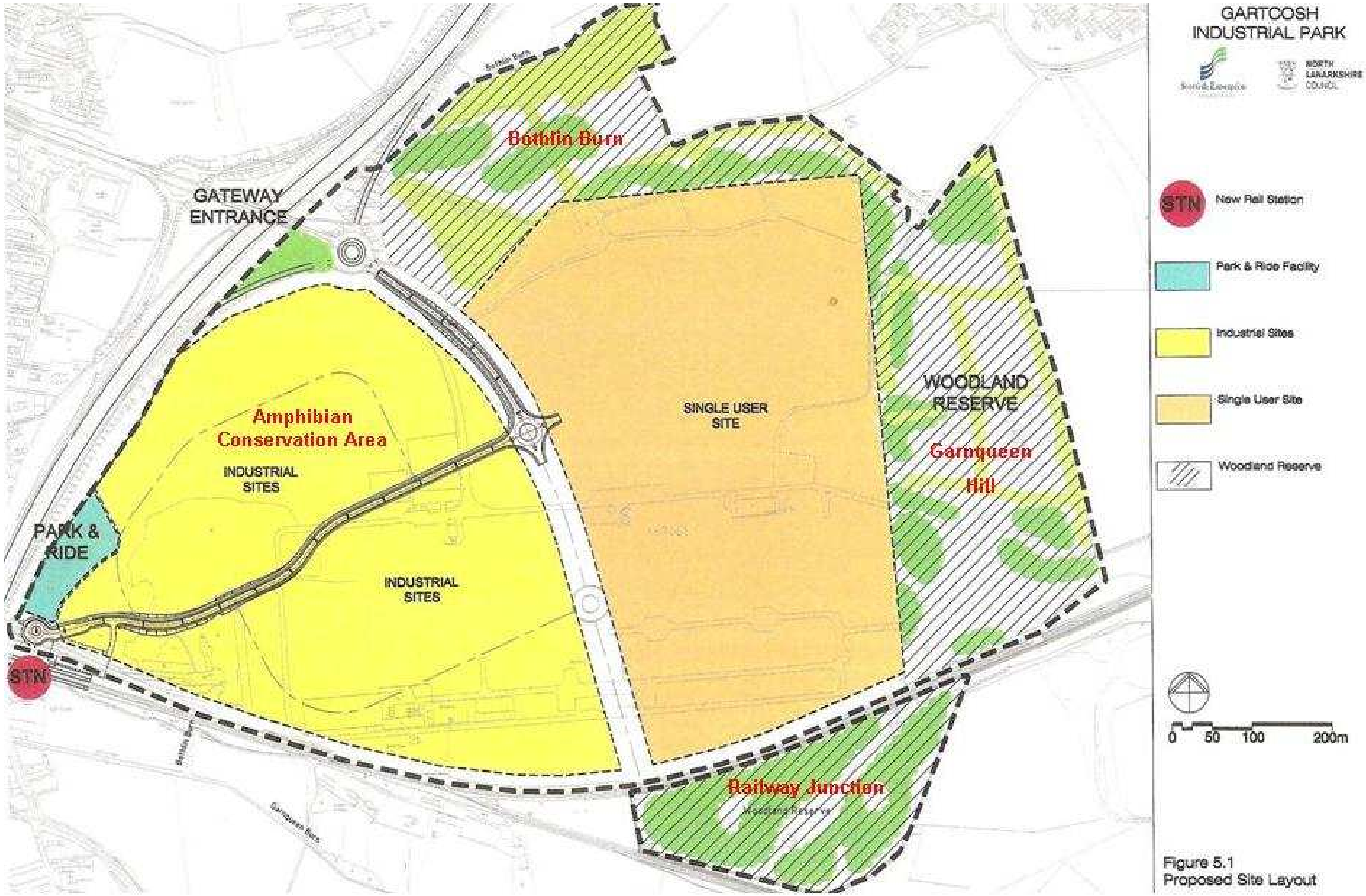


Figure 2-1: Map of the Gartcosh development site, showing the Amphibian Conservation Area 'donor' site and the positioning of the three zones within the Gartcosh Nature Reserve 'receptor' site (Bothlin Burn, Garnqueen Hill and Railway Junction). All maps reproduced with permission from Ironside Farrer.

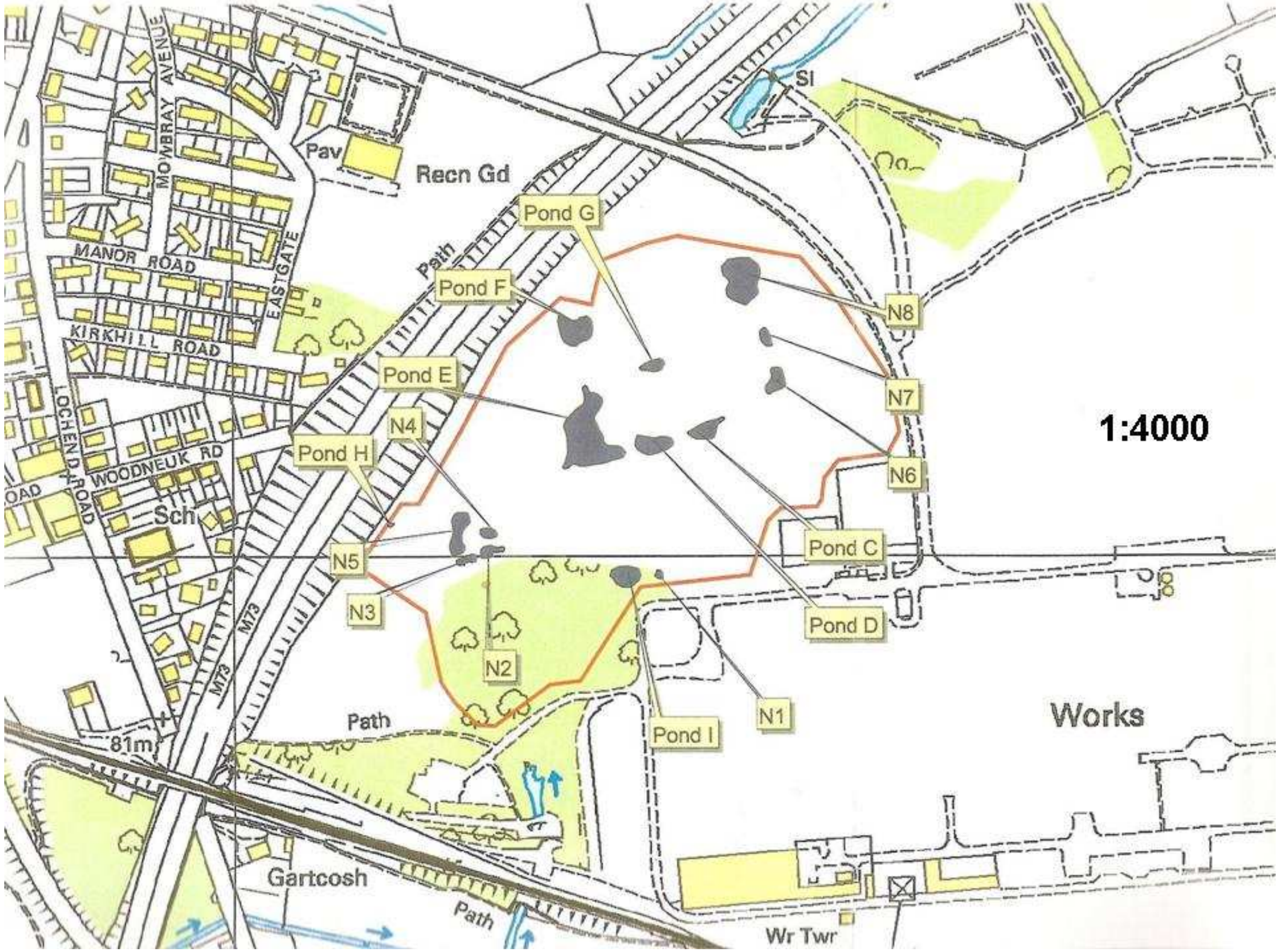


Figure 2-2: Amphibian Conservation Area (ACA) donor site. Original ponds denoted by letters, newer ponds by numbers. Red line indicates the position of an amphibian-proof perimeter, to prevent amphibians dispersing throughout the Gartcosh site, scheduled for development. Scale 1:400

Figure 2-3: Bothlin Burn Zone. Consists of eight ponds in two clusters as indicated by NP1-8, renamed BB1-8. Stepping Stone indicated by NP9 and NP10, renamed SS1 and SS2. SS3 lies to right hand side of NP9 but not shown on map. Stars show positioning of man-made hibernacula. BB and SS ponds were separated from each other by the existence of amphibian-proof fencing, preventing migration between the zones. Scale 1:3000. Refer to next page for map legend.

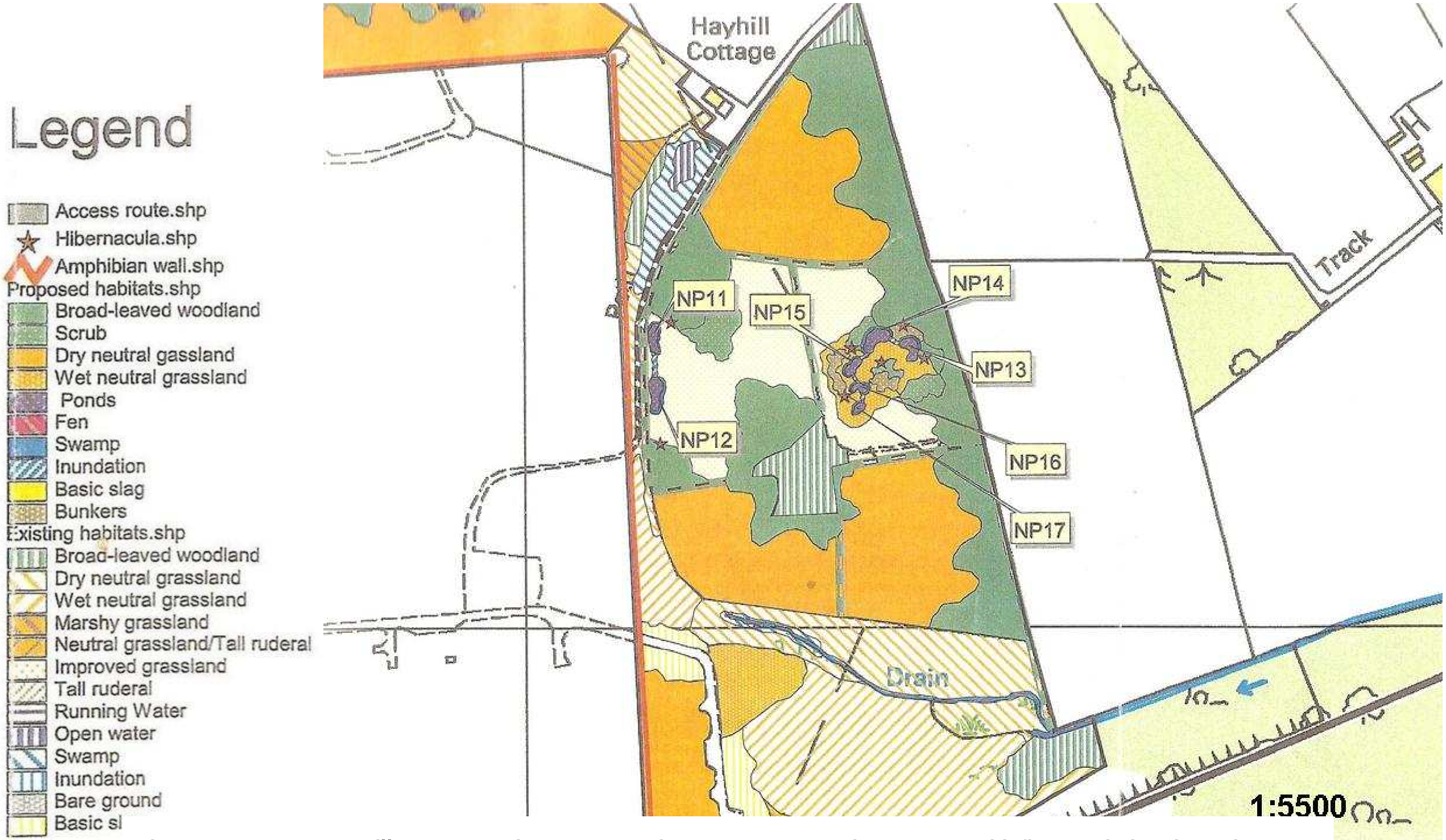


Figure 2-4: Garnqueen Hill Zone. Contains seven ponds, NP11-17 renamed GQH11-17, with five ponds (as shown by NP13-17) in a tight cluster at the top of the hill and two further ponds (NP 11 and 12) at the bottom. Newts can freely disperse between the seven ponds but are prevented from moving from the zone by amphibian-proof fencing. Scale 1:5500.

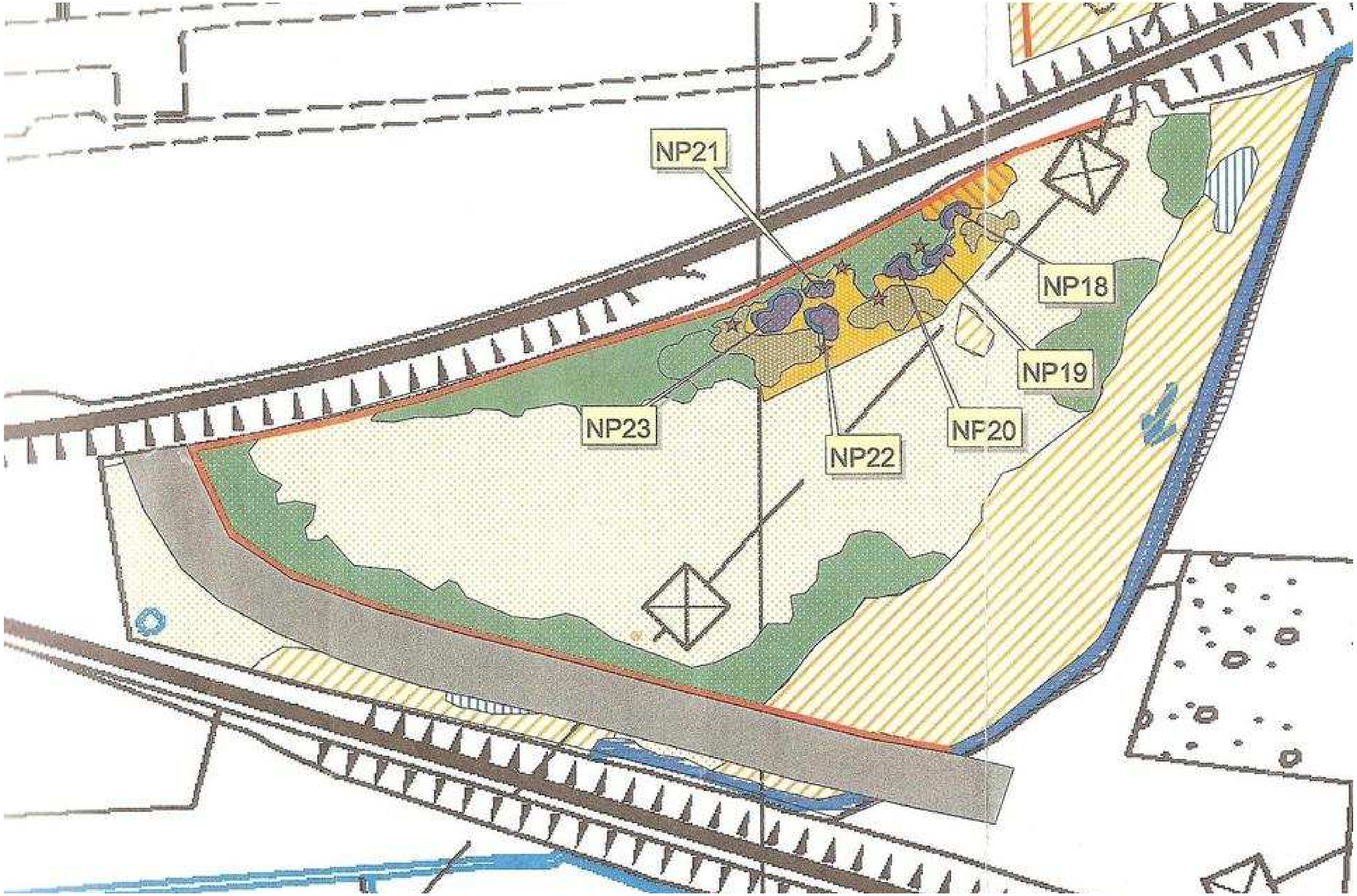


Figure 2-5: Railway Junction Zone. Consists of six small ponds renamed RJ1-6 but running in reverse order to the NP numbering system (RJ1 = NP 23, RJ6= NP18). Like the other zones, RJ is surrounded by amphibian-proof fencing. Beyond that, the zone is completely isolated by amphibian-proof walls then railway tracks to the north and south, and running water to the east. Scale 1:3000.

2.3 Methods

2.3.1 Simple Counts of Breeding Adults

As HEL undertook the pre-translocation monitoring, HEL post-translocation simple counts were used to ensure consistency in sampling methodology. Each pond was scanned using a powerful torch and peak adult counts recorded after one full circuit, in accordance with the methodology outlined in Gent & Gibson (2003). Counts per pond were summed to produce zone and site counts. The population size was classed in accordance with guidelines set out in English Nature (2001). Sampling occurred from March to May 2006 to 2009, with 2008 an exception. Heavy pond management at the beginning of 2008 significantly increased pond turbidity. Surveying took place from April to June, to allow time for settling of sediment.

2.3.2 Presence of Eggs and Larvae

Female GCN lay between 180-220 eggs in one breeding season (Arntzen & Teunis, 1993) with 50% egg mortality due to lethal homozygosity on the first chromosome (Horner & MacGregor 1985; MacGregor et al., 1990). Since each egg is individually wrapped in a leaf, identification requires opening of the leaf, exposing the egg to an increased mortality risk. As attempts to correlate egg numbers to population size are unreliable (Griffiths et al., 1996), only a small number of leaves were opened to confirm successful breeding. All ponds were searched for GCN eggs, with the focus primarily on favoured vegetation such as *Myosotis scorpioides (*water forget me not) on which the concertina-like folded leaves were readily apparent. GCN eggs can be distinguished from those of the other two newt species as the egg is yellow and larger at 4.5 - 6mm. Smooth and palmate eggs are indistinguishable from each other, being of similar size (3mm) and grey-brown (Langton et al., 2001). During 2007, surveying began in late February. In 2006 and 2008, surveying was delayed until early March due to cold temperatures and late snowfall. Ponds were surveyed for egg laying throughout the breeding period to ensure late breeding was not missed.

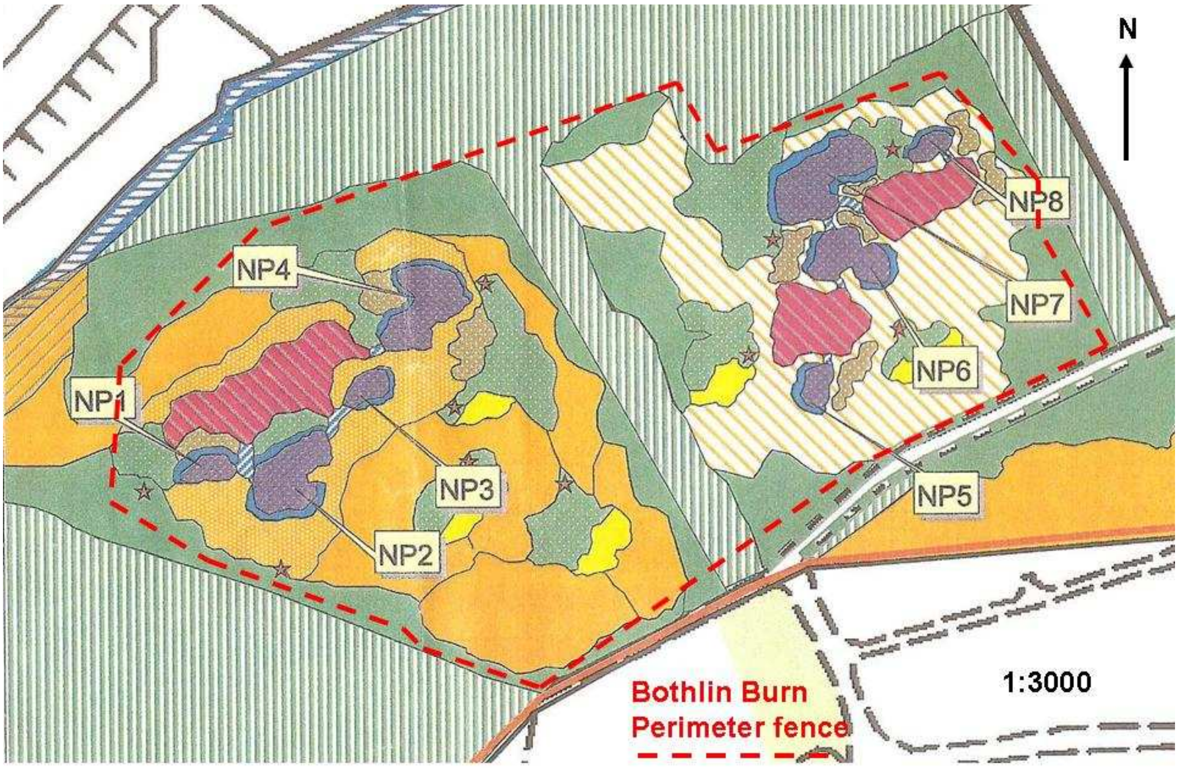
2.3.3 Relative Larval Abundance

During 2006, all ponds in the GNR were surveyed once a month from May until August for GCN larvae. A long-handled dip net (0.2 m x0.25 m net, mesh size 5 mm) was used to take 2 m sweeps from ten randomly selected points around each pond. Due to limited success in larval catches in May and August 2006, the sampling regime was altered. In 2007 and 2008, sampling took place only during June and July. The number of sweeps was increased to twenty in an attempt to improve upon low GCN larvae catch rates. Newly hatched larvae were described as unidentified if it could not be determined whether they were GCN, smooth or palmate. Smooth and palmate larvae counts were also recorded, categorised together as ‘Small’, as the two species cannot be distinguished visually at the larval stage. ‘Small’ numbers were included to ascertain if any patterns observed in GCN were mirrored across all larvae sp. There were no pre-translocation baseline data to compare the 2006 to 2008 larvae counts against. Relative abundance between years is used as an indicator of breeding success.

2.3.4 Minimum Metamorph Production

In 2006, the perimeter fence encircling BB (Fig 2-6) was surveyed for metamorphs. Peak count was indicative of minimum metamorph production. Metamorphs are described as efts (newly metamorphosed) and sub-adults (juveniles who metamorphosed the previous year or earlier). The perimeter fence measured 280m and was divided into transect bands 10m long. The survey included all amphibians observed attempting to climb the fence or located immediately beside the fence when searching vegetation. In 2007 the survey was extended to include RJ (Fig 2-6). The total perimeter of RJ is 367m (210m of fence and 157m of concrete amphibian proof wall). Both zones were again surveyed during 2008. GQH was excluded from this survey due to limited accessibility to the perimeter fence. During 2006 to 2008, 13 surveys were undertaken in BB zone. RJ was surveyed 9 times during 2007 and 2008.

This methodology utilised existing on-site barriers to produce a snapshot of minimum metamorph production. Pitfall trapping could not feasibly be used due to the large number of ponds within the two zones (*n*=14) and limited resources.



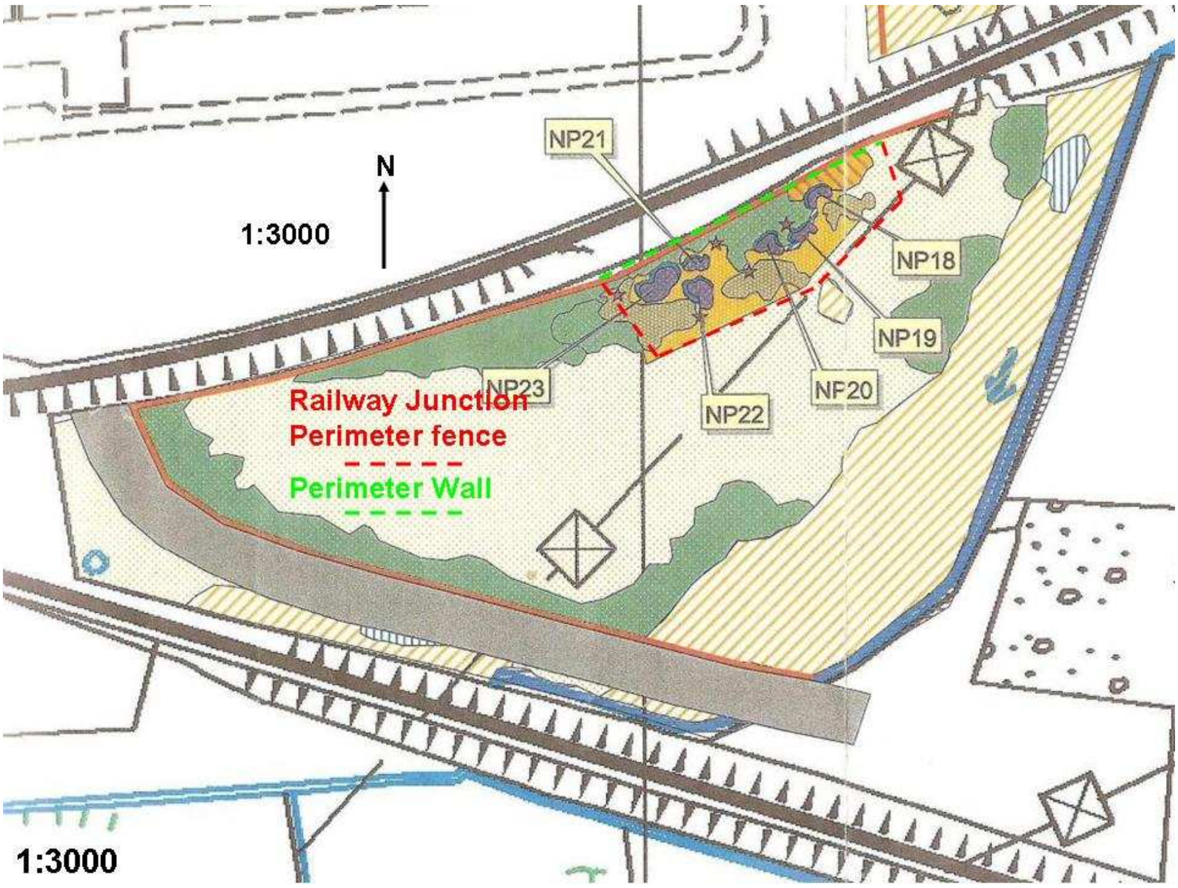


Figure 2-6: Bothlin Burn and Railway Junction Perimeter Fences. Dashed lines shows the positioning of the amphibian proof fencing around both Bothlin Burn (top image) and Railway Junction (bottom image) that was surveyed for occurrence of metamorphs.

2.4 Results

2.4.1 Simple Counts of Breeding Adults

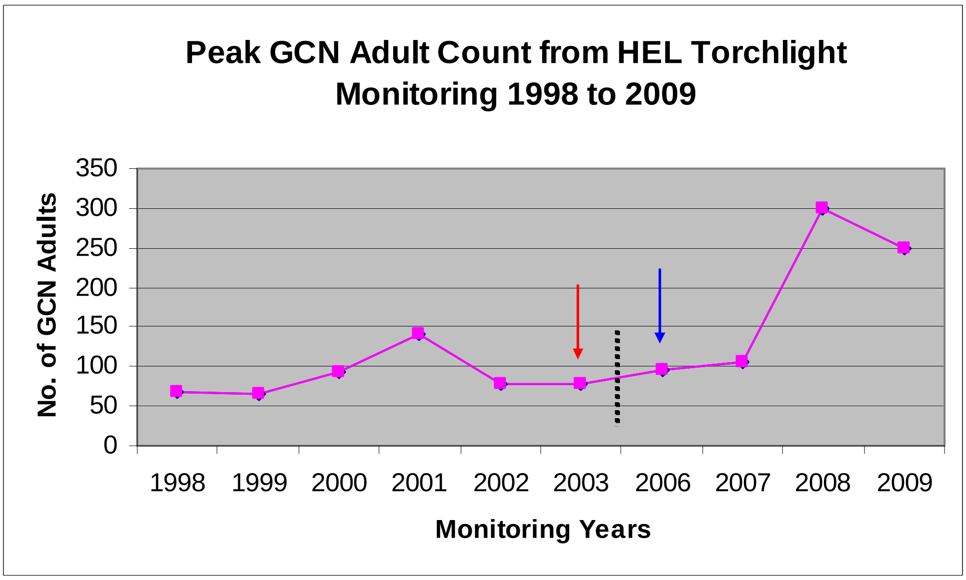


Figure 2-7: Pre-translocation data from Knowles et al. (2003). Post Translocation data from Bates & Kellett, 2004; Kellett & Bates, 2005; Kellett & Bates, 2006; 2007, 2008 and HEL, 2009 data tables from HEL. Red arrow indicates the end of pre-translocation data. Blue arrow indicates the starting point of post-translocation data. Torchlight counts were not undertaken during the translocation years of 2004 and 2005, represented by the black dotted line.

A pre-translocation peak of 140 GCN breeding adults was recorded in 2001, but in general, counts held relatively steady at between 60 to 100 breeding adults (Fig. 2-7). This pattern continued post-translocation, with approximately 100 GCN recorded in 2006 and 2007. During 2008, a second peak of 299 was recorded, remaining high through 2009 with 249 breeding adults counted.

	GCN				GCN Total	Amphibian Total
	Male	female	sa	meta		
2004	27	29	135	69	260	2,624
2005	357	299	82	65	803	5,349
2006	145	155	115	116	531	3,794
Total	**529**	**483**	**332**	**250**	**1,594**	**11,767**

Table 2-1: Annual translocation numbers for all life-stages of great crested newts (male, female, sub-adult and metamorphs) and all amphibians (GCN, palmate, smooth, frog and toad adults and sub-adults) to the Gartcosh Nature Reserve.

In 2004 only 260 GCN (56 adults) were translocated to the GNR although an annual site count of 527 (461 adults and 66 sub-adult/ metamorphs) was recorded in the ACA (Kellett & Bates, 2006). In 2005 and 2006, all captures were translocated. During the three year translocation process, a total of 11,676 amphibians were transferred from the ACA to the GNR. This included 1,012 adult great-crested newts (Table 2-2).

		Trans Pop 2004-06	HEL Torch 2006	HEL Torch 2007	HEL Torch 2008	HEL Torch 2009
Bothlin	M	285	36	43	142	118
Burn	F	246	17	11	35	37
	Total	531	53	54	177	170
Garnqueen	M	217	20	16	31	64
Hill	F	208	5	12	10	13
	Total	425	25	28	41	77
Railway	M	27	10	13	68	12
Junction	F	29	7	8	13	4
	Total	56	17	21	81	16
Stepping	M	?	1	2	0	1
Stone	F	?	0	1	0	0
	Total	?	0	3	0	1
GNR	Total M	529	67	74	241	195
	Total F	483	29	32	58	54
GNR	**Total**	**1012**	**96**	**106**	**299**	**249**

Table 2-2: Breakdown per zone of male and female GCN translocated to GNR during period 2004-2006 and post-translocation peak counts as surveyed by HEL during 2006-2009. It is unclear how many individuals were moved to Stepping Stone as this was included in Bothlin Burn counts.

The original planning for the proportion of the original population translocated to individual zones had been 50% to BB, 25% each to RJ and GQH. In 2004, amphibians were moved only to RJ. The decision was then taken by SNH and HEL not to disturb the translocated population that was establishing within the RJ (Kellett & Bates, 2005). In 2005 and 2006, 50% were moved to BB and the proportion moved to GQH was significantly increased. Adults were released into the zones in a sex ratio of 1:1±10%.

Population levels in RJ are being maintained at favourable levels during 2006 and 2007 with a count of 30-38% of the translocated population. This significantly increased in 2008, exceeding the translocated population count. By 2009, population counts had returned to 2006 levels. By comparison, BB was less successful during 2006 and 2007, returning counts of only 10% on the translocated population. This significantly improved in 2008 and 2009, with adult GCN counts reaching approximately 33% of the translocated population. GQH had been less successful in 2006 and 2007, with population estimates much lower than the translocated population, at approximately 6%. This increased in 2008 and again in 2009 (10% and 18% respectively). SS has been consistently poor although it remains unclear as to what the starting population size was.

A very similar proportion of females and males (F: M) were moved to the GNR site (1: 1.1). Torchlight sampling displayed a strong male bias; 2006 and 2007 (1: 2.3), 2008 (1: 4.2) and 2009 (1: 3.6).

	GCN Population Size Class			
Zone	**2006**	**2007**	**2008**	**2009**
BB	med	med	large	large
	53	54	177	170
RJ	med	med	med	med
	17	21	81	16
GQH	med	med	med	med
	25	28	41	77
SS	na	small	na	small
	0	3	0	1

Table 2-3: GCN population size class. Using the peak adult counts in Figure 2-7 (displayed numerically in this table), population is classified as small, medium or large. Small (≤10), Medium (11-100), Large (>100) using criteria in English Nature (2001).

Peak breeding adult counts from ponds within a 250 m radius are summed to give a population size class for the metapopulation (Table 2-3). Each zone currently exists as a separate metapopulation, although very limited exchange may be possible between zones due to fences no longer being intact in RJ and SS and the existence of gates in BB and GQH that are not amphibian proof from 2008.

2.4.2 Presence of Eggs and Larvae

Pond	2006		2007		2008	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
BB1	y	y	y	y	n	y
BB2	y	y	y	y	n	y
BB3	y	y	y	y	n	y
BB4	y	y	y	y	n	y
BB5	y	y	n	n	n	y
BB6	n	n	n	y	n	y
BB7	y	y	n	y	n	y
BB8	n	n	n	n	n	y
RJ1	y	y	y	y	y	y
RJ2	y	y	y	y	y	y
RJ3	y	y	y	y	y	y
RJ4	y	y	y	y	y	y
RJ5	y	y	y	y	n	n
RJ6	n	n	n	n	n	n
GQH11	y	y	n	n	n	n
GQH12	y	y	n	n	n	n
GQH13	n	y	n	y	n	n
GQH14	n	y	n	y	n	n
GQH15	n	y	n	y	n	n
GQH16	n	y	y	y	n	n
GQH17	n	n	y	y	n	n
SS1	n	n	n	n	n	n
SS2	y	n	n	n	n	n
SS3	n	y	n	n	n	n

Table 2-4: Presence or absence of GCN eggs and larvae.
n= no eggs/larvae; y= yes eggs/larvae.

Presence of eggs and larvae 2006 to 2008 is shown in Table 2-4. In 2006, 5 ponds contained no eggs or larvae, rising to 8 ponds in 2007. A further increase in 2008 to 12 ponds is attributed to breeding failure throughout all GQH and SS ponds. RJ1-5 ponds indicate successful breeding with the exception of RJ6, consistently devoid of eggs and larvae. RJ5 in 2008 is likely an anomaly as the pond was deepened using a mechanical digger a few months prior to surveying. No aquatic vegetation was present at the time of sampling as a result of this work.

BB ponds were also reasonably successful. Although no eggs were located in BB ponds during 2008, larvae were subsequently recorded in all including BB8 where none had been found during the previous two years. When looking across the three years, 19 out of the 72 sampling events show a lack of consensus for breeding success between observations of eggs or larvae, with 18 of the 19 recording ‘no’ for eggs but a subsequent ‘yes’ for larvae.

2.4.3 Relative Larval Abundance

To enable comparisons of 2006 data with 2007 and 2008, it was necessary to determine whether sampling for larvae during the first ten set of sweeps had significant enough of an impact on the larvae population within the pond to affect the outcome of the second set of ten sweeps. As GCN larvae numbers were very low, ‘Small’ larvae numbers were used in this comparison. The assumption made here is that the potential impact of sampling on population size would be the same between GCN and ‘Small’ species.

During 2007 and 2008, the 24 GNR ponds were sampled four times (June and July for two years). This produced a sample size of 74 out of the possible 96 due to some ponds being dry or recording no larvae captures. The slope of a straight line was calculated for each pond using the formula:

$$m = \frac{y^1 - y^2}{x^1 - x^2}$$

where
x^1 = 10 sweeps
x^2 = 20 sweeps
y^1 = sum total of Small larval captures for the first ten sweeps
y^2 = sum total of Small larval captures for the second ten sweeps

The mean m value for all 74 samples was calculated.

The investigation into the effect of removing the first 10 sweeps from a pond and possible impacts on the second 10 sweeps produced a mean slope of +0.04 (*n=74*). This number is very close to zero, sloping in a positive direction, strongly suggesting that there is no significant impact on the larval population during the first ten samples. It is therefore reasonable to compare 2006 data with 2007/2008, scaling 2006 larval counts by a factor of two (2007/2008 had twice as many sweeps of each pond).

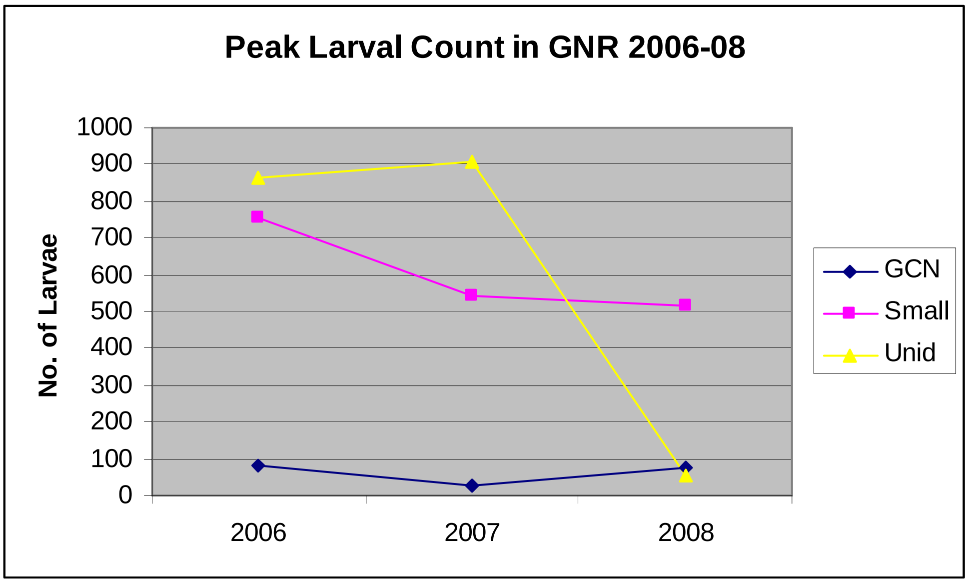


Figure 2-8: Peak count of larvae in the GNR of each species during the sampling years of 2006 to 2008. Small represents both Smooth and Palmate larvae. Unid means Unidentified, larvae that are too young to determine whether they are GCN or Small.

Overall GCN larval counts (Fig. 2-8) were lower than 'Small' as expected (1,594 GCN adults, sub-adults and metamorphs translocated compared with 2,800 smooth and 2,705 palmate) (Kellett & Bates, 2006). Both decreased in 2007, but as this coincided with an increase in unidentified in the same year, it is likely due to later breeding/ development, as the unidentified would have increased counts of both GCN and 'Small'. Unidentified numbers crashed in 2008. As 'Small' had decreased and there was only a small rise in GCN numbers, this suggests overall larval production and survival for 2008 was much lower than in previous years.

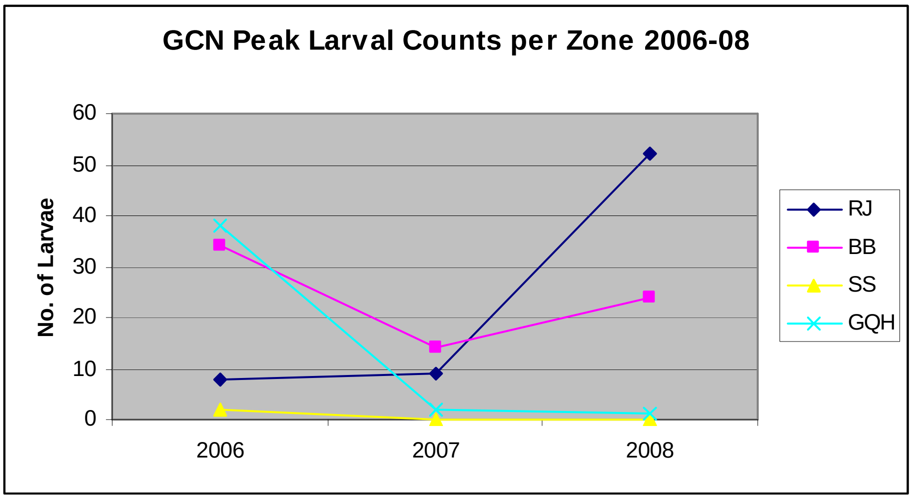


Figure 2-9: Peak counts of GCN larvae in each zone in the GNR during the sampling years of 2006 to 2008.

Is this decrease happening across the site or are particular areas performing more poorly than others as suggested by the presence of egg/larvae data? BB dipped in 2007 but appeared to be recovering by 2008 (Fig. 2-9). RJ showed a boom in numbers during 2008, accounting for a significant proportion of the GNR site total. GQH crashed in 2007 and had not recovered by 2008. SS has been consistently poor.

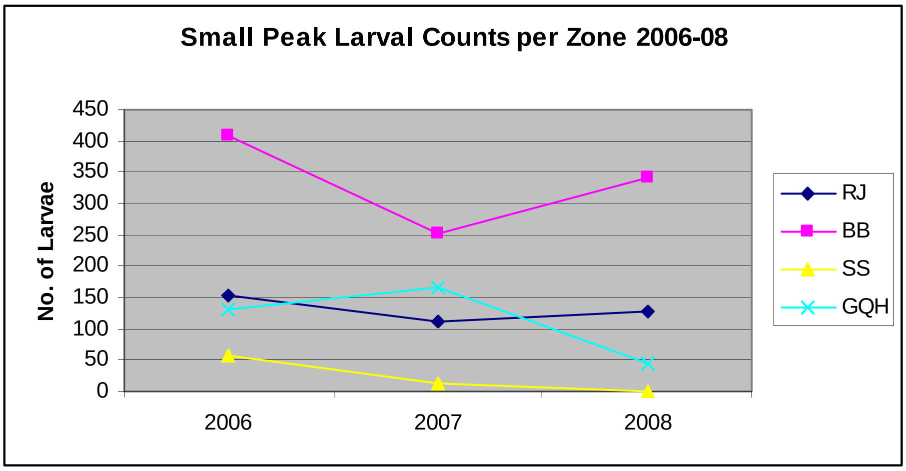


Figure 2-10: Peak counts of Small larvae in each zone in the GNR during the sampling years of 2006 to 2008.

'Small' larvae numbers echoed GCN in BB (Fig. 2-10), decreasing then recovering in 2008. RJ remained relatively stable. GQH showed a slight increase in 2007 but significantly declined in 2008. SS larvae counts were negligible by 2008.

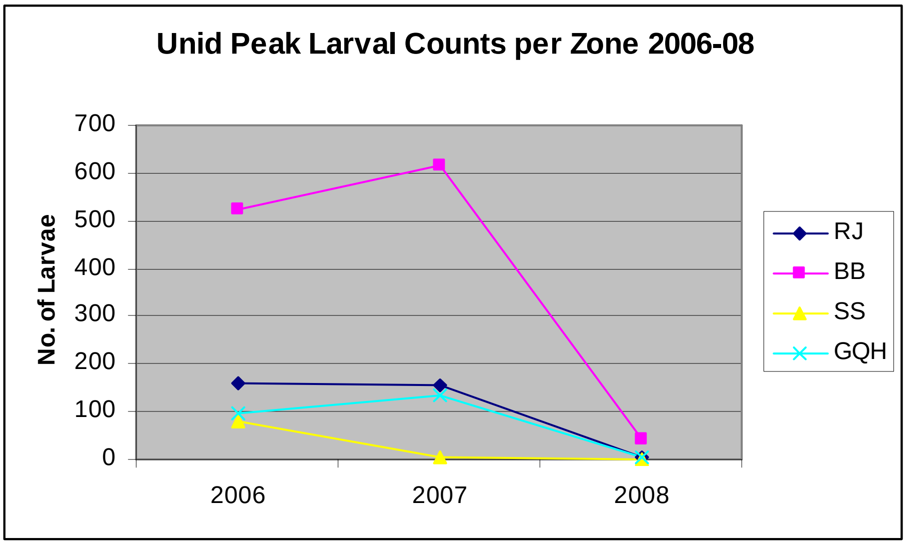


Figure 2-11: Peak counts of unidentified larvae in each zone in the GNR during the sampling years of 2006 to 2008

BB, RJ and GQH counts for unidentified larvae (Fig. 2-11) were relatively stable in 2006 and 2007, crashing in 2008. SS counts crashed in 2007 and did not recover during 2008. As unidentified were the early developmental stages of GCN and 'small' larvae, changes in unidentified counts reflect changes observed in these, as shown in Fig. 2-9 and 2-10.

		May	June	July	Aug
2006	GCN	0	41	8	4
	Small	26	123	377	210
	Unid	0	431	20	1
2007	GCN	x	25	22	x
	Small	x	541	789	x
	Unid	x	910	63	x
2008	GCN	x	76	18	x
	Small	x	517	319	x
	Unid	x	53	3	x

Table 2-5: Peak counts of GCN, 'Small' and unidentified larvae per month per year. Ponds were sampled for four months in 2006 and two months in 2007 and 2008. Months not sampled were marked by x. The scaled 2006 data were used to allow comparisons between years.

Monthly larval counts are shown in Table 2-5. Peak counts of GCN are always in June; the 'Small' peak varied and unidentified declined to negligible by late summer. Total number differences from month to month are the result of recruitment, loss through predation etc. Most unidentified must become 'Small', reflecting the overall higher numbers of 'Small' than GCN.

2.4.4 Relationship between Adult Presence and Breeding Success

Torchlight survey work (Fig. 2-7) reveals an increase in adult counts, yet sampling work on the presence of eggs and larvae (Table 2-4) and peak larvae counts (Fig. 2-8 to 2-11) show declines. From the sampling work done on breeding success looking at presence of eggs and larvae in Table 2-4, it would appear larval presence is the more reliable indicator of breeding success. Therefore, to explore the relationship between adult numbers and breeding success, peak GCN adult counts per pond were compared with peak GCN larvae counts per pond from 2006 to 2008. A histogram of residuals was plotted and a visual inspection confirmed the residuals do not deviate grossly from normality.

General Linear Modelling was used to test the relationship between the response variable 'GCN Larvae' against the explanatory variable 'GCN Adult' (Fig. 2-12).

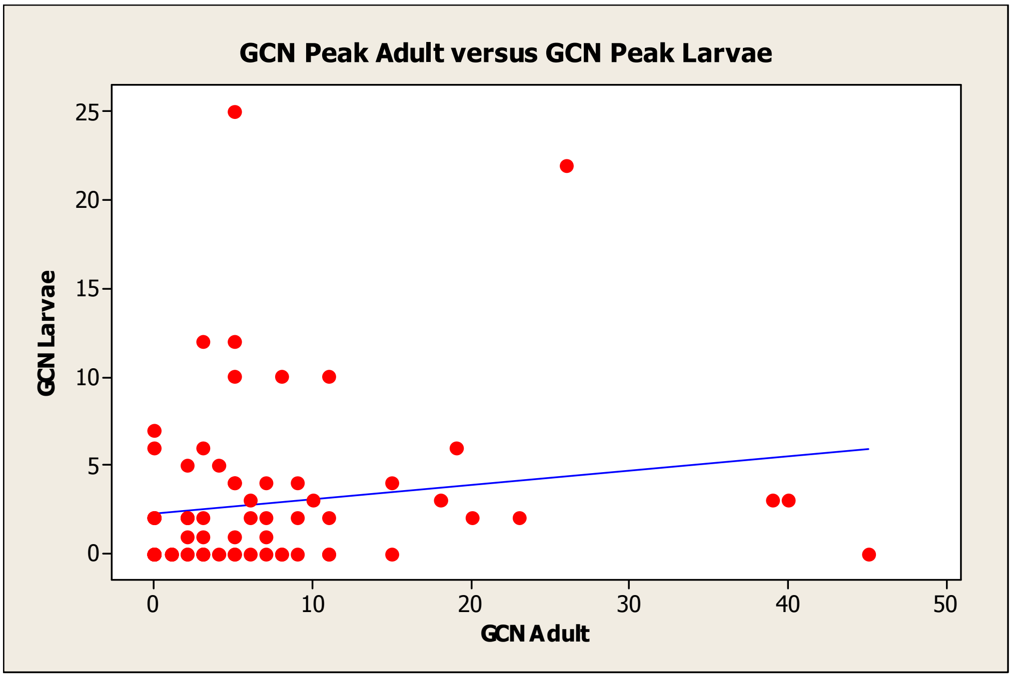


Figure 2-12: Relationship between peak adult counts and breeding success as determined by peak larval counts.

The relationship between GCN adult and larvae is described by the fitted line, GCN Larvae = 2.23 + 0.0803 GCN Adult. This was not a significant relationship (R^2= 0.03, df= 71, p=0.179).

2.4.5 Minimum Metamorph Production

The peak count per year determines minimum metamorph production within each zone as described below in Table 2-6 and 2-7.

Date	GCN		Smooth		Palmate		Frog	Toad
	sa	e	sa	e	sa	e	sa	sa
2006	23	16	100	207	98	176	54	24
2007	1	2	2	46	13	56	5	1
2008	0	2	1	22	1	32	2	0

Table 2-6: Peak counts of metamorphs of all five amphibian species for the total perimeter fence in BB during 2006 to 2008.
sa=sub-adult, e=eft.

Date	GCN		Smooth		Palmate		Frog	Toad
	sa	e	sa	e	sa	e	sa	sa
2007	0	1	4	47	5	92	4	51
2008	0	3	0	12	0	5	0	0

Table 2-7: Peak count of metamorphs of all five amphibian species for the total perimeter in RJ during 2007 and 2008.
sa=sub-adult, e=eft.

Significant declines in metamorph production were observed across all species in BB. The story was very similar in RJ from 2007 to 2008 with the exception of GCN, as numbers were too low to allow meaningful comparisons.

2.4.6 Survey Efforts

In practice, conservation efforts may be driven by cost-benefit analysis. While in certain circumstances, for example, bottle-trapping may be the most effective methodology for surveying adult newts (Griffiths et al., 1996) torchlight surveying may instead be used due to reasons such as requiring fewer staff hours. Real time taken to sample using my chosen methodology is given here. Egg searches can only be used to prove presence. As results here have shown, 'no' eggs does not necessarily mean there are no GCN present. Presence of eggs can often be quickly confirmed during other sampling regimes. Egg laying in the majority of ponds within the GNR was noted during torchlight sampling as each pond was subject to torchlight sampling on five occasions. During April and May, when adult counts were reaching their peak and eggs were readily observable in ponds, those ponds that had yet to show signs of egg laying were searched for approximately one hour during the daytime.

Relative abundance of breeding success could be easily measured on an annual basis by netting. Between four and six ponds could be netted in a day due to close proximity of the ponds. The sampling regime adopted here was twenty sweeps per pond. To sample and sort through the samples, counting GCN, 'Small' and Unidentified, then measuring the snout-vent lengths of captured larvae took approximately one hour per pond. It would not be necessary for most sampling regimes to include the measurement portion, therefore reducing time spent per pond. Some projects may wish to only record presence of confirmed

GCN larvae. Due to their larger overall body size, this would likely reduce sorting time further.

Metamorph sampling was opportunistic, taking advantage of barriers already in position. Each sampling event took approximately two hours, with good results for smooth and palmate juveniles but limited success for GCN. It is unknown whether this sampling method simply wasn't as effective for GCN or whether there was a lower output of GCN juveniles from the ponds. The alternative sampling methodology, ring-fencing and pitfall trapping each pond would require a significant funding/ time commitment, likely to be outwith the resource allocations of many projects.

Peak adult counts used within this chapter were provided by HEL, who was able to sample the entire site of twenty-four ponds in one night, using a team of six to eight experienced surveyors.

2.5 Discussion

2.5.1 Breeding Adult Population Size

A key determinant as to whether the translocation has proved successful is has the breeding adult population size been maintained at a level comparable with the pre-translocation population? Looking only to the simple adult torchlight counts, the results are favourable. The minimum and maximum post-translocation counts were higher than the equivalent pre-translocation counts by approximately a factor of two. The peak in 2008 coincided with a period of intensive pond management in January 2008. Does 2008 represent a true increase or an aberration, an artefact of increased ability to visually detect adults due to a significant reduction in macrophyte coverage? By 2009, vegetation stands had somewhat recovered, yet a high peak count of 249 was again returned. This could suggest that 2008 and 2009 described a true population increase.

Alternatively, the data show a peak in 2001. Looking to the population counts during the translocation period (Fig. 2-7); there was a second peak in 2005. Would 2009 have represented a third peak had this not been confounded by the high 2008 numbers? This would be indicative of a cyclic four year sample peak. Sampled amphibian numbers can fluctuate hugely between years (Arntzen & Teunis, 1993; Cook, 1994; Horton & Branscombe, 1994) with surveyed adult numbers reflecting either a true difference in population size or a difference in the number of adults arriving at breeding ponds, accessible to the sample methodology. As HEL will continue to monitor the site until 2015, it should be possible to ascertain whether a pattern exists.

There is a clear need for pre-monitoring in order to establish baselines for success of the translocation, but how long should pre-monitoring occur? Short monitoring periods (< 6 months) are common (Edgar & Griffiths, 2004) but can greatly underestimate the actual population size (Langton et al., 1994; Kyek et. al., 2007). This is illustrated well by looking to the population variation outlined in Fig. 2-7. Also, adults skipping a breeding season would not be captured. Using pitfall trapping of amphibians moving into ponds during the 2004 survey, Bates & Kellet (2004) established a GCN population size within the ACA of 527 (male, female and sub adult). Yet over 1,012 adults (male and female) were trapped and moved by 2006. Despite extensive surveying, the population was underestimated by at least 50%. This was then used as the baseline adult population estimate for the translocation. A significant number of GCN adults were still being trapped in the ACA and moved during 2006, suggesting the possibility that amphibians remained present within the ACA when the site was destroyed.

Migration between individual zones has been severely limited, almost negligible, due to the existence of amphibian proof fencing around the pond clusters. Therefore, the GNR has not so far constituted a true metapopulation. It is therefore important to look at how individual zones are faring. BB and RJ appear to be successfully supporting their proportion of the translocated population of adults. Whether all adults were successfully breeding is in doubt when considering egg and larvae data. Low adult counts in GQH during 2006 and 2007 were concerning, but the situation appears to be improving with an increase during 2008 and again in 2009. SS has remained consistently poor. Peak adult counts echoed the male bias commonly encountered when surveying by torchlight (Bray, 1994; Langton et al., 1994). This may be due to a lower survival rate of females to males or due to differences in breeding habits. Males remain in ponds for a longer time than females during the breeding season and may have increased visibility due to courtship displays.

English Nature (2001) recommended populations being assigned to class sizes, as determined by peak count per pond. If there is regular interchange of animals i.e. ponds are less than 250 m away from each other, pond counts can be summed to produce a size class for that cluster. At GNR, there has been regular interchange between ponds within each zone but not between zones. Therefore a population size class for the whole GNR site cannot be assigned, as had been possible for the ACA. The large population is now fragmented, designated as one small, two medium and one large population.

2.5.2 Indicators of Breeding Success

Presence of Eggs and Larvae

The number of ponds showing no eggs or larvae increased during the sampling period. By 2008, half of all ponds indicated breeding failure (Table 2-4). This suggests a worrying trend of ponds changing from successful 'source' ponds to unsuccessful 'sink' ponds. GQH has consistently shown poor presence of eggs, with significant declines in larvae presence. SS ponds have shown complete breeding failure in 2007 and 2008. It remains unclear as to how many GCN adults were moved to SS but the numbers were likely to be very low. In 2006 HEL seeded the ACA ponds with artificial egg laying substrate. Egg strips which had been used by females for breeding were then translocated to BB and GQH. Larvae were also still being translocated from the ACA to BB and GQH. While only a 'yes' for egg laying was counted if located on natural vegetation indicating breeding had occurred in the GNR, larvae captured may have been the product of breeding efforts in the ACA. This is of particular note when considering GQH, where 5 of the 7 ponds recorded no presence of GCN eggs but all ponds contained larvae.

RJ and BB ponds were reasonably successful. Although no eggs were located in BB ponds during 2008, larvae were subsequently recorded in all including BB8 where none had been found during the previous two years. When looking across the three years for all ponds, 19 out of the 72 sampling events show a lack of consensus for breeding success between observations of eggs or larvae, with 18 of the 19 recording 'no' for eggs but a subsequent 'yes' for larvae. These ponds typically had less marginal vegetation (*pers. obs.*) either naturally, as was the case GQH in 2006 and 2007 or due to site management intervention as occurred in BB in 2008. By 2008, GQH ponds were a 'no' for both eggs and larvae. The data at Gartcosh therefore suggests that larval sampling is a better indicator of breeding success than egg searches and if resources are limited, time would be better spent on larval sampling.

Relative abundance of larval production

GCN and 'Small' peak larval counts appear fairly encouraging, with 2008 numbers on a level with those recorded in previous years. However, the decline in Unidentified larvae during 2008 means that overall larval production across the GNR had significantly decreased (Fig. 2-11). Of further concern, the GCN abundance counts in 2008 reflect an upturn of counts within RJ but were masking crashes in GQH (Fig. 2-9). Evidence from 'Small' larvae in the same year suggests that neither of these zones were supporting survival of larvae (Fig. 2-10). Looking to the peak larval counts per month (Table 2-5) indicates that sampling efforts for assessing breeding success of GCN should be focused in June.

Relative abundance of the peak GCN adult counts was compared with peak GCN larvae counts to explore the relationship between adult numbers and breeding success. No significant relationship was found. As adult numbers increased, there was no corresponding increase in the numbers of GCN larvae. This suggests that the increases in peak adult counts observed in 2008 and 2009 were not true increases in the number of adults breeding but an artefact of clearing ponds of vegetation or that predation pressures on eggs and larvae within ponds had increased significantly.

Minimum Metamorph Production

In 2006, GCN metamorphs had been translocated from the ACA to BB. The high numbers recorded around the fences may have been the result of attempts to return to the original site. The subsequent reduction in metamorph numbers in following years could therefore be due to the newt population adjusting to the new habitat and not attempting to return to the original site. However, this would not explain the decline in efts, unless they were following directional cues left by sub-adults (Hayward et al., 2000). In addition, as significant colonisers of new habitats (Gill 1978; Breden, 1987) juveniles should be observed dispersing from the GNR. The decline in minimum metamorph production may be indicative of a decline in the survival of eggs to sub-adult.

BB, RJ and GQH all showed an apparent increase in adult numbers within the ponds during 2008 compared with 2006 and 2007, yet the other signs indicate breeding failure throughout the GNR. Half of all ponds had no observable eggs or larvae. Relative abundance of larvae seriously declined, as did metamorph production. This may add weight to the argument that the adult population size had not truly increased in 2008, but was simply easier to count due to removal of vegetation. Also, adults may have moved to ponds in greater numbers. Zones were not providing suitable habitat to ensure survival from egg to metamorph. This will have serious implications for long term survival of the GCN if there is a reduction in new adults being recruited into the population. Alternatively, if the adult population has truly increased, breeding failure is even worse. This aberration raises an interesting point on data accuracy in any site and how easily it can be confounded. Had this project been looking only to simple adult counts it would suggest a very positive picture when an exploration of eggs, larvae and metamorph production strongly indicates problems with the site.

There is a lag time of approximately two to three years for a juvenile to mature into the breeding adult GCN population (Latham et al., 1996). Large numbers of eggs and larvae were translocated to new ponds in the GNR during 2005. As the ponds were newly dug, invertebrate predator levels were likely to be low, representing improved conditions for egg and larval survival. This could explain the peak in sub-adults recorded in 2006 and adults in 2008 onwards. Likewise, the 2008 crash in eggs and larvae counts will begin to be observed in adult counts from 2010 onwards. However, these effects may be difficult to gauge due to the natural fluctuations in amphibian population size and/ or population observed within the breeding ponds. The management work undertaken in 2008 may have had a detrimental effect on breeding success, resulting in conditions that were less favourable for larval survival. This could be through factors such as a shortage of egg laying substrate and reduction in availability of invertebrate prey for the larvae which can also result in increased predation of larvae by adults (Beebee & Griffiths, 2000). As macrophyte coverage recovered in 2009, conditions may improve again for subsequent larval cohorts.

Herpetofauna Conservation Ltd (1991) described a scenario where a project could be considered a success due to the occurrence of egg-laying and larval metamorphoses. However, if the terrestrial or aquatic habitat did not support development and survival of the metamorphs to adulthood it would prove to be a relic population. Declines would not be apparent until translocated adults died off, with lifespan in natural conditions recorded as 14 years (Francillon-Veillot et al., 1990) to 16 years (Hagstrom, 1979). Capture-mark-recapture (CMR) may be a more appropriate means of assessing a population than simple counts by estimating the population size and confidence limits (Lewis et al., 2007). This methodology could also be used to provide evidence that metamorphs were being recruited into the breeding adult population. There is limited opportunity for immigration to the GNR site due to no other GCN populations being in close proximity and the presence of an amphibian proof fence encircling all zones. As all adults moved to the GNR were photographed, any 'new' adults found (i.e. not previously photographed) must have matured on-site (refer to Chapter 3).

When considering short term indicators of success, RJ appears to be faring well. There is, however, an inherent problem in trying to establish a population of 56 adults when immigration opportunities are minimal. Although the fencing no longer remains intact, RJ is isolated by significant barriers. Halley et al., (1996) used spatial modelling to predict that isolated populations of GCN will only persist with more than 40 females. Shaffer (1981) suggested that the minimum viable breeding population size is 100. Griffiths & Williams (2000; 2001) predicted that even larger populations of 100-200 individuals were at high risk of extinction if isolated for more than 50 years.

The aim of translocation is the establishment of a viable, self-sustaining population. Whether this has been achieved can only be ascertained through long-term, post-translocation monitoring. There are worrying signs that breeding is failing but this is manifesting only through closer examination of the survival of eggs and larvae through to metamorphs, not within the simple adult counts.

From 2009 onwards, only adult counts are to be surveyed. There is a clear need to continue investigating all life stages.

2.5.3 Critique of Methods

HEL Breeding Adults

Griffiths et al. (1996) tested the effectiveness of three methods of surveying newts; torchlight, funnel traps and netting. Funnel trapping (as described in Griffiths, 1985) was the recommended method, with higher detection rates and remained effective in ponds with a high level of vegetation that would hamper visual searching by torchlight. However, there are mortality risks to newts as a result of lost or poorly positioned traps. Trapping requires a greater time commitment, requiring surveyors to place traps for the night sampling and then return in the morning to check. It is possible that the additional staff hours and training required when undertaking funnel trapping would make this method less appealing than torchlight sampling when planning mitigation works. Netting proved to be an inefficient sampling method for adults.

For future great crested newt projects, SNH should consider supporting the use of density measures as described in Griffiths et al., (1996). Counts of newts every 2m are recorded (2m transects if using torchlight or a funnel trap positioned every 2m). Standardised survey methods expressing peak counts as density measures allow for comparisons between different sampling methods and across pond sizes. This would allow for meaningful comparisons between different projects/ sites.

Eggs

Searching aquatic vegetation is standard protocol for detecting the presence of GCN populations, often used in combination with other survey methods. Egg counts cannot be used as an indicator of population size as there is no significant correlation between the two (Gent & Gibson, 2003). At Gartcosh, egg searches were used in combination with presence of larvae to determine that breeding was occurring.

Larvae

Sampling for larvae is usually undertaken using dip-nets or funnel traps. Dip-netting was used at Gartcosh due to the logistical constraints with trapping, mentioned previously. Relative abundance between ponds was measured by comparing counts of larvae from twenty sweeps. Sampling points were randomized around the pond margin. However, for smaller ponds, this could mean that the entire pond margin was sampled.

Metamorphs

Newts are difficult to sample in the terrestrial habitat. I was looking for a sampling method that would give an indication of the relative abundance of metamorphs without necessitating a huge investment in time and resources such as would be required for pitfall trapping. Utilising the existing amphibian-proof fencing and terrestrial vegetation search achieved this. This method relied on dispersal and only sampled a very narrow band of vegetation beside the fence. This methodology clearly will not provide a robust count of metamorph emergence as a proportion of metamorphs may seek refuge within the zone boundary and never attempt to reach the perimeter fence, but did allow for the comparison of annual changes in metamorph production. To achieve robust estimates, each pond would be ringed with amphibian-proof fencing and pitfall traps positioned to capture metamorphs emerging from each pond. In Bothlin Burn alone, this would require eight individual fence-trap systems, twenty-four across the entire GNR. The traps would be opened daily for several months of summer/ autumn. The required man hours to undertake this was beyond the resources available to this project.

The staff resources required to undertake an effective monitoring programme would therefore be approximately six hours per pond. This would include five torchlight surveys undertaken throughout the breeding season, each lasting approximately one hour and one hour of larval sampling in June. An additional hour of egg searching may be appropriate in a pond failing to show presence of GCN.

3 Monitoring Population Size, Recruitment and Morphometrics in Translocated Great Crested Newts (*Triturus cristatus*)

3.1 Abstract

To determine the success of a translocation project, in-depth population analysis is required, yet rarely done. At Gartcosh, capture-mark-recapture methodology was used to determine whether this translocation had resulted in a viable population. Utilising the unique belly pattern markings of great crested newts, estimates of population size, survival rates and recruitment were calculated. Railway Junction and Bothlin Burn/Garnqueen Hill successfully maintained adult populations on a par with the number of translocated adults. A 43% survival rate was measured for Bothlin Burn/Garnqueen Hill, there was significant recruitment into the breeding adult population and pond fidelity was high (75%). Comparative morphometrics work showed that Body Condition Index and mass was greater in the Gartcosh Nature Reserve (receptor site) than in the Amphibian Conservation Area (donor site) for both males and females whereas snout-vent length was greater for both sexes in the donor site. Body length was greater for males in the donor site, with no significant difference observed between females. Annual growth increments recorded for recaptured individuals suggest that the newly created habitat was capable of the necessary resource provision. There was no discernible pattern observed when investigating sex ratio and corresponding body length of individual adults using the ponds throughout the breeding seasons. Simple adult counts will continue at Gartcosh until 2015. This will not provide the necessary information to ascertain whether the translocation will successfully achieve the creation of a population viable in the long-term. It is recommended that capture-mark-recapture study is continued at Railway Junction to provide much needed long term population data and comparisons between population size estimates and count data.

3.2 Introduction

Reviews of GCN translocation by Oldham et al. (1991), Oldham & Humphries (2000), Edgar & Griffiths (2004) and Edgar et al. (2005) could not conclusively determine success due to insufficient monitoring. When monitoring was undertaken it usually only looked to the presence of adults or simple counts. However, variability among counts and detection probabilities may impact on the usefulness of count data (Schmidt, 2004; Dodd & Dorazio, 2004). Variation could be due to the impact of the translocation, natural fluctuations in population size and recruitment or the ability to detect the presence of newts (Arntzen & Teunis, 1993; Cooke, 1994, 1995, 1997; Latham et al., 1996; Baker, 1999; Griffiths & Williams 2000; Kupfer & Kneitz, 2000; Oldham & Humphries, 2000; Schmidt, 2004).

In chapter 2, the results of the simple counts undertaken by HEL to monitor the population were investigated. In order to determine whether a translocation has been a sustainable success, it is important to get good estimates of population size and adult survival rates. Capture-mark-recapture models (CMR) can be used to garner this information (Krebs, 1999; Pollock et al., 1990). Great crested newts have distinctive belly patterns, unique to each individual (Hagstrom, 1973). Population size estimates can be made using this natural pattern as an identifying ‘mark’ in CMR studies (Cooke, 1985; Arntzen & Teunis, 1993; Baker, 1999; Cooke & Arnold, 2003).

Information on adult GCN population size estimates and survival are not representative of the entire population. GCN adults have been recorded as surviving to 16 years old in natural conditions (Hagstrom, 1979). This can result in a ‘relic’ population (Arntzen & Teunis, 1993) where counts appear to hold steady due to the longevity of the species, but may mask a decline or lack of ‘new’ adults being recruited into the breeding population. There is a real need to extend sampling efforts beyond adults to include the other life stages. In chapter 2, the sampling regime included eggs, larvae and metamorphs. Yet even with this additional effort, a very clear gap remained. Were metamorphs surviving to be recruited into the breeding adult population? Gartcosh affords a unique opportunity to study recruitment. All adults located within the GNR reserve were originally from the ACA and each individual was photographed by HEL before being moved and released. The belly pattern is not generally fixed in metamorphs (Arntzen & Teunis, 1993) so photographs were restricted to the adult lifestage. Any adult captured in the GNR that was not matched to this photographic record must therefore have matured on site within the GNR as there is no known source of migrants, proof that juvenile lifestages are surviving to be recruited into the adult population.

The principal aims of this chapter are to assess whether new adults are being recruited into the population, to assess survival of the original translocated population and to explore the effect relocation has on subsequent pond fidelity. Seasonal changes in sex ratio and body length of individuals utilising the ponds throughout the breeding season and annual growth rates as a proxy for provision of good habitat were also be investigated.

3.3 Methods

3.3.1 Population Estimates and Survival Rates

During the three year translocation, HEL was tasked with photographing the belly patterns of all adult GCN moved from the ACA to the GNR. HEL and the Scottish Government very kindly made this photographic record available for use, providing an excellent opportunity to undertake a CMR study. HEL made no distinction between photographs of newts moved to BB or GQH. As such, these zones must be considered together. RJ will be analysed separately. For information on the sites and zones, refer to Chapter 2. For further details on ponds within the zones, refer to Chapter 4.

All ponds within the GNR zone were sampled on five occasions throughout the peak breeding season, March until May, for a period of three years (2007 to 2009). This gave four sampling events; the first capture event during the translocation (newts were moved to RJ in 2004 and to BB/GQH over 2005/2006) and the three years of recaptures. Each pond was scanned using a powerful torch. Numbers of observed adults were recorded and an attempt was made to capture each individual using a long-handled net. If unsuccessful, the area was revisited in a second attempt to catch the newt after the pond circuit had been completed. Captured adults were sexed, weighed using a spring balance to the nearest 0.1g, measured from tip of the snout to anterior cloacal vent (snout-vent length- SVL) and from the tip of the snout to the tip of the tail (body length- BL) using callipers to the nearest 1mm. A Mander Masher (see Fig. 3.1) was built in accordance with the description within Gent & Gibson (2003) for use in belly pattern photography. Each newt was allowed to walk across the Perspex side then the foam side was gently closed over, trapping the newt. *In-situ* photography using a digital camera was possible without the need to anaesthetise the animals.

Figure 3-1: Mander-Masher equipment used to hold GCN during belly pattern photographs (Gent & Gibson, 2003) and examples of the variation in belly patterns among individuals.

Photographs were hand sorted for matches using the unique belly pattern as an identifier (Hagstrom, 1973; Arntzen & Teunis, 1993; Oldham & Humphries, 2000). Between-year recaptures were used in CMR analyses. The true number of individual adults captured per year was calculated by subtracting the number of within-year recaptures from the total number of catches. The surveyor's ability to match recaptures was tested using the following method: 100 photographs, including 20 'recaptures' were printed. The photographs were set aside and analysed two weeks later to simulate a hand-sorting event. A 100% success rate in recognised matches was obtained. Two obvious flaws in this test were; prior knowledge of the number of matches and that exactly the same photo was being compared as the capture and recapture. In reality, photographs would exhibit variation due to factors such as animal positioning and quality of photograph. By comparison, Oldham & Nicholson (1984) estimated a 14% error in matching by eye. It was recognised that due to the number of photographs in the back catalogue that hand sorting would be a very time consuming process. In collaboration with the Geography department at the University of Glasgow, digital image processing techniques were explored for photograph matching. This included a vector approach supported within GIS and preliminary work using 2D Gaussian filters to smooth out images for automated comparison. This work was abandoned after it became obvious that the processing work would be very laborious and time consuming.

Population size estimates of the breeding adult population (not the entire GCN population) and confidence intervals were calculated using the Jolly-Seber methodology for open populations as described in Krebs (1999) and Pollock et al. (1990). Assumptions of the Jolly-Seber method were met for breeding adults only e.g. other lifestages did not have the same probability of being caught due to the sampling method used. This population size estimate was compared with the number of adults translocated to the GNR and peak breeding adult torchlight counts undertaken by HEL (methodology described in Chapter 2). Survival and dilution rates were calculated (formulae in Krebs, 1999). In this model, survival refers to animals remaining alive within the study zone. Loss could be due to migration and mortality. Dilution is a measure of addition, from immigration and births. As incidence of emigration/immigration is negligible within the Gartcosh site, survival and dilution are essentially measures of mortality and birth rates.

The effectiveness of the sampling method in catching newts for marking was tested by comparing the numbers counted during the torchlight survey portion with the actual numbers captured by the torchlight/netting technique.

3.3.2 Fidelity

Pond use within the three zones of the GNR can be compared within and between the years of 2007 to 2009 by examining data recorded during the CMR study, detailing within which pond each newt was located when netted.

3.3.3 Recruitment to Breeding Population

There were no known individuals in the GNR prior to the translocated population arriving and there is no known source of immigration to the site (refer to Chapter 4). As such, any adults appearing in the photographic record that was not marked during the translocation must have matured in the GNR. They may have been translocated as eggs, larvae or metamorphs originally from the ACA or are the product of successful breeding within the GNR. GCN have generally attained sexual maturity by four years old but commonly by two (males) and three (females) (Francillon-Vieillot et al., 1990; Oldham, 1994).

In RJ, comparisons of photographs were made between 2004, 2007, 2008 and 2009 to look for 'new' males and females. In BB/GQH comparisons of photographs were made for females between 2005/2006 and 2007, 2008 and 2009. For males, only 2006 photographs were compared with subsequent years, therefore male recruitment within this zone cannot be accurately ascertained as there may be matches in the 2005 photographic catalogue. It was simply not possible to analyse all the photographs within the time constraints of this project.

3.3.4 Morphometrics

Pre versus Post Translocation

Body Condition Index (BCI) was calculated for all adult males and females that were translocated from the ACA during 2004 and 2006 and those breeding adult males and females recaptured in the GNR during 2007 to 2009.

BCI = $(mass/SVL^3) \times 10^6$ where mass (g) and SVL (mm). (Platenberg & Griffiths, 1999; Arntzen et al., 1999).

A 2-sample t test was used to compare the BCI of ACA males and females (pre translocation) with those in the GNR (post translocation). The null hypothesis was that there was no significant difference in BCI between adults in the ACA and in the GNR. This was repeated for body length, snout-vent length and mass.

Individual

Annual growth rates were examined by comparing individual morphometrics (BL) of animals between capture events. Between-year captures where only a year had passed between catches were considered (i.e. individual caught in 2007 and recaptured in 2008 was included whereas a recapture in 2009 would not have been). This was to prevent making assumptions on annual growth if the time between recapture events was two years or greater. Not all recaptures could be included in the analyses as HEL recorded body length by photographing a newt beside a ruler. Unfortunately a number of photographs omitted the ruler from the image or the picture was too blurry to allow for reading of the measurements.

3.3.5 Seasonal Variation in Sex Ratio and Size

Seasonal variations in sex ratio and body length of adult newts visiting the ponds were examined throughout the 2008 and 2009 breeding seasons. The dataset was derived from the CRM methodology, assessing the five, within-year breeding pond sampling efforts as described in section 3.3.1 ‘Population Estimates’. Data from 2007 were not included in this survey work as timing of sampling visits to each zone was not evenly spaced throughout the breeding season as they were in subsequent years. A male bias was expected, as was found during HEL torchlight sampling (refer to chapter 2).

3.4 Results

3.4.1 Population Estimates and Survival Rates

Population size estimates could not be calculated for the first and last year of sampling using CRM i.e. was only possible for 2007 and 2008. Survival and Dilution rate could not be calculated for the first, last or second last year using this method i.e. was only possible for 2007. There were no recaptures during RJ 2007 sampling, therefore population estimate/ survival/ dilution was not possible in this zone as Jolly-Seber is dependant upon the size of the marked population and the proportion of animals actually marked (Jolly, 1965). Results are shown in Table 3-1 and the capture/ recapture data can be found in Appendix 1.

	N	CI U	CI L	Survival	Dilution
RJ_{2008}	171.1	155.3	86.9	na	na
BB/GQH_{2007}	826.1	116.9	95.1	43	559.6
BB/GQH_{2008}	914.8	363.2	188.7	na	na

Table 3-1: CMR Jolly-Seber model results, estimates of population size (N), upper 95% confidence limit (CI U), lower 95% confidence limit (CI L), percentage of loss due to death (Survival) and addition of individuals to the population due to births (Dilution) (Krebs, 1999; Manly, 1984; Seber, 1982; Jolly, 1965). Asymmetric Confidence Intervals calculated by N + CI U and N – CI L.

In 2005 and 2006 956 adults were translocated to BB and GQH. The population size estimates in 2007 and 2008 are consistent with the breeding adult population being maintained at a comparable level, although the CI’s for 2008 are large. In 2004, 56 adults were translocated to the RJ. The population size estimate for 2007 suggested an increase in population size but the CI’s are large. Even considering the lower CI, the population estimate is larger than the translocated population.

As only two population size estimates could be calculated for BB/GQH, statistical comparison with HEL annual peak adult counts (refer to chapter 2) was not possible. If we compared 2007 peak adult/CMR (82/826) with 2008 peak adult/CMR (118/915), the figures are variable (10% to 24% respectively).

Survival rate appears low (43%) although we have no pre translocation survival rate with which to compare this and there is evidence of significant recruitment.

Catching Success

What percentage of newts observed by torchlight were actually caught using this torchlight/ netting method? Data are shown in Table 3-2.

	2007		**2008**		**2009**	
	M	**F**	**M**	**F**	**M**	**F**
Torched	142	56	286	104	272	100
Caught	47	34	173	86	129	66
% Caught	33.1	60.7	60.5	82.7	47.4	66

Table 3-2: Catching success. The number of males and females counted during GNR torchlight surveys were compared with the numbers successfully caught by the netting technique.

Capture rates improved considerably from 2007 to 2008, dipping again in 2009. Females were consistently easier to catch than the males.

3.4.2 Pond Fidelity

Incidence of recaptured newts utilising different ponds is shown in Table 3-3.

	$N_{M/F}$	08	09	07-08	08-09	% Non Fidelity
RJ F	8	1			2	37.5
RJ M	14			1		7.1
BB F	13					0
BB M	24			2^1	6^3	33.3
GQH F	3				1	33.3
GQH M	5		1		1	40

Table 3-3: Pond Fidelity. $N_{M/F}$ refers to the total number of recaptured individual caught. The within or between years data describes the number of times an individual was caught in a different pond and when. % Non-Fidelity is calculated by Years/ $N_{M/F}$. The numbers in superscript refer to the numbers of individuals that moved from BB Cluster 2 to Cluster 1.

The possibility of movement between zones was minimal due to the existence of amphibian-proof fencing that remains in place around Bothlin Burn and Garnqueen Hill. The movement between ponds referred to was within individual zones. There was a mean pond fidelity of 75% (females=76.4%; males=73.2%) across the three years of recaptures within the GNR. In most instances, ponds within a zone are situated very close to each other (refer to maps in chapter 4). One exception to this is Bothlin Burn where there are eight ponds located in two distinct clusters of four ponds. Each cluster is in a separate field, divided by a thin strip of woodland presenting no barrier to migration. This makes the movement by several males between the two fields noteworthy as this was unlikely to have been simply an error due to close proximity of ponds. Three males were observed moving within the same breeding season.

3.4.3 *Recruitment to Breeding Population*

Recruitment of new adults to the Railway Junction is shown in Table 3-4.

	Netted		New Adults		% New	
	M	**F**	**M**	**F**	**M**	**F**
RJ 2007	5	5	5	5	100	100
RJ 2008	29	24	19	21	66	88
RJ 2009	29	12	25	9	86	75
BB 2007		29		9		31
BB 2008		55		32		58
BB 2009		52		28		54

Table 3-4: The percentage of 'new' adults found in the RJ was calculated by establishing the number of unmarked male and females captured during the torchlight/ netting samples. In BB, 'new' females only was calculated.

In RJ, high proportions of the males and females captures were new to the breeding adult population. Comments on annual variation are perhaps spurious due to the small number of captures in 2007. The proportions were lower in BB.

3.4.4 Morphometrics.

ACA versus GNR

Males and females moved from the ACA were compared with subsequent recaptures in the GNR, looking at Body Condition Index, Body Length, Snout-Vent Length and Mass, as shown in Fig. 3-2, 3-3, 3-4 and 3-5 respectively. A visual inspection of histograms showed there were no gross deviations from normality.

Body Condition Index

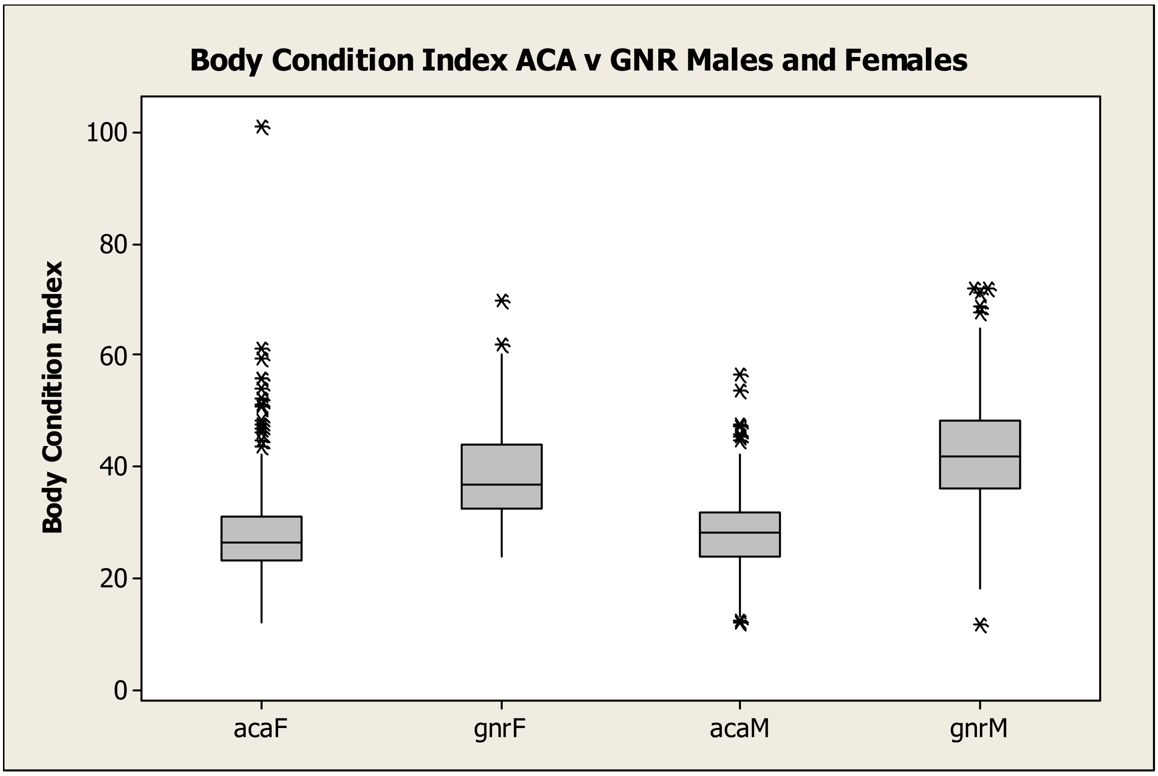


Figure 3-2: Body Condition Index compared between ACA and GNR males and females. The box plot shows the lower quartile, median and upper quartile; whiskers indicate the lowest and highest values within the lower (Q1-1.5) and upper (Q3+1.5) limits and * show the position of any unusually small or large outliers beyond the whiskers.

ACA female *n*= 446, GNR female *n*= 188: (t_{female}= 15.29, d.f.=335, p<0.001) highly significant difference. ACA male *n*= 505, GNR male *n*= 344: (t_{male}= 24.66, d.f.=517, p<0.001) highly significant difference. The BCI of both males and females were significantly higher in the GNR when compared to the ACA.

Body Length

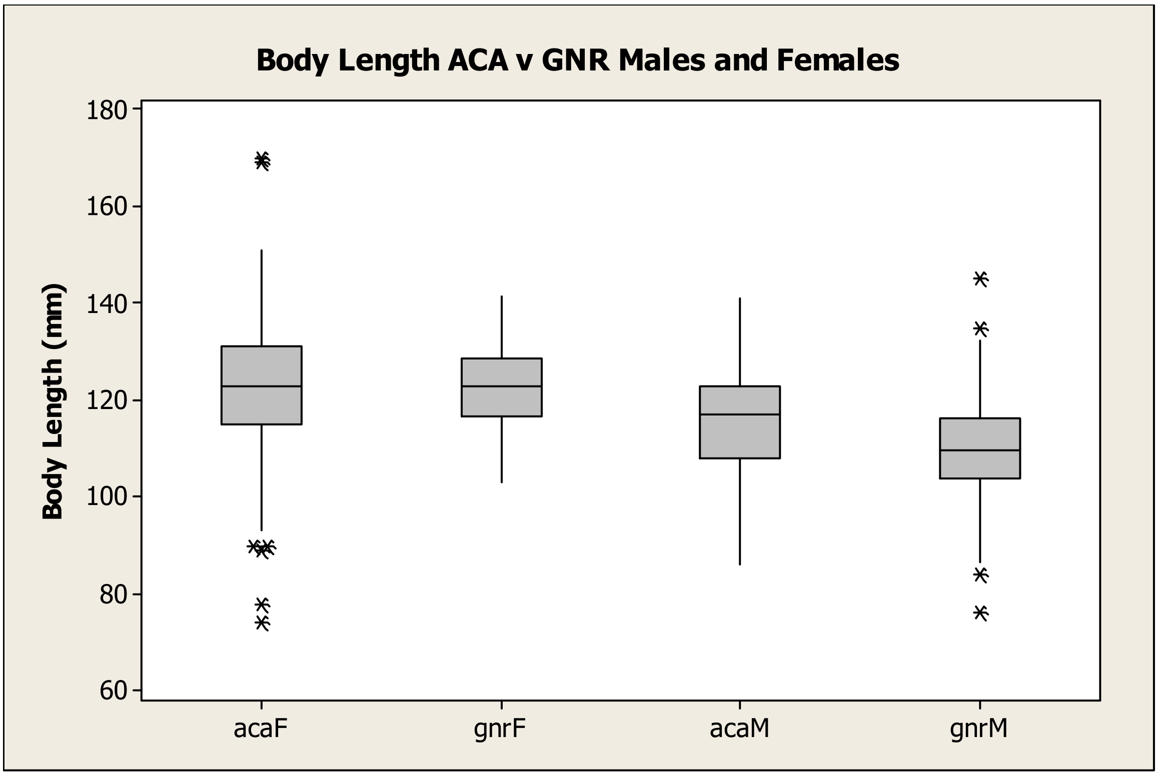


Figure 3-3: Body Length (mm) compared between ACA and GNR males and females. The box plot shows the lower quartile, median and upper quartile; whiskers indicate the lowest and highest values within the lower (Q1-1.5) and upper (Q3+1.5) limits and * show the position of any unusually small or large outliers beyond the whiskers.

ACA BL female *n*= 345, GNR female *n*= 187: (t_{female}= 9.68, d.f.=521, p=0.939) not significantly different. ACA BL male *n*= 361, GNR male *n*= 344: (t_{male}= 8.98, d.f.=7, p<0.001) highly significant difference. The BL of males were significantly higher in the ACA when compared to the GNR but there was no significant difference observed in females.

Snout-Vent Length

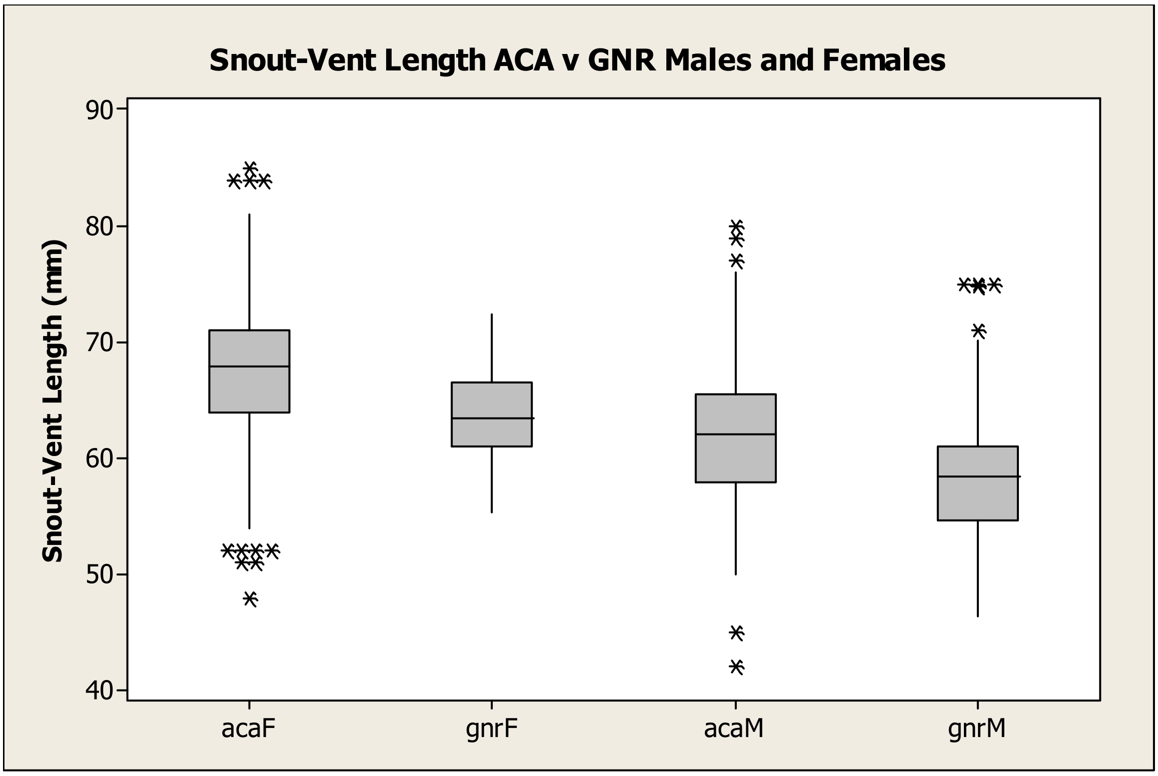


Figure 3-4: Snout-Vent Length (mm) compared between ACA and GNR males and females. The box plot shows the lower quartile, median and upper quartile; whiskers indicate the lowest and highest values within the lower (Q1-1.5) and upper (Q3+1.5) limits and * show the position of any unusually small or large outliers beyond the whiskers.

ACA SVL female *n*= 446, GNR female *n*= 188: (t_{female}= 9.68, d.f.=524, p<0.001) highly significant difference. ACA SVL male *n*= 505, GNR male *n*= 344: (t_{male}= 8.98, d.f.=799, p<0.001) highly significant difference. The SVL of both males and females were significantly higher in the ACA when compared to the GNR. There were a greater number of SVL measurements than BL in the ACA due to the method of photography used by HEL, resulting in a number of photographs not showing the full animal.

Mass

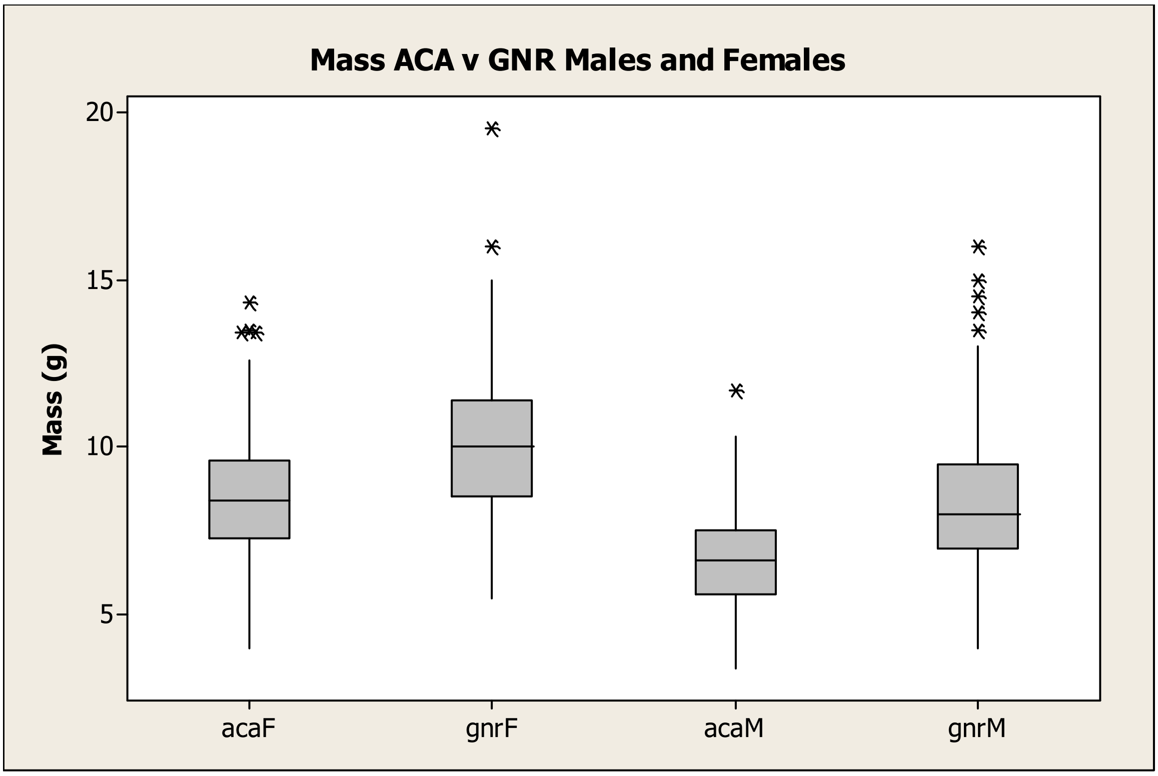


Figure 3-5: Mass (g) compared between ACA and GNR males and females. The box plot shows the lower quartile, median and upper quartile; whiskers indicate the lowest and highest values within the lower (Q1-1.5) and upper (Q3+1.5) limits and * show the position of any unusually small or large outliers beyond the whiskers.

ACA Mass female *n*= 446, GNR female *n*= 188: (t_{female}= 8.84, d.f.=300, p<0.001) highly significant difference. ACA Mass male *n*= 505, GNR male *n*= 344: (t_{male}= 15.02, d.f.=550, p<0.001) highly significant difference. The masses of both males and females were significantly higher in the GNR when compared to the ACA.

Variability in mass throughout a breeding season due to factors including food availability or reproduction was investigated by looking at differences in mass of individuals recaptured within the same year, as described in Table 3-5.

		Increase	No Change	Decrease
Male	*n=18*	8	4	6
Female	*n=11*	7	1	3

Table 3-5: Within-year recaptures of males and females were weighed and mass compared between capture events. Mass of newts could be found to increase, decrease or not change.

There was considerable variability observed in measurements of mass between capture events within a single breeding season, suggesting that mass may be of lesser use as a comparative morphometric.

Individual Recaptures of ACA v GNR

			Diff BL	Diff SVL	Diff Mass
male	2004	2008	-1	-0.5	-1.4
male	2004	2008	2.8	2	0.8
male	2004	2008	-1	-1	-0.9
male	2006	2008	19	0.8	2.7
male	2006	2008	14	9	4
male	2006	2009	-0.2	1	1.9
female	2004	2008	18	8.5	2.6
female	2004	2008	0.5	-0.2	0.2
female	2006	2007	1	0.4	6.4
female	2006	2007	2.2	-1.6	6.5
female	2006	2007	-0.2	-5	5.6

Table 3-6: Morphometric analysis of individuals from the ACA recaptured in the GNR. Recapture measurement was subtracted from the original measurement to give a difference in BL-body length (mm), SVL-snout-vent-length (mm) and mass (g).

Despite a large sampling effort, data on changes in individuals in a large population is hard to get. A complex picture emerges; individuals vary a lot in the changes between these there measures. This will perhaps be confounded by different measurement techniques used and different individuals performing the measurements.

Individual Growth Increments in GNR

Individuals recaptured in consecutive years were compared to give annual body length growth increments as shown in Table 3-7.

Zone	Sex	Capture Range	N	Growth (mm)
RJ	M	2007-08	3	8.8
BB/GQH	M	2007-08	3	5.7
BB/GQH	M	2008-09	11	8.5
BB/GQH	F	2006-07	4	4.3
RJ	F	2007-08	1	4.2
BB/GQH	F	2007-08	3	0.7
RJ	F	2008-09	3	5.8
BB/GQH	F	2008-09	4	8

Table 3-7: Mean annual growth increment of male and female GCN within RJ and BB/GQH. Capture range refers to the between-sampling years within which the capture was made. N= number of individuals sampled and growth is mean additional body length in mm.

The number of useable recaptures was very low but all show an increase in BL over a year period. Average annual growth for males in the GNR was 7.7mm and for females was 4.6mm. Annual Growth Increment: Female *n*= 15, Male *n*= 17: (t= 3.74, df=25, p=0.001) highly significant difference. The annual BL growth increment of males was significantly higher than females.

3.4.5 Seasonal Variation in Sex Ratio and Size

The number of individuals, body length and sex ratio of males and females using the ponds at different points throughout the breeding season is shown in Table 3-8.

	2008					2009				
	M		F		Ratio	M		F		Ratio
	N	BL	N	BL	F:M	N	BL	N	BL	F:M
v1	17	111.4	9	128.2	1:2	20	110.2	8	119.7	1:4
v2	50	109.9	24	122.0	1:2.8	22	112.3	16	122.6	1:1.9
v3	31	109.4	35	119.9	1:2.5	31	114.0	17	130.0	1:2.7
v4	66	105.5	16	121.3	1:4.5	17	112.7	9	124.7	1:2.5
v5	4	106.9	4	116.8	1:0.75	2	118.9	4	120.9	1:2

Table 3-8: GCN breeding adults were sampled on five occasions throughout the breeding season (v1-5). N=number of males and female caught, BL is the mean body length (mm) of the individuals caught and sex ratio is number of males per 1 female.

Both sexes followed the same general pattern of arriving in peak numbers towards the middle of the breeding season (except the decline in males 2008, v3). There is no discernible pattern when considering the size of individuals using the ponds at different times. In 2008, mean male BL decreased from v1 to v5 with the opposite occurring in 2009. In 2008, mean female BL also showed a tendency to decrease across subsequent visits with the exception of v3/4, then in 2009, increasing in BL as the season progressed then decreasing toward the latter visits.

The ratio of captured males was highest in v4 during 2008 and v1 in 2009. The mean sex ratio for both years was 1:2.7. HEL's torchlight sampling produced a mean sex ratio of 1:4.2 in 2008 and 1:3.6 in 2009, suggesting that the torchlight/ capture regime used here was less biased towards males.

3.5 Discussion

Population Estimates

The breeding adult population sizes estimated using the CMR models were very positive. Taking into account the large range in the upper and lower 95% confidence intervals, the populations of both RJ and BB/GQH appear to be faring well. Adult numbers are being maintained at a level comparable with numbers originally translocated to the GNR. A CMR study of four years duration can only achieve two years of population estimates, one year of survival and addition rates. A larger sample size upon which to base success or otherwise would prove very beneficial. BB/GQH survival rate was 43%, higher than the 20% rate recorded by Hatchel et al. (2005), on a par with reported survival rates of 45% (Oldham, 1994), 49% (Arntzen & Teunis, 1993) and 55% ± 18% (Griffiths, 2010) but much lower than 68% (Edgar & Bird, 2005) and 78% (Hagstrom, 1979). Griffiths (2010) suggest that adult survival rates less than 30% have a 0.5 probability of going extinct within 10 years. The addition rate indicated a high number of new adults being recruited into the population. In Gartcosh, this is indicative of births, as immigration opportunities are negligible. The impact of translocation on the survival and addition rate of the Gartcosh population would have been best measured against a pre translocation baseline. Future work on survival and addition rates in the post translocation population could offer valuable information on long-term prospects.

With so many photographs being compared, there is a very real possibility of missing matches. Oldham & Nicholson (1984) reported a 14% ‘missed’ rate. This should not impact significantly on the CMR study as each newt has an equal opportunity to be unidentified. The methodology used here is very light on field work resources but extremely resource intensive in terms of data analysis, due to the size of the photograph catalogue. It could prove beneficial to continue the CMR study for RJ alone, where the numbers of photographs being compared are more manageable. Alfords & Richards (1999) argue that counts are a better use of resources due to the large confidence intervals obtained through CMR. Schmidt (2004) countered that it was important to have the confidence intervals, as a measure of whether a count is reliable.

Capture rates increased from 2007 to 2008, possibly reflecting improved technique and subsequent management of the ponds in 2008 meaning there was less vegetation to snag the netting. It was interesting to note that the method was more effective at catching females, despite the male bias observed for torchlight counts.

Fidelity

Significant proportions (25%) of the CMR newts were found to be using different breeding ponds within a single zone, with the proportion of males slightly higher than females. This is perhaps unsurprising in a translocated population as they adjust to a new site and have no sense of fidelity to a specific pond. Capture rates were too low to allow for statistical analyses of whether fidelity increases with subsequent years post-translocation.

Recruitment

‘New’ adults may have matured from translocated eggs, larvae or metamorphs. Alternatively, they may be the result of successful breeding within the GNR and would appear in RJ from 2007 and GQH/ BB from 2008. This assumes a three year lag to maturity (normally 2 years for males, 3 for females). It is not possible to confidently differentiate between the two as size cannot be used as an indicator for age (Francillon-Vieillot et al., 1990). The occurrence of ‘new’ adults does provide evidence that the newly created habitat is capable of supporting the development of the juvenile stages to breeding adults.

In RJ, the percentage of 'new' decreased for females from 2007 to 2009. For males, there was a significant drop between 2007 and 2008, increasing again in 2009. BB/GQH females show a lower percentage of 'new' females compared with RJ although this may be a feature of there being no gap in the photographic record being examined as there was in RJ (BB/GQH: 2006 to 2009; RJ: 2004, 2007 to 2009). A high proportion of new recruits would appear promising, indicating that juveniles are surviving to reach breeding adult status. However, too high a percentage may be indicative that the older, translocated adults were not surviving. It would be very useful to draw comparisons between recruitment and survival rates. If this high level of recruitment is matched by a corresponding high survival rate, then the population would appear to be faring well. It would have been useful to have a pre-translocation baseline with which to compare. It was not possible to calculate a survival rate for RJ and there is only one year estimated for BB/ GQH of 43%. The survival rate is low but appears normal in the context of reported survival rates in the literature.

Morphometrics

Increased body size and mass can be used as a proxy to indicate that adults are in good health and have adequate habitat (Horton & Branscombe, 1994; Pechmann et al., 2001). Body length, snout-vent length, mass and Body Condition Index were calculated for all adults translocated from the ACA and all adults captured in GNR breeding ponds (subsequent recaptures plus 'new' adults). The BL of males and the SVL of both males and females were significantly higher in the ACA when compared to the GNR but there was no significant difference observed between BL of females. The photographic set up used by HEL was a fixed unit, with each newt photographed standing beside a ruler. A number of BL photographs from the ACA could not be included as the entire animal was not in the photograph, preventing accurate measurement. This may suggest that larger bodied animals were more likely to be excluded from analysis for failing to fit within the margins of the fixed frame of the photograph.

Conversely, the BCI and mass of both males and females were significantly higher in the GNR when compared to the ACA. BCI is a function of both mass and SVL. The significant differences observed when examining SVL and mass suggest that BCI is more heavily influenced by mass. Mass is a more variable measure than length, influenced by factors such as food availability and egg weight. Examinations of mass measurements of within-year recaptures at Gartcosh were very variable, with mass increasing, decreasing or remaining constant. MacGregor (1985) captured a female on seven occasions, at least twice a year over a three year period. Weight fluctuated by up to a factor of two between sampling points.

Length measurements suggest that larger-bodied (possibly older) individuals in the ACA have not survived in the GNR and that 'newer' smaller recruits are predominating. It is difficult to tease apart the meaning of the BCI/ mass results. It may be that the GNR has improved resource provisioning than the ACA. Alternatively, it could be that animals in breeding ponds measure heavier due to aquatic feeding and/or carrying eggs. GNR measurements were made of animals within breeding ponds. ACA measurements included animals captured on land outwith the breeding season.

Individuals

The number of useable recaptures was very low but all show an increase in BL over a year period. Average annual growth was significantly greater for males captured in the GNR (7.7mm) than for females (4.6mm). This is indicative of a habitat that is capable of meeting adult resource requirements. Gartcosh growth rates are greater than the average annual growth rates recorded in the literature of 0.73mm (Francillon-Vieillot et al., 1990) although this was an extrapolated figure, not drawn from recapture data, 0.67mm (Hagstrom, 1980) and 0.98mm (Hagstrom, 1977). This may be the result of climatic variability (Arntzen, 2000), a feature of the small sample size or indicative of increased resource availability. Morphometrics measurements on a non-anaesthetised animal may have in-built inaccuracies due to movement through the body, notably the tail. This however, is likely to result in under-estimates of the body length. Little or no increase in observed growth rates could be due to factors including larval overcrowding (unlikely in the GNR as larval populations were declining; refer to Chapter 2), low quantity and quality of food (unlikely in the GNR from invertebrate/ pond analyses; refer to chapter 4), of high levels of predation pressure, including adults eating young (Langton et al., 1994).

Seasonal Variability

The translocated population had a sex ratio close to 1:1. In Chapter 2, the torchlight survey counts indicated a heavy male bias. This was also observed by Langton et al. (1994). This was likely due to male displaying behaviour and the shorter time spent by females in the water over the course of a breeding season. There were few discernible patterns observed across the sampling years for both changes in sex ratio and size of adults using the ponds at different periods throughout the breeding season. Other studies found that males arrived earlier and stayed longer (Bell, 1979; Verrell & Halliday, 1985). Arntzen (2002) found a male bias at the start of the breeding season and a female bias towards the end. We would therefore expect a higher ratio skewed towards males at visit 1. Perhaps this would have been more noticeable had the sampling regime started earlier. However, extremely cold conditions at Gartcosh at the beginning of the breeding seasons made it unlikely that newts could have arrived at breeding ponds much earlier than was observed. The mean sex ratio for both 2008 and 2009 was 1:2.7. HEL's torchlight sampling produced a mean sex ratio of 1:4.2 in 2008 and 1:3.6 in 2009, suggesting that the slightly altered torchlight/netting regime used here was less biased towards males.

3.5.1 Conclusion

Despite the large data-set generated through this project, it is still not possible to fully resolve the question as to the status of the population within the new situation. We can confidently say that population size is being maintained and that there is recruitment of new adults. What we cannot determine is whether survival rates have changed, whether the recruitment is a true gain or indicative of the 'old' newts having died off and whether survival and recruitment are high enough to continue to maintain the population at previous levels. Post monitoring is scheduled for the GNR until 2015, relying on simple counts of breeding adults. This will provide information on annual fluctuations but is insufficient monitoring to provide the necessary answers. There is a real opportunity at Gartcosh to produce a valuable data set, building on the work detailed within this project. Further CMR in RJ will provide annual estimates of population size, survival and insight into recruitment, while allowing for comparisons to be made between simple counts and population size. Future translocations would benefit immeasurably from the inclusion of surveying population dynamics, survival, recruitment and growth rates in the pre monitoring stages. This would provide a comparative baseline with which to compare post monitoring.

3.5.2 Critique of Methods

In a recent review of translocation by Lewis et al. (2007) only one project was recorded as using CMR. To test the effectiveness of translocations, detailed studies of population size and survival rates are required. Field work for CRM projects is relatively straight forward, utilising bottle traps, ring fencing/ pitfall traps or perhaps the torchlight/netting methodology described here. Bottle traps are effective in ponds with high macrophyte cover (Griffiths, 1985). This method could not be utilised here due to limited time and volunteer availability. While it was possible to sample most nights that conditions allowed, the part-time nature of the research severely restricted the morning revisits that bottle trapping would have required. Ring-fencing/ pitfall trapping could not be used as there were 24 ponds that would have required consecutive daily visits. It would simply not have been possible to visit all traps daily with the available man power. The torchlight/netting methodology tested here was very simple to do and cheap to resource.

In a large scale translocation of the kind reported here, an automated method for matching photographs would be hugely beneficial. Development of a possible method proved beyond the resources available here. Hand-sorting of the photographs was extremely time consuming and took up a considerable portion of the time allocated to this project. It was simply not possible to get through it all. This was partially due to not receiving the back catalogue of photographs until later on in the project as it took a couple of years for a copy to be located, and partially due to the immense amount of work involved.

It would be a useful study to compare the effectiveness of torchlight/netting against bottle trapping. Both methods sample the margins only, unless the pond is small enough to allow sampling with the net towards the middle. Netting only provides sampling of a pond during the hour or so that the survey takes whereas bottle traps are *in-situ* overnight. With netting, a surveyor can actively 'track' newts whereas a trap is passive.

CMR would have benefited from more intensive capture events per pond. With twenty-four ponds in the GNR a decision had to be made; sample all ponds or a subset of ponds more intensively. The decision was made to sample all ponds. In hindsight, this appears to be the correct decision due to variability in ponds and pond usage by all lifestages.

4 Assessing the Suitability of Newly Created Habitat in the Gartcosh Nature Reserve for Great Crested Newts (*Triturus cristatus*)

4.1 Abstract

The provision of good quality aquatic and terrestrial habitat is essential to the survival of great crested newts. The mitigation efforts at Gartcosh Industrial Site led to the destruction of the original habitat and the creation of a new habitat within the Gartcosh Nature Reserve. There has been a loss of terrestrial habitat, an increase in the number of ponds but subsequent decrease in pond surface area. An investigation into the suitability of the new habitat to support the translocated population of great crested newts was undertaken. Predictive System of Multimetrics (PSYM) was used as a measure of pond quality. In 2006, a proportion of ponds measured were scored as ‘moderate’ improving to ‘good’ by 2007. There was no correlation between PSYM score and either adult or larval counts. Two-way Indicator Species Analysis (TWINSPAN) classified old and new ponds into groups according to similarity of macrophyte communities. Habitat Suitability Index (HSI) evaluated the combination of both aquatic and terrestrial habitat for use by great crested newt populations. The Gartcosh Nature Reserve receptor site scored a higher mean HSI than the Amphibian Conservation Area donor site, further suggesting the ability of the newly created habitat to support the newt population. HSI scores were correlated with adult counts but not larval counts. The continued existence of amphibian fencing surrounding individual zones remains problematic, fragmenting the new site. The Gartcosh population is isolated within the wider landscape. The nearest known great crested newt population is over 1 km away, separated by significant migration barriers.

4.2 Introduction

Gartcosh Industrial site, to the East of Glasgow, houses the largest known population of GCN in Scotland. To resolve conflict between redevelopment of the brownfield site and conservation of this European protected species, mitigation was undertaken to create a new pondscape and translocate the GCN population to it. Good quality aquatic habitat is vital to GCN for breeding, egg laying and larval development. Suitable terrestrial habitat is equally as important as a GCN adult will spend at least half the year on land (MacGregor, 1995; English Nature, 2001). Upon metamorphosis, a sub-adult may be entirely terrestrial until returning to ponds as a sexually mature adult to breed, two to three years later. Previously studied translocations have failed due to predictable reasons including unsuitable aquatic and terrestrial habitat or habitat provision inadequate in size (Oldham et al., 1991).

Characteristics of a good GCN pond have been said to include a surface area between 100-750 m^2 (100-300 m^2 -English Nature, 2001; an optimum of 250 m^2 - Gent & Gibson, 2003; 500-750 m^2 -Swan & Oldham, 1993), free of fish (Oldham & Nicholson 1986), occasional drying to reduce invertebrate predation (Oldham, 1994; Griffiths, 1997) and a good source of prey items such as molluscs, microcrustaceans, insects and other amphibian larvae and adults. Substantial vegetation cover is required to provide habitat for prey items, suitable egg laying substrate and refuge from predation. The provision of open, non-vegetated areas is desired for courtship displays. Gent & Gibson (2003) recommend 25% vegetation cover. Oldham (1994) found that ponds with 25-50% emergent vegetation and 50-75% submerged were more strongly associated with good GNC populations.

Pond clusters with a range of sizes and successional stages will potentially provide better habitat than single ponds, by buffering against catastrophic events such as pollution or introduction of fish (Cooke, 2001b). Ponds currently unsuitable for GCN may later become useful or may be used by invertebrate and other amphibian prey (Grayson, 1994; English Nature, 2001). Ponds are considered part of a cluster if they are within a 250 m radius and there are no barriers (English Nature, 2001).

The existence of connected 'newt friendly' terrestrial habitat is essential to allow dispersal between ponds within a cluster or between clusters, reducing the likelihood of extinction and in-breeding. Although difficult to define, it is generally accepted that features of 'newt friendly' habitat include rough grassland, woodland, wetlands, scrub and mature gardens (Laan & Verboom, 1990; Oldham, 1994; English Nature, 2001; Gent & Gibson, 2003). Arable land and pasture are not considered suitable (English Nature, 2001; Beebee, 1981) although it has been found that when there is a high pond density, GCN populations can be supported on such land (English Nature, 2004). The provision of excellent quality aquatic habitat may be able to compensate for substandard terrestrial habitat (Swan & Oldham, 1993).The habitat must provide suitable refugia, aestivation/ overwintering areas and foraging opportunities, with GCN consuming items such as earthworms, slugs and insects.

The minimum requirement is for good habitat extending 100 m beyond the ponds (English Nature, 2001), preferably continuing to the dispersal limit of 500 m (Oldham & Nicholson, 1986; Franklin, 1993; Baker & Halliday, 1999; Oldham & Humphries, 2000). Maximum migration distances, including significant contributions made by juvenile dispersal (Cushman, 2006) are described as 1000 m (Arntzen & Wallis, 1991), 1,100 m (MacGregor, 1995), 1,200m (Gent & Gibson, 2003) and 1,290 m (Kupfer, 1998). These distances determine the upper limit of pond/ cluster connectivity, assuming no dispersal barriers exist. When planning a translocation, consideration should be given to the potential carrying capacity of the site, to prevent the new population exceeding this. Although this can be difficult to ascertain, good quality habitat has been variously shown to be capable of supporting 250 adults per Ha (Langton, 1994), 200-400 adults per Ha (Foster, 1997) and 1000 adults per Ha in very good habitat (Latham et al., 1996).

The aim of this chapter is to investigate whether the newly created GNR provides good quality aquatic and terrestrial habitat, mitigating for the loss of the original ACA and to assess the potential for the GNR to support the long term survival of the translocated population of great crested newts.

4.3 Site Description

Gartcosh Industrial Site

Figure 4-1: Details the existing habitat and layout of the entire Gartcosh Industrial site in 1999. Map reproduced from Smith & Bates (2000).

The Gartcosh site has a history of Industrial usage stretching back to 1858 (Lanarkshire Development Agency, 1999). Referring to Fig. 4-1, the 86Ha site was predominantly derelict land (1) and open grassland (2) with areas of scrub and woodland (2a and 3). Anecdotal evidence from local residents suggests the newt population was in residence from at least 1972, possibly earlier (Archibald Laing *pers. comm.*). A survey of the site undertaken in 1998 found that there were 13 water bodies present, seven deemed significant for GCN use (ponds C to I).

The seven ponds and an area of terrestrial habitat approximately 10 Ha were designated the Amphibian Conservation Area (ACA) and surrounded by an amphibian proof wall in July 1998 (refer to Fig. 2-2). An additional eight ponds (New Ponds 1-8) were dug into the ACA. Sub-optimal ponds outside the ACA were destroyed over a period of two years to allow translocation of any captured amphibians into the ACA. For a full description of the Gartcosh site history, refer to Chapter 1. Ponds C, D, E & F are early successional stage, shallow ponds. Ponds G & I are late successional stage. Pond H is seasonal woodland. Of the new ponds dug, five were non seasonal and three were shallow to allow sporadic drying.

With the decision taken to include the ACA in the Gartcosh development plans, work was undertaken to create the Gartcosh Nature Reserve (GNR) and translocate the amphibian population to the new habitat. This consisted of three main zones: Bothlin Burn, Garnqueen Hill and Railway Junction. A small cluster of ponds was designed as a 'Stepping Stone' to aid movement between Bothlin Burn and Garnqueen Hill.

Bothlin Burn Zone

Figure 4-2: Bothlin Burn habitat creation works. Top image shows the original area that became Bothlin Burn and bottom image details the terrestrial habitat and pond creation work carried out (new ponds NP1-8). Map from Smith & Bates (2000). Scale 1:3000.

Bothlin Burn is 9.1 Ha in size, has eight ponds and includes 'newt friendly' woodland, hedgerow, grasslands and swamp. This should provide sufficient range and type of habitat, with good opportunities for overwintering spots in the woodland. Ten stone/ rubble hibernacula were added, with the position of each indicated on the map by a star.

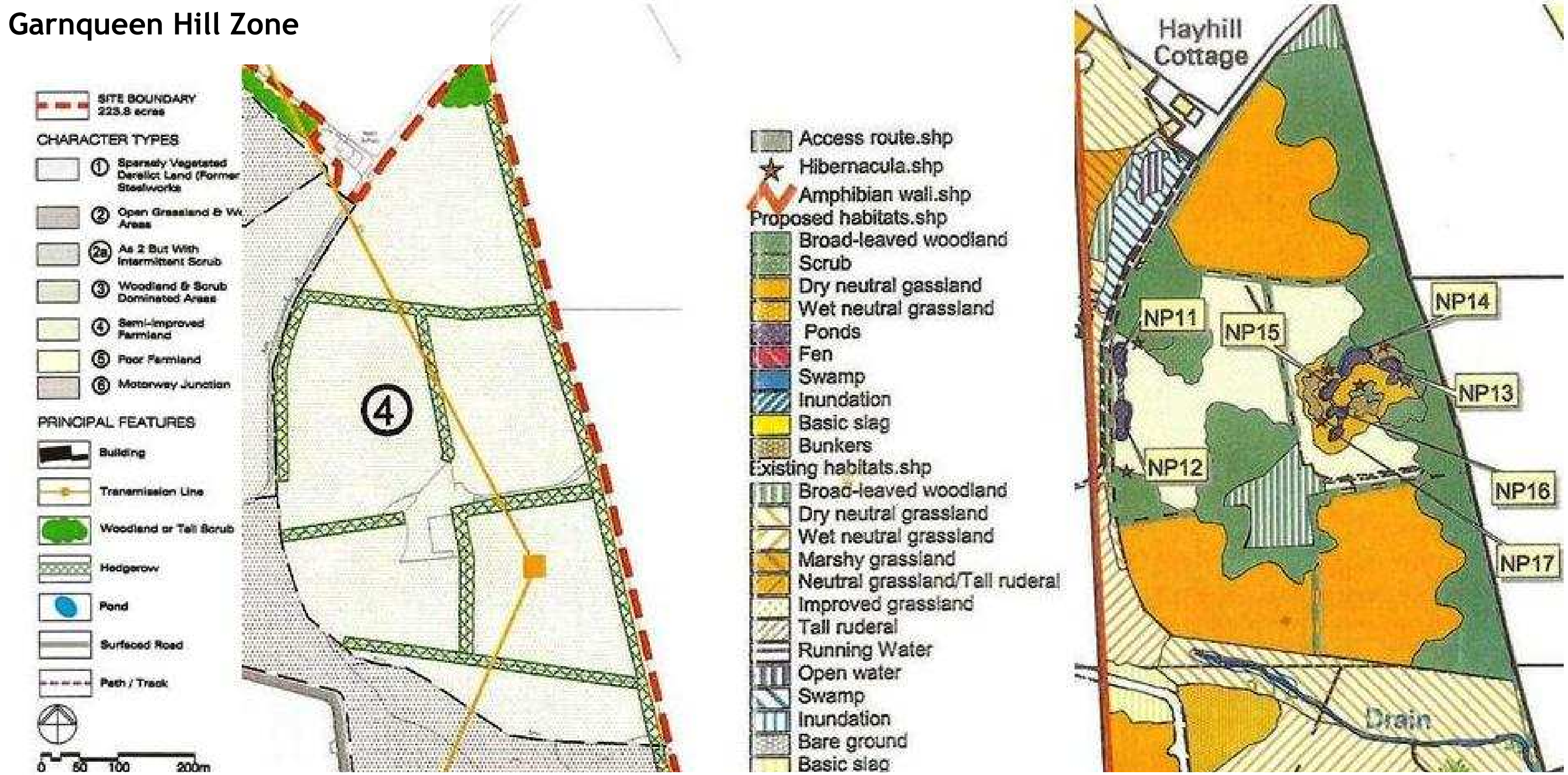


Figure 4-3: Garnqueen Hill habitat creation works. Left image shows the original area that became Garnqueen Hill and image on right hand side details the terrestrial habitat and pond creation work carried out. Map from Smith & Bates (2000).

Garnqueen Hill is the largest zone at 14.5 hectares and contains seven ponds. Five clustered at the top of the hill, two at the bottom. The area consisted mainly of farmland (grass) and required extensive work to diversify the habitat and improve suitability for GCN. Seven hibernacula were added.

Railway Junction

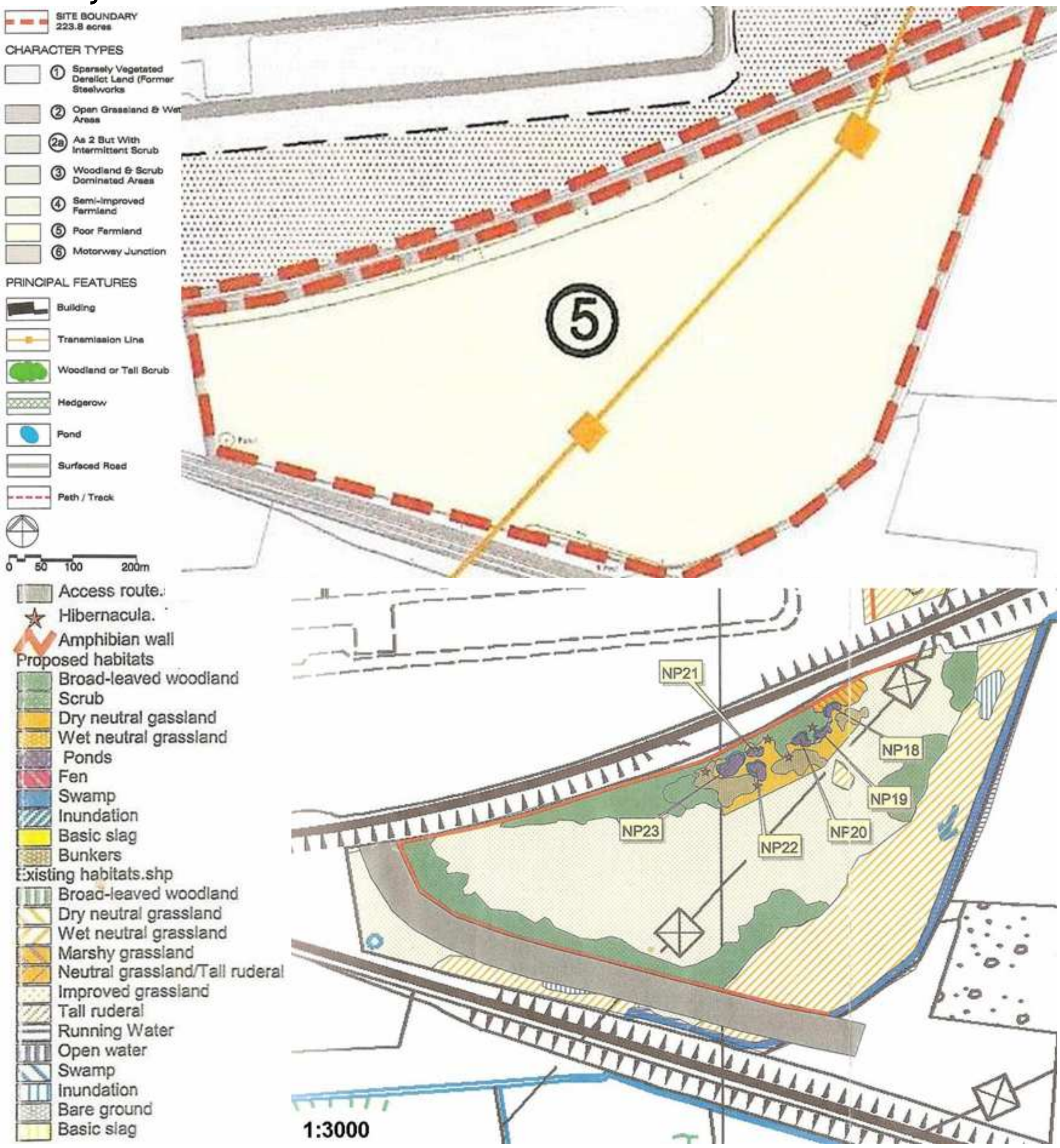


Figure 4-4: Railway Junction habitat creation works. Top image shows the original area that became Railway Junction and bottom image details the terrestrial habitat and pond creation work carried out. Map from Smith & Bates (2000). Scale 1:3000.

Railway Junction is the smallest zone at only 5.4 hectares and contains six ponds, two intended to dry periodically. The zone consisted predominantly of (5) ‘poor farmland’ (pasture), making it unsuitable for GCN. Considerable site management was required, including the creation of scrub and grassland. Five hibernacula were added to improve the availability of refuge. Barriers were present around all three sides (wall, railway tracks, pasture and flowing water).

North Lanarkshire

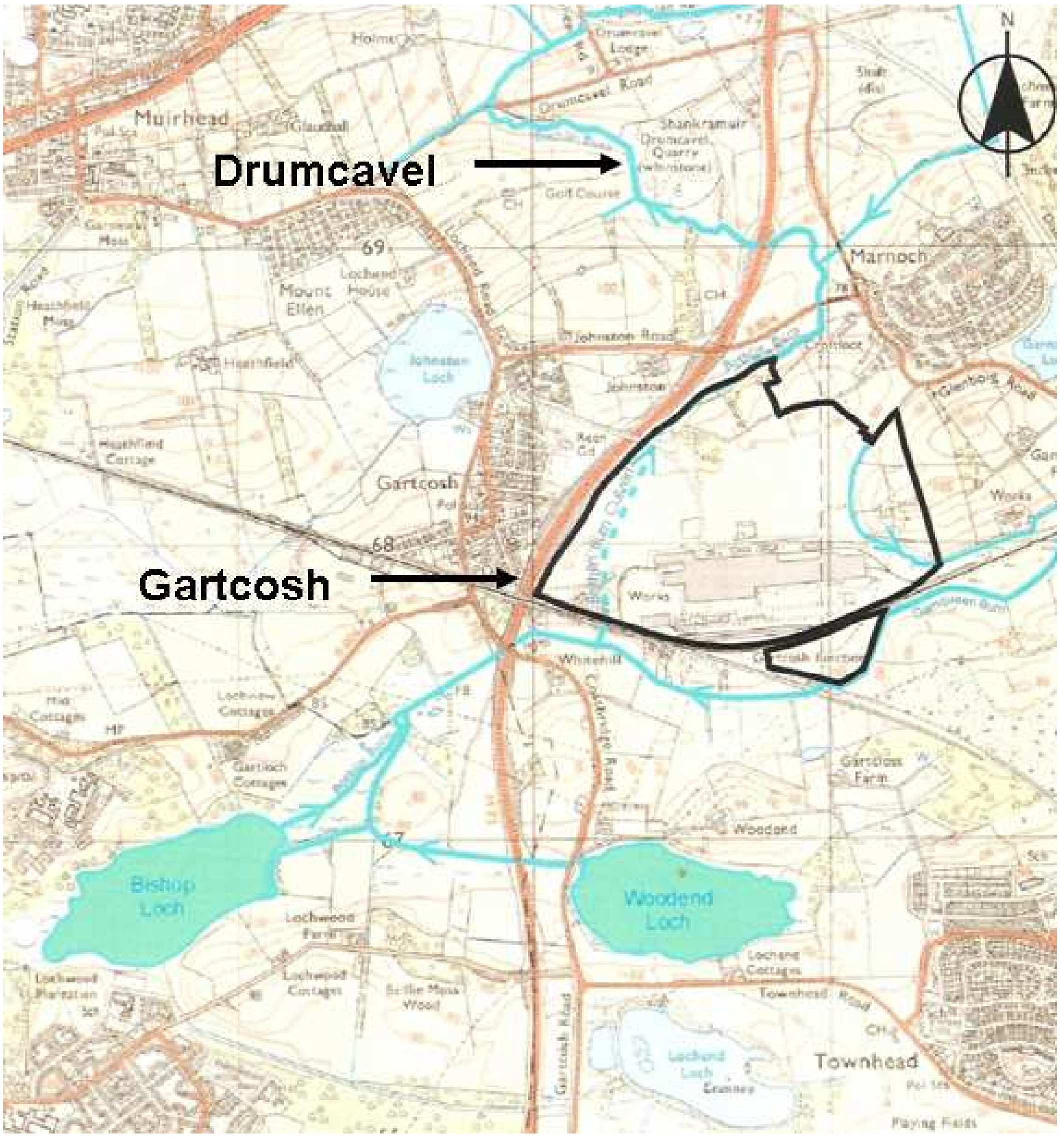


Figure 4-5: Shows the location of Gartcosh and surrounding water bodies. The other known population of GCN in the surrounding area is located at Drumcavel, highlighted near the top of the map. Bothlin Burn runs to the north, west and south, Garnqueen Hill Burn to the East. Scale 1:43,000.

There are a number of water bodies in the surrounding area although these are at least 1 km away, at the outer limits of GCN dispersal. There is one known GCN population (7 adults) approximately 1 km to the north of Gartcosh, in the Drumcavel Quarry (*pers. comm*. T. Kellett). The Gartcosh site is isolated on all sides by the M73 motorway, the flowing waters of Bothlin Burn and its tributaries, Garnqueen Hill Burn, suburban landscape, intensively managed farmland and railway lines. The fragmentation of the landscape means there is little or no possibility of emigration or immigration in the foreseeable future.

4.4 Methods

Aquatic and terrestrial habitat was surveyed during summer 2006 in the ACA before it was destroyed and in the GNR during 2006 and 2007. The habitat surveying work was intended to extend into 2008, but was discontinued due to extensive management work (by North Lanarkshire Council) in January 2008, where a mechanical digger was used to remove heavy growth of macrophytes from the GNR ponds. As two of the principal components of the survey methodology involved sampling macrophytes and invertebrates within the ponds, the on-site management work compromised the usefulness of comparative work in the 2008 field season.

4.4.1 Sampling

Ponds were surveyed for information on size, pond characteristics, macroinvertebrates, macrophytes and GCN adults and larvae. Information on terrestrial habitat areas was provided by Ironside Farrer, who undertook the habitat creation works, and HEL, responsible for extensive on-site surveying.

Size: Pond surface area was determined using a tape measure for both summer and maximum winter drawdown. A number of ponds were recorded as dry during the summer sampling period.

Pond characteristics: Temperature, pH and water conductivity were measured *in-situ* using hand-held meters (refer to Appendix 2). Shade, inflow/outflow and grazing were determined through visual surveying. Base geology was established from pond creation maps, described by Ironside Farrer.

Macroinvertebrates: Sampling occurred in 22 ponds across the ACA and GNR during 2006 and 10 ponds in 2007 (refer to Appendix 3). Sampling followed methodology outlined by Pond Action (Biggs et al., 1998). Pond mesohabitats were identified in accordance with macrophyte groupings and a standard three minute net in water time was divided equally among the number of mesohabitats present (e.g. floating vegetation, emergent *Juncus* sp stands). When a mesohabitat existed with patchy distribution, the sampling time allocated to that mesohabitat was further divided to allow sampling of the patches. A long handled net (0.2 x 0.25 m, mesh size 5 mm) was used, all amphibian larvae removed from the samples and invertebrates preserved in 80% ethanol. Invertebrates were identified in the laboratory to family level and abundance of each family counted.

Macrophytes: Species richness, percentage cover and biomass were sampled in 2006 and 2007 (refer to Appendix 2 and 4). This occurred later in the summer than the invertebrate sampling. As a result, ponds that held water allowing invertebrate sampling may be recorded as dry during the macrophyte sampling (pond area was measured at this time). Macrophyte species were sampled by walking around the perimeter, use of a grapnel and wading into deeper areas. Percentage cover was a visual estimate, described as percentage cover of floating, emergent, submerged and total vegetation cover. Biomass was sampled using a quadrat (0.25 m^2) for emergent and floating vegetation and a Lambourn sampler (0.05 m^2) for submerged vegetation. Vegetation was dried in an oven and described as grams dry weight per m^2.

GCN Adults and Larvae: Peak adult counts were carried out by HEL in the ACA from 1998 to 2003 and in the GNR from 2006 to 2009. GCN larval counts were sampled by this surveyor from 2006 to 2008. For sampling methodology, refer to Chapter 2.

4.4.2 Pond Quality: PSYM Analysis

The Predictive System for Multimetrics (PSYM) uses environmental data to predict which macroinvertebrate families and macrophyte species should be found within a pond and compares this with the existing communities as sampled, resulting in a water quality percentage, Index of Biological Integrity (IBI), which can be used to assess for environmental degradation (PSYM Manual, 2002). There are nine environmental predictors: grid reference, altitude, base geology, area, pH, shade, grazing, presence of inflow and percentage emergent plant cover. The IBI is summed from three plant metrics: number of submerged and emergent species, trophic ranking score (TRS), uncommon species index and three invertebrate metrics: average score per taxon (ASPT), number of Odonata and Megaloptera (OM) and number of Coleoptera (Col). Each metric is compared to a predicted score and represented on a scale from 0-3, with 0 meaning poor quality, 3 meaning good. All metrics were then summed to give a quality index, described as a percentage of the possible maximum score. Refer to Appendix 5 for a sample data sheet that would be completed by the surveyor and sent to Pond Conservation Trust (PCT formerly Pond Action).

This method was devised and tested for use in England and Wales. Upon discussion with PCT, it was agreed that this method could be applied to Scottish ponds with the following caveats; that the ponds were only compared with other ponds in the Gartcosh site, not nationally and that the overall IBI score was recalculated to omit the TRS. This was decided after PSYM analysis of a sample Gartcosh pond indicated that PSYM was over-predicting TRS due to the acidic nature of the ponds (*pers. comm.* P. Williams). Sampling methodology remains unaltered. Omission of TRS simply requires a re-scoring of the metrics provided by PCT, out of a possible 15 (5 metrics with a maximum score of 3) instead of the usual 18 (6 metrics with a maximum score each of 3). Refer to Appendix 6 for a sample of the results metrics provided by PCT to the surveyor, detailing the Scottish TRS amendment.

The relationship between IBI scores of the GNR ponds and both peak GCN adult and larval counts was explored using General Linear Modelling. The IBI percentages were arcsine-root transformed and residuals checked for normality. Adult and larvae data were not available for the ACA in 2006 due to the translocation and by 2007, the ponds were infilled.

4.4.3 Pond Diversity: TWINSPAN Analysis

TWINSPAN (Two-way Indicator Species Analysis) classifies a sample then uses this to classify species within the sample (Hill, 1979). In this case, samples were all ACA and GNR ponds and the species used to classify the ponds were macrophytes, as sampled in 2006. This analysis was not repeated in 2007 as the ACA ponds were no longer in existence. Analysis was undertaken using the programme WinTWINS v2.3 (Hill & Smilauer, 2005). Macrophytes were selected for the classification process due to the important role they play in determining community structure (Oertli et al., 2002) providing food, refuge, egg laying substrate and being influenced by pond characteristics (Stumpel & Van der Voet, 1998). Alternatively, the ponds could have been classified according to invertebrate families or amphibian species.

By classifying ponds into groups using TWINSPAN it was possible to determine which ponds were most similar to each other in terms of macrophyte communities. Using ANOVA, significant differences between groups in terms of temperature, pH, water conductivity and biomass of vegetation (emergent, submerged and floating) were explored and residuals checked for normality. GCN adult and larval peak counts were included (data collection described in Chapter 2) but only for the GNR ponds within the groupings, as no counts were available for the ACA due to the translocation occurring.

4.4.4 Habitat Suitability

The Habitat Suitability Index (HSI) evaluates the suitability of a habitat (terrestrial and aquatic) for great crested newt populations in accordance with the methodology outlined in Oldham et al. (2000). The determination of habitat quality is based on ten criteria: location, pond area, age of pond, water quality, perimeter shading, number of water fowl, presence of fish, pond count within a 1km radius, terrestrial habitat quality and percentage of macrophyte cover. For full description of methodology see Oldham et al. (2000).

An 'HSI Fenced' score was determined for each pond using the conditions that existed in the summer 2006. Amphibian proof perimeter fences fully surrounded each zone, acting as barriers and reducing the available terrestrial range. A second set of scores 'HSI Best Case' were calculated based on the best possible scenario of habitat design i.e. no fence barriers and ponds at maximum winter drawdown surface area. It should be noted that other barriers were still in existence around the site (e.g. roads) but these were outwith the control of site management. HSI scores were used to compare between the ACA and GNR and to explore the difference between existing conditions and the site optimum (i.e. Fenced versus Best Case). HSI scores of the GNR ponds were correlated with peak GCN adult and larval counts to determine if a relationship existed between HSI score and population size.

4.5 Results

4.5.1 Habitat Loss or Gain

The original Gartcosh site was approximately 86 Ha in size; a significant portion of this would have been available for use as amphibian foraging ground. The site contained 13 ponds, seven recorded as used by GCN. The ACA was formed from a small portion of the Gartcosh site, containing the six original ponds in which GCN has been recorded. When regarding a comparison between the ACA and GNR, consideration must be given to the knowledge that it was within the context of the larger, original Gartcosh site that the population of GCN had thrived. The ACA was in itself a mitigated site, with terrestrial habitat range reduced to 10 Ha, six original ponds and seven ponds newly constructed in 1999. As such, if comparing the GNR to the original Gartcosh site then the number of ponds had increased while available terrestrial habitat had decreased from 86 Ha to 29 Ha. Habitat loss or gain is described in Table 4-1.

	Original	ACA	GNR
Terrestrial Habitat (Ha)	86	10	29
Extent of Woodland/Scrub (Ha)		1	10
Carrying Capacity (250 adults/Ha)		2500	7250
No. of Ponds	13	13	24
No. of Ponds Retaining Water Summer 06		9	22
No. of ponds Retaining Water Winter 06		13	24
Summer 06 Pond Surface Area (m^2)		2144	3412
Winter 06 Pond Surface Area (m^2)		5890	4351
No. Pond Clusters	1	1	4

Table 4-1: Analysis of whether a net habitat loss or gain has been achieved with the creation of the GNR. 250 adults per Ha (Langton, 1994).

When comparing the ACA to the GNR, a terrestrial land area gain has been achieved with the creation of the GNR. However the GCN population cannot freely disperse throughout the 29 Ha as this has been divided into distinct pond clusters, surrounded by amphibian proof fencing. The positioning of the fences has reduced the terrestrial habitat range potentially available within each zone. Estimates of the terrestrial area enclosed within the fencing are BB (6.4 Ha), SS (1.7 Ha), GQH (8 Ha) and RJ (3.1 Ha). BB and SS combine to give a terrestrial habitat area available to amphibians of 8.1 Ha, 89% of the entire BB zone, GQH has 57% available and RJ also has 57%. The fencing was no longer fully intact in

RJ and SS by 2008 but remained in place within BB and GQH during the last time checked in June 2009. Limited migration may have been possible through small gates (2 in BB, 1 in GQH) or tunnelling under the fence. Observations of both adults and sub-adult stages suggested that GCN could not climb over the fencing.

There is a significant increase in the proportion of the newt friendly habitat (woodland or scrub) made available to the GCN, comprising of one-third of the GNR compared with only one-tenth of the ACA. The extensive improvements made to the terrestrial habitat within the GNR are detailed in Fig. 4-2 to 4-4. This proportion was again, slightly less in reality, compromised by the existence of the fencing. In BB for example, there are stands of mature woodland that would offer excellent refuge and hibernation spots that are excluded. The estimated carrying capacity of the ACA and GNR both greatly exceed that of the GCN population (based on carrying capacity of 250 GCN per Ha of good habitat: Langton, 1994 and a known translocated GCN population 1012 adults).

The numbers of ponds almost doubled in the GNR, and were more likely to retain water during the crucial aquatic larval developmental stage. Only 8% of ponds within the GNR dried during summertime (RJ5 and RJ6), compared with 31% in the ACA during 2006 (ACA6, ACA7, ACAD and ACAG). Subsequent sampling in the GNR during 2007 to 2009 showed that the two RJ ponds regularly dried out. During the summer, the overall pond surface area was greater in the GNR. The opposite was true during measurements taken of maximum winter drawdown. The number of pond clusters had increased from one to four.

Pond Surface Area	ACA	GNR
<100 m^2	1	10
100-300m^2	6	9
300-500 m^2	0	3
500-750 m^2	5	2
>750 m^2	1	0

Table 4-2: Categorises the number of ponds within a specified range of pond surface area, based on maximum winter drawdown as measured in 2006.

English Nature (2001) recommends a pond surface area of 100-300 m^2 for GCN. Gent & Gibson (2003) suggested that up to 500 m^2 could be suitable for all five amphibian species (optimum for GCN was 250 m^2). Swan & Oldham (1993) found optimum size to be between 500-750 m^2. While there is therefore debate over the preferred surface area, there is agreement in the literature that ponds below 100 m^2 or above 750 m^2 are less suitable. A total of ten GNR ponds fall below this minimum (Table 4-2), including all six ponds of RJ and all three ponds of SS. One ACA pond was below the minimum and one exceeded the maximum threshold. This means that 42% of GNR ponds do not meet the accepted criteria for surface area for GCN compared with 15% of ACA ponds.

4.5.2 Pond Quality: PSYM Analysis

Pond quality results using the PSYM methodology are shown in Table 4-3.

Pond	2006					2007				
	% IBI	PSYM	ASPT	OM	Coleo	% IBI	PSYM	ASPT	OM	Coleo
ACA2	67	moderate	3	3	2	x	x	x	x	x
ACA3	67	moderate	3	3	2	x	x	x	x	x
ACA4	53	moderate	3	3	1	x	x	x	x	x
ACA5	60	moderate	3	3	2	x	x	x	x	x
ACA7	80	good	3	3	3	x	x	x	x	x
ACA8	80	good	3	3	2	x	x	x	x	x
ACAE	67	moderate	3	3	2	x	x	x	x	x
ACAF	73	moderate	3	3	3	x	x	x	x	x
BB1	67	moderate	3	3	1	80	good	3	3	3
BB2	67	moderate	3	3	2	73	good	3	3	3
BB3	60	moderate	3	3	1	–	–	–	–	–
BB4	60	moderate	3	3	1	–	–	–	–	–
BB6	67	moderate	3	3	2	–	–	–	–	–
SS1	67	moderate	3	3	1	–	–	–	–	–
SS2	67	moderate	3	3	1	80	good	3	3	3
SS3	73	moderate	3	3	2	–	–	–	–	–
RJ1	73	moderate	3	3	2	80	good	3	3	3
RJ2	60	moderate	3	2	2	–	–	–	–	–
RJ3	80	good	3	3	2	–	–	–	–	–
GQH11	80	good	3	3	2	87	good	3	3	3
GQH13	73	moderate	3	3	1	87	good	3	3	3
GQH15	80	good	3	3	2	80	good	3	3	2

Table 4-3: PSYM Results. % IBI: Index of Biotic Integrity; ASPT: average score per taxon; OM: Odonata (dragonfly) and Megaloptera (alderfly); Coleo: Coleoptera (beetle). IBI >75%=Good, 51-75%= Moderate, 25-50%=Poor, <25%=V Poor). ASPT/OM/Coleo is described by a scale of 0-3; 0= V Poor, 1=Poor, 2=Moderate, 3=Good, reflecting the IBI scoring. An x indicates that the ponds were destroyed. A – Indicates that invertebrate sampling was not undertaken in 2007 in these ponds, therefore it was not possible to derive a PSYM value.

In 2006, 22 ponds were sampled for PSYM analysis (8 ACA ponds and 14 GNR, those labelled BB, SS, RJ and GQH). Only 23% were classified as 'good'; the remaining 77% were 'moderate'. ACA4 scored an IBI of 53%, close to the cut off for 'poor'. All moderate ponds scored a 1 or 2 for Coleoptera suggesting that improvements could be achieved by improving habitat suitability for invertebrates. In 2007, all seven ponds sampled were scored as ‘good’. Five of the ponds had improved from ‘moderate’, now scoring a 3 for Coleoptera.

4.5.3 Peak GCN Adult and Larval Numbers by Pond

Peak adult numbers for the ACA are shown in Table 4-4. Peak adult and larval counts for the GNR are shown in Table 4-5.

	GCN Peak Numbers (adults)					
Pond	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
ACA1	-	-	2	2	1	2
ACA2	-	-	0	4	3	4
ACA3	-	-	0	5	0	2
ACA4	-	-	5	5	1	3
ACA5	-	-	0	1	0	0
ACA6	-	0	5	6	2	2
ACA7	-	0	1	3	1	2
ACA8	-	0	1	0	1	1
ACAC	5	9	5	7	3	2
ACAD	2	2	3	12	13	8
ACAE	22	20	24	23	22	30
ACAF	1	2	1	0	0	0
ACAG	1	1	3	3	0	4
ACAH	0	0	0	0	0	0
ACAI	37	32	43	69	30	18
TOTAL	**68**	**66**	**93**	**140**	**77**	**78**

Table 4-4: Peak count of adult Great Crested Newts in the ACA as determined by torchlight surveying during 1998-2003 (Knowles et al. 2003). Original ponds (ACAC-I), new ponds (ACA1-8) dug in 1999.

Ponds I and E were of particular importance to GCN breeding adults in the ACA pond cluster. Ponds C and D were used moderately. Ponds F and G were of limited use and Pond H appeared to hold no value as a GCN breeding pond. The new ponds were dug in 1999, with ponds 6-8 ready in time to be included in sampling for that year. Within one year, three of the eight ponds were colonised by breeding GCN, albeit in low numbers. Use of the ponds remained low, notably 5 and 8.

POND	GCN Peak Adult				GCN Peak Larvae		
	2006	2007	2008	2009	2006	2007	2008
BB1	11	15	2	11	5	4	5
BB2	7	5	19	14	0	4	6
BB3	8	7	10	3	5	1	3
BB4	7	2	45	3	2	1	0
BB5	6	4	40	7	1	0	3
BB6	11	5	20	14	1	4	2
BB7	3	8	18	48	0	0	3
BB8	0	8	23	55	3	0	2
SS1	0	3	0	0	0	0	0
SS2	1	0	0	1	0	0	0
SS3	0	0	0	0	1	0	0
GQH11	0	6	3	0	1	0	1
GQH12	3	9	1	8	6	0	0
GQH13	5	2	11	16	6	2	0
GQH14	5	2	0	25	5	2	0
GQH15	2	4	0	12	1	5	0
GQH16	9	5	11	1	1	0	0
GQH17	1	0	15	15	0	2	0
RJ1	3	6	39	0	3	3	3
RJ2	3	5	26	9	0	1	22
RJ3	5	9	7	5	0	4	2
RJ4	3	0	5	0	1	7	25
RJ5	0	0	2	0	0	0	0
RJ6	3	1	2	2	0	0	0
TOTAL	**96**	**106**	**299**	**249**	**42**	**40**	**77**

Table 4-5: Peak adult and larval GCN counts in the GNR (male and female adults combined). Larval sampling was not undertaken during 2009.

No ponds stand out as being consistently used by large number of breeding adults over the four sampling years. In 2008, the four ponds of BB4, BB5, RJ1 and RJ2 supported 50% of the site total. RJ zone ponds contribution (81 adults equating to 27% of site total) is especially noteworthy due to the initial translocated population numbering only 56 to that zone. All four of the key ponds showed significant declines in use during 2009 while BB7 and BB8 showed considerable increases, supporting 41% of the site total. GQH14 and 15 showed a marked increase of use in 2009. SS1, SS2, SS3, RJ5 and RJ6 were unfavourable to breeding adults throughout the study.

Reflecting the adult findings, no ponds consistently recorded large numbers of GCN larvae over the three sampling years of 2006 to 2008. SS zone was particularly poor, with only one GCN recorded over the entire time. Numbers declined in GQH and by 2008, only one larva was recorded. Counts within RJ increased annually. By 2008, two RJ ponds, RJ2 and RJ4, accounted for 64% of the entire GNR larval count.

4.5.4 Relationship between IBI with GCN Adults and Larvae

A visual inspection of histograms of residuals shows that there were no gross deviations from normality. The relationship between the IBI score and both GCN adult and larvae counts are shown in Fig. 4-6.

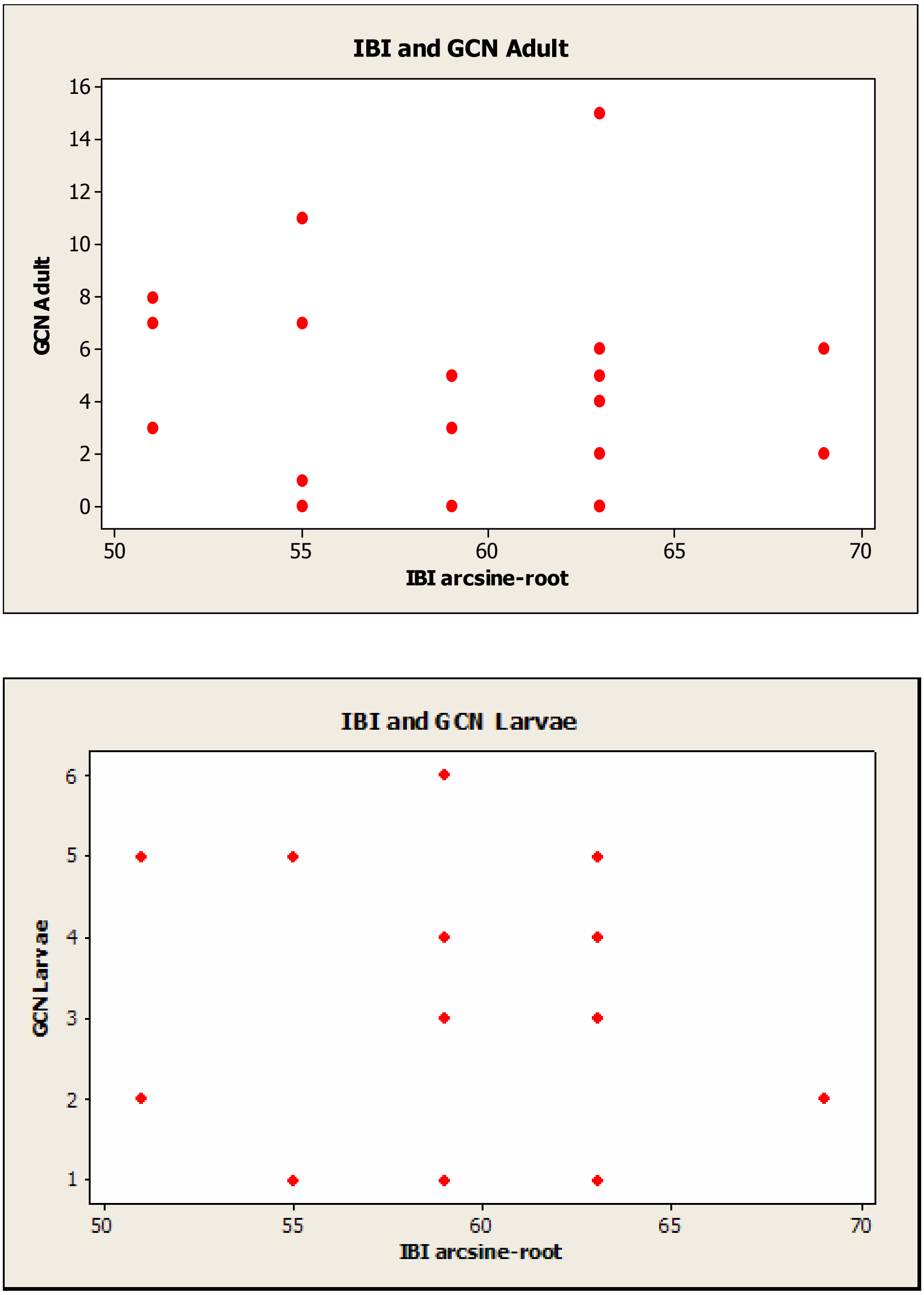


Figure 4-6: Index of Biotic Integrity (IBI) correlated with the a) peak GCN adult counts and b) peak GCN larval counts per pond.

A total of twenty-one GNR ponds were included in the IBI and GCN Adult sampling (n_{2006}= 14; n_{2007}= 7). The relationship between IBI and GCN adults was not significant (R^2=0.07, df= 20, p=0.878). A total of fourteen GNR ponds were included in the IBI and GCN Larval sampling (n_{2006}= 9; n_{2007}= 5). As the relationship being tested is for the suitability of a pond for larval development, ponds with a zero count for larvae were omitted as this is a measure of adult reproductive failure. Ponds that were not included were, from 2006, BB2, SS1, SS2, RJ3 and RJ3 and from 2007, SS2 and GQH11. The relationship between IBI and GCN larvae was not significant (R^2=0.06, df= 13, p=0.956).

4.5.5 Pond Diversity: TWINSPAN Analysis

Results of the TWINSPAN analysis of macrophytes sampled in 2006 are shown in Fig. 4-7, Table 4-6 and Table 4-7.

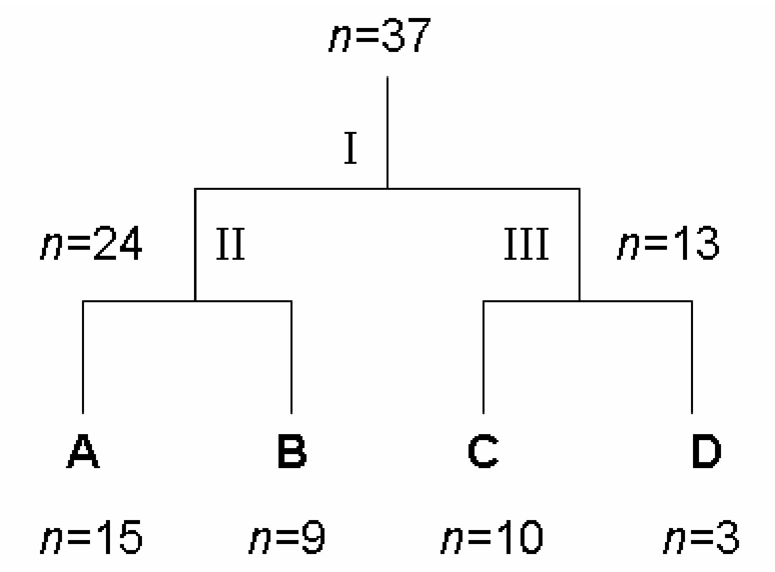


Figure 4-7: TWINSPAN hierarchical division of the ACA and GNR ponds (*n*=37) into four groups A to D.

Classification of the sample ponds is hierarchical, with ponds divided into categories based upon their macrophyte communities. Ponds with similar macrophyte communities will cluster together in a group. The ponds were divided into two groups at the first division (I) then further divided into two groups at second division (II) and two at the third division (III). Subdivision will continue until a selected group size is obtained as determined by *n* values.

A (n=15)	B (n=9)	C (n=10)	D (n=3)
ACA4	ACA2	BB5	GQH11
ACA5	ACA3	BB7	GQH15
ACA6	ACAE	BB8	GQH16
ACA7	ACAI	SS1	
ACA8	BB1	SS2	
ACAC	BB2	SS3	
ACAD	BB3	GQH12	
ACAF	BB4	GQH13	
ACAG	BB6	GQH14	
RJ1		GQH17	
RJ2			
RJ3			
RJ4			
RJ5			
RJ6			

Table 4-6: TWINSPAN analysis separated the 37 ponds of the ACA (n=13) and GNR (n=24) into four groups (A-D) to the third division as outlined in Fig. 4-7.

TWINSPAN provides an eigenvalue for each division, as a measure of the overlap between the groupings. Low eigenvalues (eigenvalues range from 0-1) would indicate there was considerable overlap between the group macrophyte communities. The eigenvalue of division II (group A and B) was 0.136; the eigenvalue of division III (group C and D) was 0.095. Differences between the group means were explored using ANOVA.

Groups	A		B		C		D	
No of Ponds	15		9		10		3	
Indicator Sp	*R. lingua*		*C. pendula* *J. acutiflorus* *E. angustifolium*		*E. palustre* *V. anagallis-aquatica*		no indic	
Smacro	16		16		19		20	
Temp	6.73^{a}	(0.16)	7.03^{ab}	(0.21)	7.45^{b}	(0.08)	7.33^{ab}	(0.19)
Cond	375^{a}	(54)	271^{ab}	(30)	155^{b}	(25)	103^{b}	(3)
pH	9.03^{a}	(0.13)	8.51^{bc}	(0.12)	8.38^{bc}	(0.14)	8.63^{abc}	(0.03)
Amax	226.27^{a}	(70.1)	493.22^{a}	(184)	192.20^{a}	(49.8)	162.00^{a}	(20.1)
Asummer	83.67^{a}	(39.8)	263.78^{b}	(57)	153.20^{ab}	(43.3)	131.67^{ab}	(12.8)
Bemer	594.00^{a}	(127)	656.93^{a}	(142)	479.16^{a}	(109)	518.27^{a}	(128)
Bfloat	66.25^{a}	(36.6)	160.40^{a}	(44.1)	148.84^{a}	(41)	105.33^{a}	(25.4)
Bsub	342.92^{a}	(163)	392.67^{a}	(81)	241.00^{a}	(58.8)	244.00^{a}	(141)

Table 4-7: Differences between TWINSPAN pond groupings. Number of ponds per TWINSPAN group, indicator species per group (if present) *Ranunculus lingua*, *Carex pendula, Juncus acutiflorus, Eriophorum angustifolium, Epilobium palustre, Veronica anagallis-aquatica,* Smacro: macrophyte species richness; mean environmental variables and biomass with standard errors in brackets; temp (ºC); Cond: conductivity (mS); Amax: maximum winter drawdown surface area m2; Asumm: surface area as present in summer 2006 m2;; Bemer: emergent biomass g dry weight m-2; Bfloat: floating biomass g dry weight m-2; Bsub: submerged biomass. Means sharing the same superscript letter are not significantly different (p>0.05, Tukey's test).

Significant differences (Table 4-7) are observed between sample pond group means in temp (p<0.05), conductivity (p<0.001), pH (p<0.001). There were no significant differences (p>0.05) in terms of Area maximum but there was a significant difference in Area summer between groups A and B (B>A). Although TWINSPAN showed significant differences between the make up of the macrophyte communities between pond samples, there was no significant difference (p>0.05) between emergent, submerged or floating biomass. All indicator species were emergents, so further investigation of emergent biomass was made. Groups A and B were closer in make up to each other than to the ponds in C and D. A two sampled t-test was performed to investigate possible significant differences between mean emergent biomass of groups A+B (n=24) and groups C+D (n=13). There was no significant difference (p>0.05).

Using the same TWINSPAN groups, peak GCN adult and larvae counts for GNR ponds only were compared, as the equivalent data were not available for 2006 in the ACA ponds (Table 4-8).

Groups	A		B		C		D	
No of Ponds	6		5		10		3	
GCN Adult	2.83^a	(0.65)	8.8^b	(0.92)	2.4^a	(0.73)	3.67^a	(2.72)
GCN Larvae	0.67^a	(0.5)	2.6^a	(1.03)	2.2^a	(0.81)	1^a	(0)

Table 4-8: Number of GNR only ponds per TWINSPAN classification group, mean peak breeding GCN adult and mean larvae numbers with standard errors in brackets. Means sharing the same superscript letter are not significantly different (P>0.05, Tukey's test).

There is a significant difference between the groups in terms of GCN peak adult counts (p=0.001) with group B having significantly higher adult counts, but no significant difference between the groups in terms of GCN peak larvae counts (p>0.05).The results should be treated with caution due to the low counts involved.

4.5.6 Habitat Suitability

Ponds	Best Case	Fenced	Ponds	Best Case	Fenced	Ponds	Best Case	Fenced
BB1	0.82	0.76	**GQH11**	0.80	0.74	**ACA2**	0.77	0.62
BB2	0.83	0.76	**GQH12**	0.78	0.64	**ACA3**	0.74	0.64
BB3	0.78	0.70	**GQH13**	0.81	0.74	**ACA4**	0.74	0.63
BB4	0.87	0.82	**GQH14**	0.86	0.79	**ACA5**	0.77	0.67
BB5	0.80	0.75	**GQH15**	0.82	0.75	**ACA6**	0.84	dry
BB6	0.82	0.77	**GQH16**	0.78	0.72	**ACA7**	0.72	dry
BB7	0.87	0.82	**GQH17**	0.82	0.77	**ACA8**	0.85	0.73
BB8	0.77	0.71	**RJ1**	0.69	0.59	**ACAC**	0.56	dry
SS1	0.64	0.35	**RJ2**	0.64	0.51	**ACAD**	0.84	dry
SS2	0.66	0.22	**RJ3**	0.63	0.49	**ACAE**	0.86	0.75
SS3	0.67	0.37	**RJ4**	0.62	0.52	**ACAF**	0.70	0.52
			RJ5	0.61	dry	**ACAG**	0.87	0.74
			RJ6	0.63	dry	**ACAI**	0.81	0.70

Table 4-9: HSI scores per pond. ‘Fenced’ refers to scores calculated as of summer 2006 with the perimeter fences intact, meaning a smaller terrestrial habitat and existence of barriers. ‘Best Case’ was recalculated to include maximum terrestrial habitat upon removal of the fences and maximum pond surface area.

Oldham et al. (2000) found the range of HSI scores that supported breeding populations of GCN was 0.43-0.96 with a median value of 0.66. In a straightforward comparison between the old ACA and new GNR sites, ACA Fenced (*n*=9, median 0.67, range 0.52-0.75) excluding 4 dry ponds had a lower median than GNR Fenced (*n*=22, median 0.73, range 0.22-0.82) and ACA Best Case (*n*=13, median 0.77, range 0.56-0.87) had a lower median than GNR Best Case (*n*=24, median 0.79, range 0.61-0.87). All four medians were higher than the median observed by Oldham et al. (2000), although ACA fenced was only marginally so.

The minimum range of All HSI Fenced (*n*=31, median 0.71, range 0.22-0.82) was much lower than HSI Best Case (*n*=37, median 0.78, range 0.56-0.87). Three HSI Fenced ponds (SS1, SS2 and SS3) fall below the minimum threshold of 0.43 HSI, as described by Oldham et al., (2000) and a further four were close (RJ2, RJ3, RJ4 and ACAF). All seven ponds fell comfortably within the range determined by Oldham et al. (2000) of 0.43 to 0.96, when considering HSI Best Case.

ACAC-I are the original ponds and ACA2-8 were created in 1999. A Mann-Whitney non-parametric test was performed to establish whether there was any difference between the HSI scores of the old versus new ponds in the ACA. No significant difference was found in either Fenced or Best Case. ACA Best Case/ Fenced were then compared with GNR Best Case/Fenced and no significant differences were found. A significant difference was found when comparing All Best Case versus All Fenced (U=791, *n*=68, p<0.0006) suggesting that the habitat has been designed well but the existence of fences was causing problems as was reduced pond surface area, although to a lesser extent as dry ponds were excluded from the survey.

Fig. 4-8 shows the relationships between HSI and peak GCN adult counts.

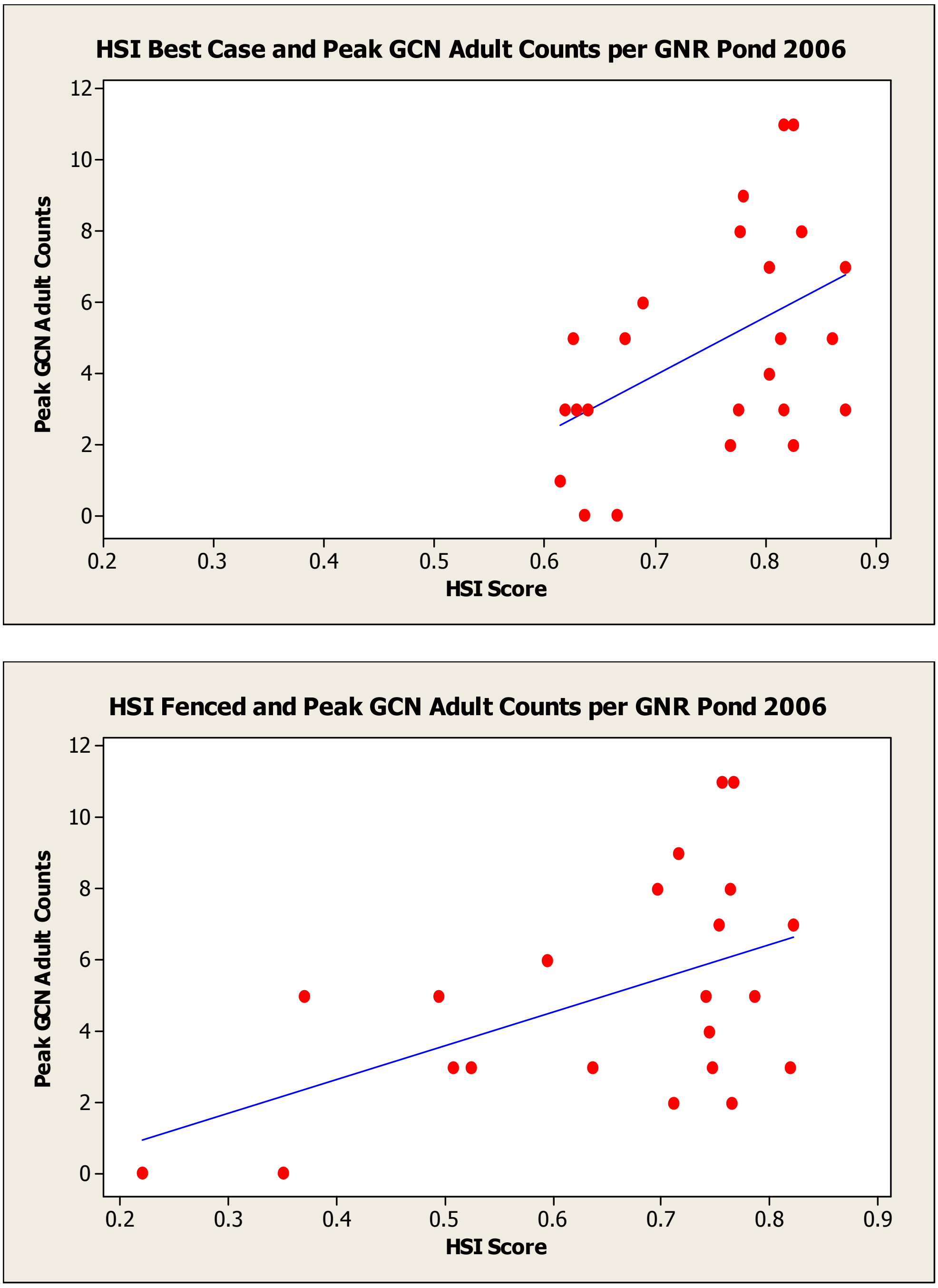
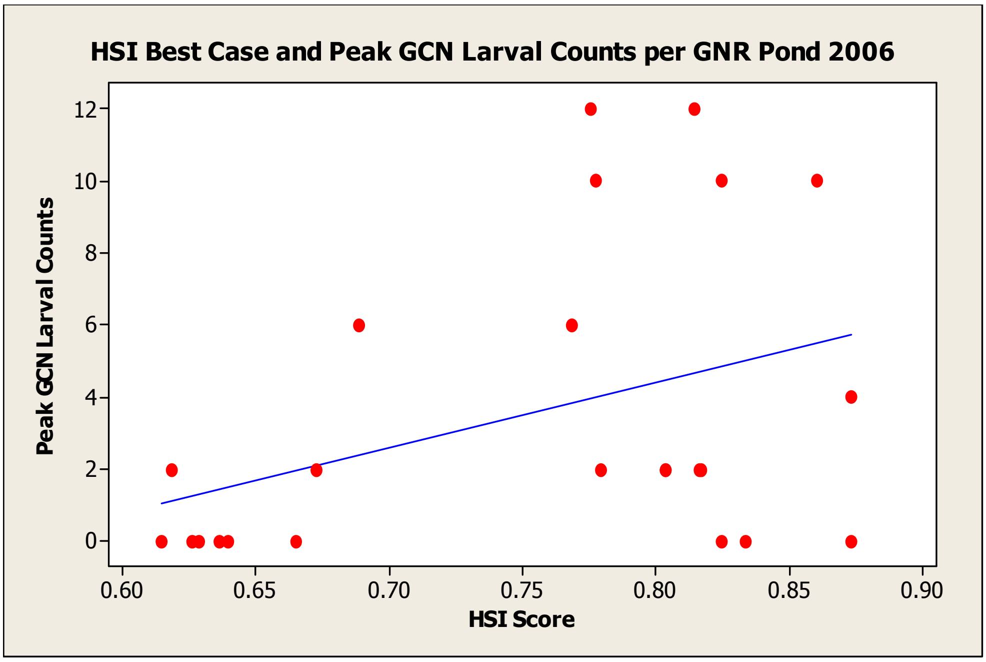


Figure 4-8: HSI scores correlated with the peak adult GCN count per pond (male and female) sampled in 2006 for a) Best Case and b) Fenced.

Using the table of critical values of Spearmans rank correlation coefficient, when *n*= 24, our calculated value for Best Case r^s=0.480, exceeds the critical tabulated value of 0.409 at p=0.05. The null hypothesis is rejected and there is a significant positive correlation between HSI Best Case scores and peak adult GCN counts.

For Fenced, *n*=22 and the calculated vale for Fenced r^s=0.408 does not exceed the critical tabulated value of 0.409 at p=0.05. The null hypothesis cannot be rejected and there is no significant correlation between HSI Fenced scores and peak adult GCN counts.

Fig. 4-9 shows the relationships between HSI and peak GCN larval counts.



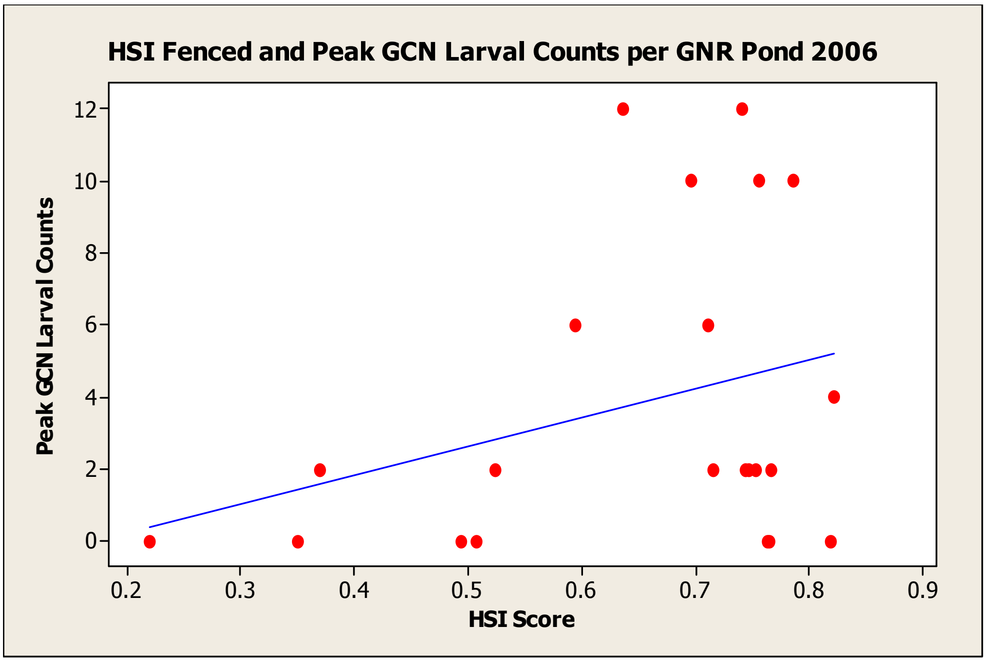


Figure 4-9: HSI scores correlated with the peak GCN larval count per pond sampled in 2006 for a) Best Case and b) Fenced.

Using the table of critical values of Spearmans rank correlation coefficient, when *n*= 24, our calculated value for Best Case r^s=0.321, does not exceed the critical tabulated value of 0.409 at p=0.05. The null hypothesis cannot be rejected and there is no evidence of a significant correlation between HSI Best Case scores and peak GCN larval counts.

For Fenced, *n*=22 and the calculated vale for Fenced r^s=0.174 does not exceed the critical tabulated value of 0.409 at p=0.05. The null hypothesis cannot be rejected and there is no evidence of a significant correlation between HSI Fenced scores and peak GCN larval counts.

Oldham et al., (2000) described the lower limit of HSI scores used by GCN to be 0.43. Two of the three ponds falling below this threshold (SS1 and SS2) did not contain any GCN adults or larvae as expected. SS3 fell below the threshold yet contained peak adult and larval GCN counts on a par or greater than 50% of the ponds with an HSI score above 0.43.

4.6 Discussion

In order to determine whether the mitigation works have produced suitable habitat in relation to what supported the population over decades in the original site and would continue to do so in the future, a range of strategies were employed. Translocation offers a real opportunity for conservation gain. At the very least, there should not be a net loss of habitat. In simple terms this was described by the quantity of habitat made available in the GNR in comparison to what had existed within the ACA. Further exploration was required to assess the quality of the habitat. PSYM methodology was applied to establish a measure of pond quality. TWINSPAN classification was used to determine the diversity of ponds within the cluster and whether there were similarities to the original ponds, known to be successful breeding GCN ponds. A combination of terrestrial and aquatic habitat indices was used to give an overall score, describing the suitability of this newly created habitat to support GCN populations. These approaches allowed for identification of ponds/ zones that were not faring as well and what aspects of the habitat could be improved upon.

Habitat Loss or Gain?

The ACA was created by ring-fencing a portion of land within the Gartcosh Industrial Site, significantly reducing the terrestrial range available for the GCN population. With the creation of the GNR, a terrestrial land area gain had been achieved with respect to the ACA but this was still only approximately one-third the size of the original site. The GCN population cannot freely disperse throughout the GNR as this has been divided into distinct pond clusters, surrounded by amphibian-proof fencing. The positioning of the fences has further reduced the terrestrial habitat that could have potentially been available within each zone. Comparing the ACA to the GNR, there was a significant increase in the proportion of good, newt-friendly habitat. This has again been compromised by the existence of the fencing. In BB area for example, there are stands of mature woodland offering excellent refuge and hibernation spots but these were excluded from the BB zone. The carrying capacity of the ACA and GNR both greatly exceed that of the current GCN population.

The numbers of ponds almost doubled in the GNR but there was a net loss in pond surface area when the maximum winter drawdown was considered. This highlighted a problem with pond creation works that was revealed through examination of individual pond surface areas. All ponds belonging to two zones (RJ and SS) were designed with a maximum surface area below that recommended by English Nature (2001) for GCN ponds (100 m^2).

During the summer, overall pond surface area was greater in the GNR as the new ponds were less prone to drying than the old. Ponds drying during the crucial aquatic larval developmental stage meant that larvae would be unable to complete metamorphosis. However, intermittent drying can be beneficial to the population as a whole in the long term by reducing the abundance of predators during subsequent years (Oldham, 1994). It was unclear whether drying was a regular occurrence in the ACA or caused by a particularly dry summer, as there were no records of pond permanence. Subsequent sampling of the GNR in 2007-2009 showed that the two ponds that dried during 2006 surveying (RJ5 and RJ6) regularly dry out. The number of pond clusters had increased from one to four. This will be beneficial if the population can freely migrate between the pond clusters. If migration remains restricted, then a large population has been divided into four smaller, distinct populations.

Pond Quality

Good quality ponds are important to the survival of the translocated GCN population, providing food, refuge and egg laying substrate. PSYM water quality analysis, Index of Biological Integrity (IBI), indicated that a significant number of the ponds were only of moderate quality and that it was the invertebrate family communities that were causing the lower scores. During mitigation, invertebrate dispersal can occur through active or passive translocation. Specific invertebrates may be targeted and moved or non-targeted species may be moved in water when transferring newts or attached to translocated macrophytes. It may take years for an invertebrate population to stabilise (Bullock, 1998). Further colonisation may occur by active or passive dispersal. Active dispersal affords a species the advantage of rapid colonisation of a new habitat and selection of favourable conditions (Rundle et al., 2002). Passive dispersal relies upon another species for transportation e.g. wading birds.

Improvements to the invertebrate communities were observed when a subset of the ponds was sampled in 2007. The two 'good' ponds from the 2006 survey remained 'good' and the five ''moderates' improved to 'good', reflecting improvements in the Coleoptera metric.

There was no significant relationship between IBI scores and counts of either GCN adult or larvae. It would be beneficial to compare this over a longer timeframe due to the fluctuating adult and larval counts observed between sampling years (refer to Tables 4-4 and 4-5). The ponds were recently created and had shown improvement in terms of IBI score in a short time.

GCN Counts

In the long term stable pond system of ACA, two ponds were clearly preferred by GCN over the others, pond E and I. There has been no such preferred pond consistently within the GNR so far. This may be a function of translocating a pond fidelic species, symptomatic of changing conditions within newly established ponds or perhaps due to the site management work affecting pond conditions/ choice in 2008 and 2009. Within the ACA system, natural colonisation of the new ponds was rapid, with five of the eight ponds utilised by GCN adults within the year. There were no data available on egg laying or larval production within these ponds to assess whether they were being utilised for breeding. New ponds with low vegetation cover can successfully support metamorph development if they contain egg laying substrate and few predators (Horton & Branscombe, 1994). Visual estimation of percentage macrophyte cover indicated that ponds E and I were in late successional stage and would have required mitigation work in the near future to prevent infilling, as would ponds F, G, and new pond 7. Natural succession is a significant threat to the survival of GCN populations (Swan & Oldham, 1991). The new ponds were dug in 1999 and were not vegetated to allow for increased site diversity. As older ponds became unsuitable due to natural succession, new ponds would provide an alternative habitat. Rapid encroachment of pond 7 suggests potential problems with new pond design.

Pond Diversity: TWINSPAN

TWINSPAN was used to classify all ACA and GNR ponds into four groups (A-D), according to the presence of macrophyte species. The group divisions are based on the similarity of ponds in terms of their macrophyte communities. A group may be characterised by an indicator species. Within this analysis, three of the four groups were described by an indicator species, all of which were emergents. The groupings provide useful information on the creation of new habitat, and whether they reflect design features of ponds known to support GCN populations, using the old ponds as the baseline. Conversely, knowing which groups of ponds are least similar allows an examination of key characteristics which may explain differences.

By looking to the ACA, judgements can be made as to what has proven successful within this particular site. ACA ponds have been grouped with GNR ponds across the first division, suggesting that a number of the new ponds have been created mirroring conditions within the old ponds. The two most successful ponds in the ACA, E and I, are most similar to five ponds within BB, all of which were reasonably successful in terms of GCN adult numbers. A range of ponds with diverse conditions could prove beneficial to the long term survival of the GCN population in the GNR (Cooke, 2001a). Looking to the whole site, this would appear to have been achieved, with the new GNR ponds divided across four groups. However, as the site was fragmented, diversity within individual zones increased in importance. All RJ ponds fell within the first group, suggesting limited diversity of conditions within that zone. The same is true for SS ponds. GQH ponds were split across two groups, BB across a division, indicating that there were differences in the macrophyte communities within the zones.

Scottish waters generally have low pH (SNH Trends, 2004). Gartcosh proved an exception to this, presumably due to the site’s industrial history. The ACA ponds’ pH range was 8.2-9.8 (mean 8.9) and the GRN ponds’ pH range was 7.5-9.8 (mean 8.6) as measured in 2006. Cooke & Frazer (1976) found a positive association between high pH ponds and GCN abundance. Oldham & Nicholson (1986) reported that GCN were associated with ponds exhibiting a pH range of 5.2-8.3 (mean 7.2). Only seven of the 37 ACA and GNR ponds sampled fell within that range, with all other ponds exceeding this, yet a healthy population of GCN were supported. There were no significant differences in mean pH found between A or D and B or C, but there where significant differences between A with B and C.

GCN sites in Scotland showed a conductivity range of 30-1000 μS, although the majority ranged between 70-450 μS (SNH, 1998). The ACA ponds ranged from 230-880 μS, GRN ponds 90-350 μS. Higher conductivity in the ACA was likely due to the presence of leachates. Lower conductivity in the GNR is a function of the lower base status of the clay substrate. Significant differences were found between mean conductivity of group A and both B and C.

Group B ponds accounted for significantly higher GCN adult counts than the other three groups, unsurprisingly, as this group contained both ACA E and I, the two most successful breeding ponds within the old site. There were no significant differences in larval counts between groups but numbers were very low.

Habitat Suitability

The median HSI values in the newly created site were greater than the values for the original ACA, with both scoring higher than the median HSI value for GCN ponds as described by Oldham et al. (2000). These were positive indicators for the suitability of the GNR to support GCN populations. The existence of the amphibian proof fencing has been proven to be reducing habitat suitability, putting three ponds below the HSI threshold and fragmenting the habitat. There was a significant correlation between population count and HSI scores, but only when considering the Best Case scenario. However, the newts were not free to choose from all ponds, being restricted to the ponds within the zone to which they were translocated, perhaps affecting subsequent pond selection. There was no relationship between HSI fenced scores and adults. Nor were any relationships observed when considering both best-case and fenced with larval counts, although, as with previous larval analysis, counts were very low.

Habitat survey work had been intended to continue into 2008. This was not deemed worthwhile following extensive on-site management work in early 2008, removing aquatic macrophyte growth. This was required only three years after pond creation. A second bout of vegetation clearance occurred two years later, in 2010. This suggests possible long-term management issues as rapid macrophyte growth can reduce the suitability of a pond for great crested newt use.

Fragmentation of the GNR due to the existence of barriers would appear to be a significant problem, severely limiting dispersal (Halley et al., 1996; Latham et al., 1996; Griffiths & Williams, 2000; Oldham et al., 2000). By 2009, the fences were down in places in SS and RJ but remained intact throughout both BB and GQH. The only source of migration from these sites was through two un-meshed gates positioned in Bothlin Burn and another in Garnqueen Hill during 2007.

Although RJ appears to be faring well, there is an inherent problem within the zone due to the decision to move only 56 adults to an area with minimal opportunities for immigration due to existence of temporary fencing and isolated position. Isolated amphibians living within a fragmented habitat are at an increased extinction risk (Hanski & Gilpin, 1997; Hitchings & Beebee, 1997; 1998). Inbred populations may be less capable of responding to a changing environment (MacGregor, 1995). Minimum viable breeding population size has been described as 40 females (Halley et al., 1996), 100 adults (Shaffer, 1981) or 100-200 adults (Griffiths & Williams, 2000; 2001). The Gartcosh study echoes the finding of Lewis et al. (2007) where 13 mitigation sites were isolated by development work. It is not enough to simply mitigate for lost habitat. Connectivity within an increasingly fragmented landscape must be considered.

There was general fragmentation of the surrounding area and continuous corridors such as Bothlin Burn were severed by the M73 motorway and culverting. As a result, Gartcosh does not form part of a wildlife corridor and can only be seen as a potential ‘stepping stone’ habitat in landscape ecology terms. The site has no links with other sites of ecological interest; these are all at least 1 km distant and isolated from Gartcosh site by the M73, suburban areas and intensively managed agricultural farmland of little or no ecological value. This includes Drumcavel Quarry, the only other known GCN population in the area, approximately 1 km north of Gartcosh site.

Conclusion

The newly created GNR is providing good quality aquatic and terrestrial habitat, mitigating for the loss of the original ACA although there has been an overall terrestrial habitat loss in comparison with the original site. Several measures were used to investigate this. Use of the PSYM methodology requires staff or volunteers trained in invertebrate/ macrophyte sampling and subsequent identification to the family/ species level. Although the IBI score was not related to GCN adult or larvae counts, it proved a very useful measure of pond quality and indicators for improvement. A good quality pond may become useful to amphibians in the future, through colonisation or providing a seed stock for invertebrate prey items to other ponds that are being utilised by amphibians. The methodology is currently designed for use in England and Wales, although this may be extended in the future.

HSI is an excellent tool for determining the suitability of habitat for GCN adult populations. Developers could use this as a tool for creating habitat, with the aim of designing a set of conditions capable of achieving a high HSI score. This method has the additional benefit of taking into account both aquatic and terrestrial habitat and does not require specialist knowledge or macrophyte or invertebrate identification. TWINSPAN provided useful insight into comparative success of pond creation using existing ponds known to support GCN populations as the standard. This is a useful research tool but perhaps of lesser practical use than the HSI methodology.

The potential for the GNR to support the long term survival of the translocated population of GCN will be improved with the removal of perimeter fences currently which, as of 2009, remained intact around both BB and GQH. However, the population will remain isolated within the wider human-dominated landscape. The nearest known GCN population in Drumcavel was subject to a translocation in 2005, with new ponds being built to mitigate for ponds lost due to ongoing work within the quarry and a total of seven adults and 96 juveniles captured and moved (Kellett & Bates, 2005). Guidelines promote the siting of new ponds within close proximity to the original ponds where possible (English Nature, 2001). This may not be the best option on a metapopulation level. Perhaps translocation of the Drumcavel population to a new site across the motorway barrier, allowing potential exchange with the Gartcosh population would have offered a better long-term solution for the viability of both populations. Planning and implementing measures to improve connectivity of GCN populations within North Lanarkshire and beyond will be crucial to long term survival.

5 Terrestrial Distribution Behaviour in a Translocated Population of Great Crested Newts (*Triturus cristatus),* Smooth Newts *(Lissotriton vulgaris)* and Palmate Newts *(Lissotriton helveticus)*

5.1 Abstract

The dispersal patterns of translocated populations of great crested, smooth and palmate newts (*Triturus cristatus*, *Lissotriton vulgaris* and *Lissotriton helveticus)* were monitored over a period of three years at two sites within the newly created Gartcosh Nature Reserve in North Lanarkshire. Circular statistics were used to establish preferred migration direction of adults and juveniles. Both lifestages of smooth and palmates displayed a strong directional bias towards the original donor ponds. This bias did not appear to diminish in subsequent years, post translocation. Great crested newt juveniles orientated towards a stand of woodlands in the opposite direction from the donor ponds. There was a relationship between direction choice of the lifestages of smooth and palmate newts. Smooth and palmate juveniles showed a significant preference to migrate during the daytime. Peak juvenile counts declined over successive years. The sampling methodology provided a cheap, resource-light means of surveying dispersal preference and metamorph output, a difficult lifestage to survey.

5.2 Introduction

Adult *Triturus cristatus* (great crested), *Lissotriton vulgaris* (smooth) and *Lissotriton helveticus* (palmate) newts have an aquatic and terrestrial phase, spending up to five months in breeding ponds during spring/summer before dispersing through the terrestrial habitat. Upon successful completion of metamorphosis, juvenile newts emerge from water bodies onto land. Both lifestages utilise terrestrial habitat for feeding, location of overwintering refuge and migration from the original site. The ability to disperse and colonise new ponds remains essential to the long term survival of these species but has become increasingly challenging within fragmented landscapes (Halley et al., 1996; Latham et al.,1996; Hanski & Gilpin, 1997; Hitchings & Beebee, 1997; 1998; Griffiths & Williams, 2000; Oldham et al., 2000).

A directional bias has been observed in GCN (Franklin, 1993; Jehle & Arntzen, 2000; English Nature, 2004) towards woods, scrub and other preferred habitat (MacGregor, 1995; Jehle, 2000; Jehle & Arntzen, 2000). An understanding of dispersal direction choice could prove useful to inform the planning of wildlife corridors and identification of important habitat to support migration and the design of nature reserves.

A number of mechanisms have been suggested as to how newts determine direction of migration routes. These include olfactory cues such as chemical signalling from other newts or pond odour, celestial compass, magnetic fields or visual landmarks (Joly & Miaud, 1993; Hayward et al., 2000; Joly et al., 2001; Malmgren et al., 2007). Translocation may have a detrimental effect on survival rates of a newt population by disrupting these cues and reducing their ability to safely negotiate the new terrestrial environment.

This chapter focuses on the direction of migration patterns by adults and juveniles of three species of newts (GCN, smooth and palmate) upon leaving the aquatic habitat and annual changes in direction travelled as the translocated population has become accustomed to the new surroundings and orientation cues. Hayward et al. (2000) found that GCN juveniles followed adults from ponds. A conflicting story emerged from work by Malmgren (2002) on GCN and smooth newts, with juveniles travelling independently of adult routes. Diurnal versus nocturnal timing of migrational activity was investigated as was the effectiveness of barrier fences in combination with terrestrial vegetation searches as a resource-light survey method for counts of amphibians in the terrestrial habitat.

5.3 Methods

The Gartcosh Nature Reserve (GNR) consists of four pond clusters, each isolated from the other due to the existence of an amphibian-proof perimeter. The Bothlin Burn fence measured 280 m (Fig. 5-1). Railway Junction perimeter measured 367 m and consisted of fencing (210 m) and amphibian proof wall (157m) (Fig. 5-2). Garnqueen Hill was not included in the survey due to the inaccessibility of large sections of the fencing. Stepping Stone was not included due to very low number of amphibian adult’s present and subsequent low breeding effort. Perimeters were searched in ten metre transect bands, recording all amphibians observed attempting to climb the fence/wall or located in the vegetation immediately beside were counted per ten metre transect bands (i.e. 28 sections in BB, 37 sections in RJ). Surveying began in BB in 2006 and RJ in 2007, occurring during the autumn months.

5.3.1 Peak Count

BB was surveyed between 2006 and 2008 (*n=18 surveys*). RJ was surveyed between 2007 and 2008 (*n=14 surveys*). Peak counts of each lifestage were recorded to give an indication of minimum output. Peak counts were used to give an indication of minimum output of juveniles and annual fluctuations.

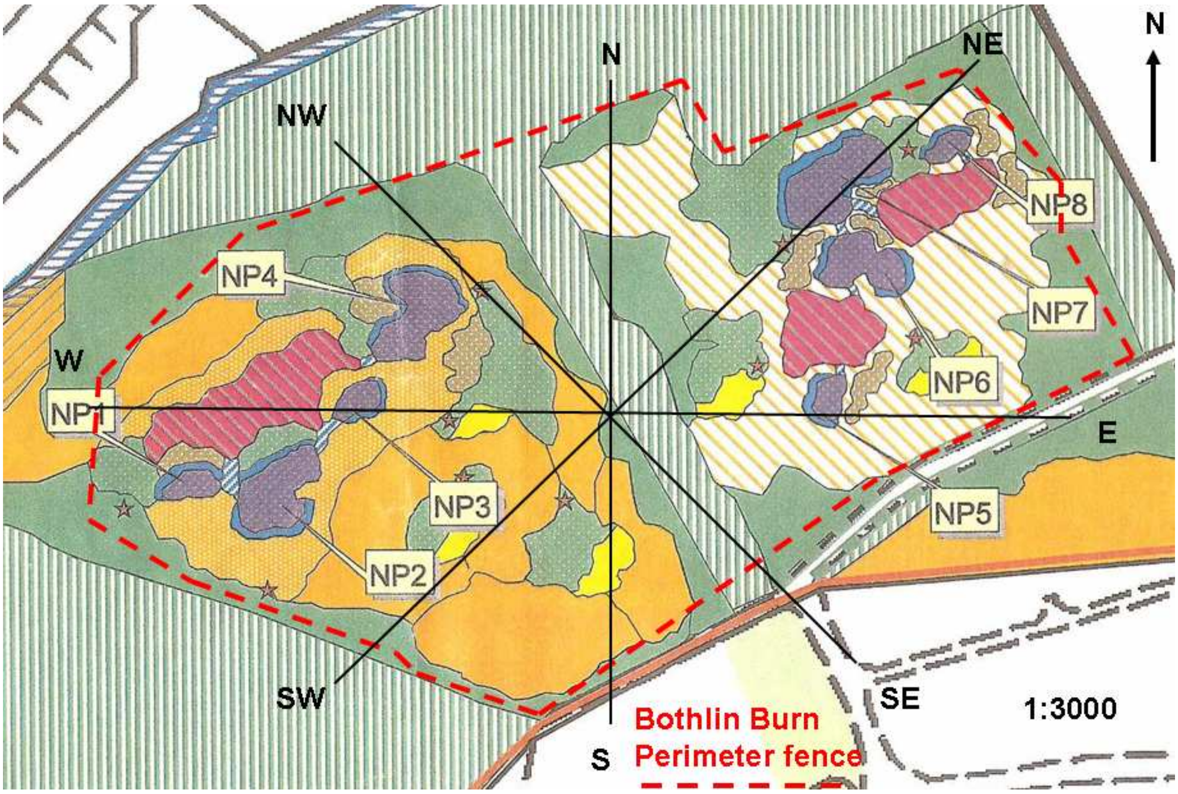


Figure 5-1: Amphibian-proof fencing surrounding Bothlin Burn shown in dashed red line. Compass bearings over-laid on the map in solid black line, demarking the eight groupings and transect direction used in dispersal analyses.

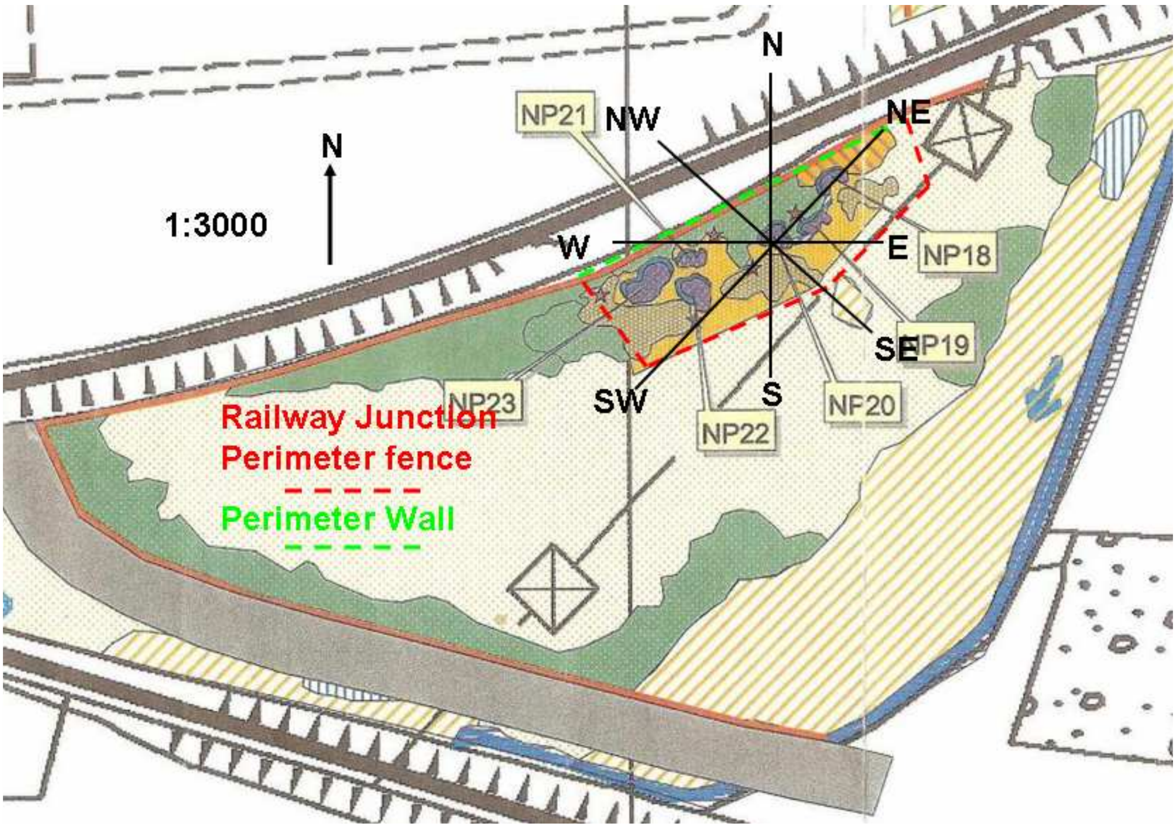


Figure 5-2: Amphibian-proof perimeter surrounding Railway Junction. The fencing is shown in dashed red line, the wall shown in dashed green line.

5.3.2 Day versus Night

Day and night counts were compared to explore differences in timing of the movement between the species and lifestages of each species. The zone perimeters were surveyed twice per day and took approximately two hours; night time surveying commenced at approximately 10pm; day time at 1pm. Data were pooled from BB and RJ during 2007 and 2008 (n=9; 4 BB, 5 RJ).

5.3.3 Dispersal

Between-year migration patterns could only be examined for smooth and palmate juveniles (annual counts were too few for great crested juveniles and all three adult species). Counts were then pooled across years, allowing and examination of migration patterns in both adults and juveniles of all three species. Data from BB 2006 to 2008 were used (n=13; 4 in 2006, 6 in 2007, 3 in 2008). By 2008 sections of fencing in RJ had become degraded, allowing exit points for amphibians. RJ was therefore excluded from between-year and pooled distribution analyses. Preferred direction was plotted for smooth and palmate juveniles for the 2007 data set.

Amphibians were able to disperse in any direction throughout a zone. Circular statistics (Batschelet, 1981; Zar, 1999) were used to analyse migration patterns. The assumption was that the individuals travelled in a straight line from their chosen pond exit point in their intended direction, eventually meeting the fence/ wall barrier. Observations of a considerable number of the amphibians trying repeatedly to climb over the barriers suggested this was a reasonable assumption, although there would very likely be a channelling effect of the fence, with an amphibian choosing to turn left or right once reaching an impediment to their forward movement.

Transects were grouped into 45° angular orientations based on compass bearings (see Fig. 5-1). The compass bearing used in analyses was the midpoint of each group i.e. the transects running from North to North East were grouped under the middle bearing of North-North East (22.5°). Sample distribution was tested for normality (unimodal distribution) by graphing circular histograms and visually checking. Rayleigh’s test was used if unimodal distribution was observed. The null hypothesis for Rayleigh's was that the population was uniformly distributed. The alternative hypothesis was that there was evidence of a preferred direction. Non-normal samples (bimodal/ multimodal distribution) were analysed using a Chi-squared test. Oriana version 3 software was used to graph and calculate the circular statistics (Kovach, 2009). As the data were grouped, a correction factor, as provided by Batschelet (1981) must be applied to the calculated mean vector length (r) as calculated using Oriana, to give corrected mean vector length (r_c). For groupings k=8, λ=45°, the correction factor is c=1.0262 (Batschelet, 1981). To compare between years and between adults and juveniles, multi-sample Chi-squared circular statistics were used. The null hypothesis was that the samples showed uniform distribution. If the null was rejected then the samples differ from each other, but this test does not specify which parameters differ. Variation in mean angle (μ), corrected vector length (r_c) and dispersion (1- r_c) were then compared. Two age classes were used in analyses, male and female counts combined as 'adult'; young-of-the-year and sub-adults combined as 'juveniles'.

As the fence was not set out in a circle (see Fig. 5-1) each 45° section had different fence lengths varying from 20 to 50 metres, depending upon how close the fence was to the centre of the zone. This resulted in the potentially confounding effect of different sampling effort. To test for possible effects of fence length on distribution, tests were rerun on the three juvenile species, corrected for fence length by standardising each 45° section to a mean count of newts per ten metre transect.

5.4 Results

5.4.1 Peak Counts

	GCN		Smooth		Palmate	
	adult	**juv**	**adult**	**juv**	**adult**	**juv**
BB 2006 Peak	1	39	7	307	11	274
BB 2007 Peak	2	3	1	48	10	69
BB 2008 Peak	0	2	4	23	4	33

Table 5-1: Peak adult and juvenile counts of the three amphibian species, as sampled from the perimeter fence surrounding BB.

In BB, all juvenile peak counts declined over succeeding years. Adult peak counts declined from 2006 to 2008 but results must be interpreted with caution due to small overall counts (Table 5-1).

	GCN		Smooth		Palmate	
	adult	juv	adult	juv	adult	juv
RJ 2007 Peak	1	1	1	51	9	97
RJ 2008 Peak	1	3	2	12	6	5

Table 5-2: Peak adult and juvenile counts of the three amphibian species, as sampled from the perimeter fence surrounding RJ.

In RJ, peak counts of smooth and palmate juveniles and palmate adults declined by 2008 (Table 5-2). GCN juveniles increased although again should be interpreted with caution due to low counts.

5.4.2 Day versus Night

	GCN		Smooth		Palmate	
	adult	juv	adult	juv	adult	juv
day	1	8	4	96**	8	124*
night	0	14	8	40	43	67

Table 5-3: Summed counts of each amphibian species per Day versus Night sampling event (n= 9 days/nights) from BB (n=4) and RJ (n=5) during 2007 and 2008. *(p<0.05), **(p<0.001).

A pair-wise t test was run to compare day versus night for each species and lifestage, with the exception of GCN adults as counts were too low (Table 5-3). Higher juvenile GCN numbers were observed at night, but this was not a statistically significant result ($t=1.63$, $df=8$, $p>0.05$). Adults of both the small-bodied newt species had higher night counts, but these results were not significant different; smooth adult ($t=1.08$, $df=8$, $p>0.05$) and palmate adult ($t=1.89$, $df=8$, $p>0.05$). Significantly higher counts were observed during the day compared with night for smooth juvenile ($t=5.00$, $df=8$, $p=0.001$) and palmate juvenile ($t=2.69$, $df=8$, $p<0.05$).

5.4.3 Dispersal

Dispersal throughout the new GRN habitat and intended direction of travel was explored in relation to habitat within and outwith the GNR (Fig. 5-3).

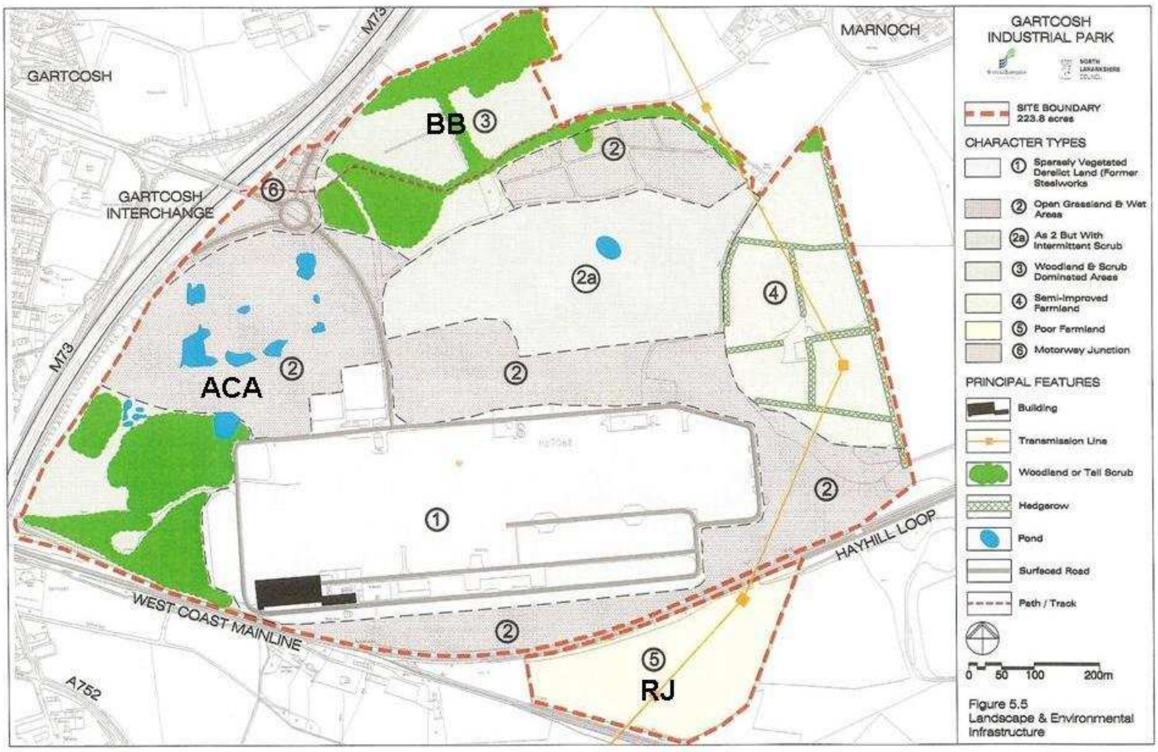


Figure 5-3: Gartcosh Industrial Site, detailing the original donor site- Amphibian Conservation Area (ACA) and the two zones of the Gartcosh Nature Reserve (GNR), indicating Bothlin Burn (BB) and Railway Junction (RJ). Map courtesy of Ironside Farrer.

Referring to Figure 5.1 the areas to the north and southwest of BB are woodland/ scrub but sit outwith the fenced boundary. A thin strip of woodland is found on the south and southeast sections across a path, also outwith the boundary. Migration patterns described by the following circular histograms indicate the directions within this landscape that the newts were attempting to travel (Fig. 5-4 to 5-6).

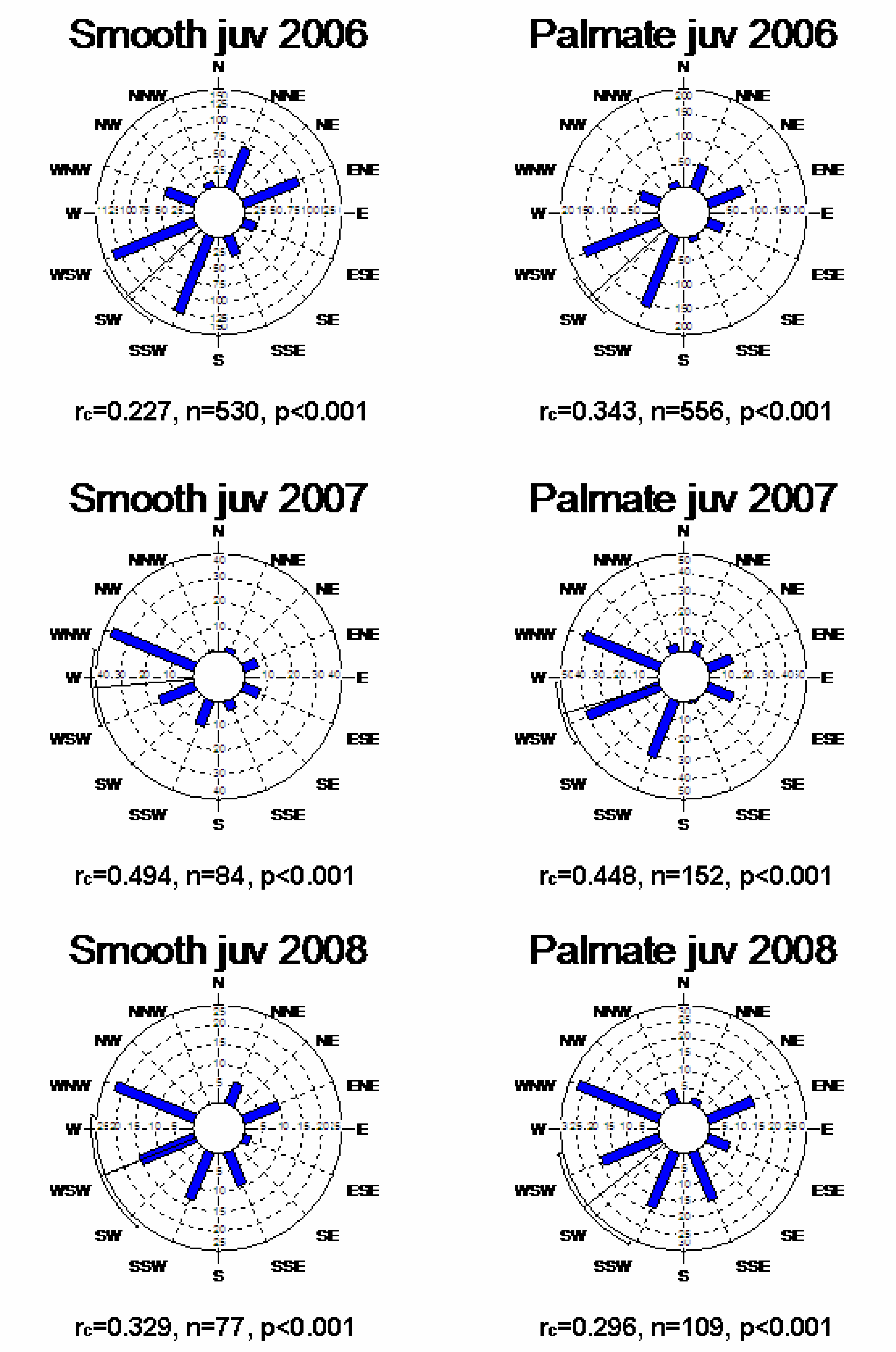


Figure 5-4: Circular histograms of juvenile migration patterns of smooth and palmate newts in Bothlin Burn during the sampling period of 2006 to 2008. The black line radius connected to the arc outside the histogram indicates the mean angle (μ) with 95% confidence limits. Each histogram bar represents the number of juveniles moving in that direction. Sample size (n), corrected mean vector length (rc) and level of significance are shown.

For smooth juveniles, direction travelled differed significantly between 2006 to 2007 (X_2=83.397, df=7, p<0.001) and 2006 to 2008 (X_2=31.262, df=7, p<0.001) but not between 2007 to 2008 (X_2=31.262, df=7, p>0.05). Variation was observed among the parameters of mean angle (μ_{2006}= 227.6°, μ_{2007}= 265°, μ_{2008}= 247.9°), corrected mean vector length (r_c) as shown in Fig 5-4 and in inverse dispersion (1- r_c). When preferred direction travelled was considered, although close, there was no overlap of confidence limits between 2006 and 2007. There was considerable overlap between the confidence limits of 2006 and 2008.

For palmate juveniles, direction travelled differed significantly between all three sampling years: 2006 to 2007 (X_2=50.499, df =7, p<0.001), 2007 to 2008 (X_2=25.504, df=7, p<0.001) and 2006 to 2008 (X_2=74.334, df=7, p<0.001). Variation was observed among the parameters of mean angle (μ_{2006}= 228.5°, μ_{2007}= 252.9°, μ_{2008}= 231.9°), corrected mean vector length (r_c) as shown in the histograms above and its inverse dispersion (1- r_c). When preferred direction travelled was considered, confidence limits overlapped for all sampling years (only a slight overlap for 2006 to 2007).

Both species of juveniles showed a preference for migrating between west-northwest and south-southwest. This takes them in the direction of the original ACA ponds (Fig. 5-3).

Although the RJ site was excluded from the between-year directional analyses due to gaps in the perimeter fence during 2008, an interesting observation was made when plotting the preferred direction travelled by smooth and palmate juveniles in RJ during 2007 (Fig. 5-8). Juveniles showed a directional preference between west-northwest and north-northeast, moving away from the wooded areas around the south of RJ and towards the original ACA ponds (Fig. 5-5).

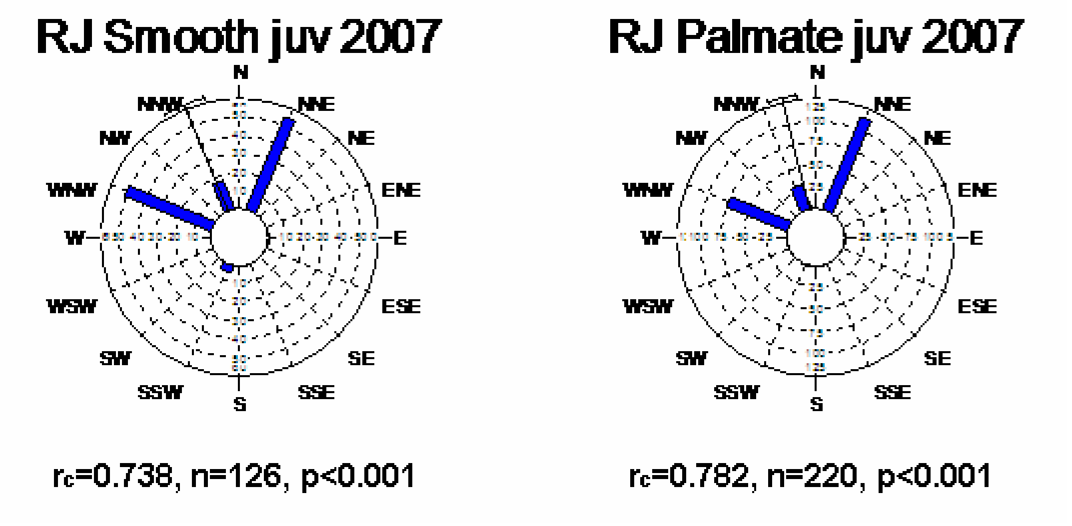


Figure 5-5: Circular histograms of juvenile migration patterns of smooth and palmate newts in Railway Junction during 2007. The black line radius connected to the arc outside the histogram indicates the mean angle (μ) with 95% confidence limits. Each histogram bar represents the number of juveniles moving in that direction. Sample size (n), corrected mean vector length (rc) and level of significance are shown.

It was not possible to compare directions travelled by GCN adult with juveniles due to low adult counts (Fig. 5-5). Juvenile GCN (BB) showed a mean preferred direction to the north-west. A multi-sampled Chi-squared test was performed to test the null hypothesis that there was no significant difference between the migration patterns of smooth and palmate adults with juveniles from BB.

The null hypothesis was rejected for both the Smooth adult versus juveniles (X_2=14.51, df=7, p=0.043) and the Palmate adult versus juveniles (X_2=17.967, df=7, p=0.012). There was a significant but unspecified difference in the distribution of the two lifestages. Variation was observed among the parameters of mean angle smooth: (μ_{adult}=259.3°, μ_{juv}=238.7°); palmate (μ_{adult}=245.3°, μ_{juv}=235.1°), corrected mean vector length (r_c) as shown in Fig. 5-6 and in inverse dispersion (1- r_c). For both species there was overlap in the 95% confidence limits of the mean directions, with adults and juveniles of both species moving in a preferred west-southwest direction.

Figure 5-6a)

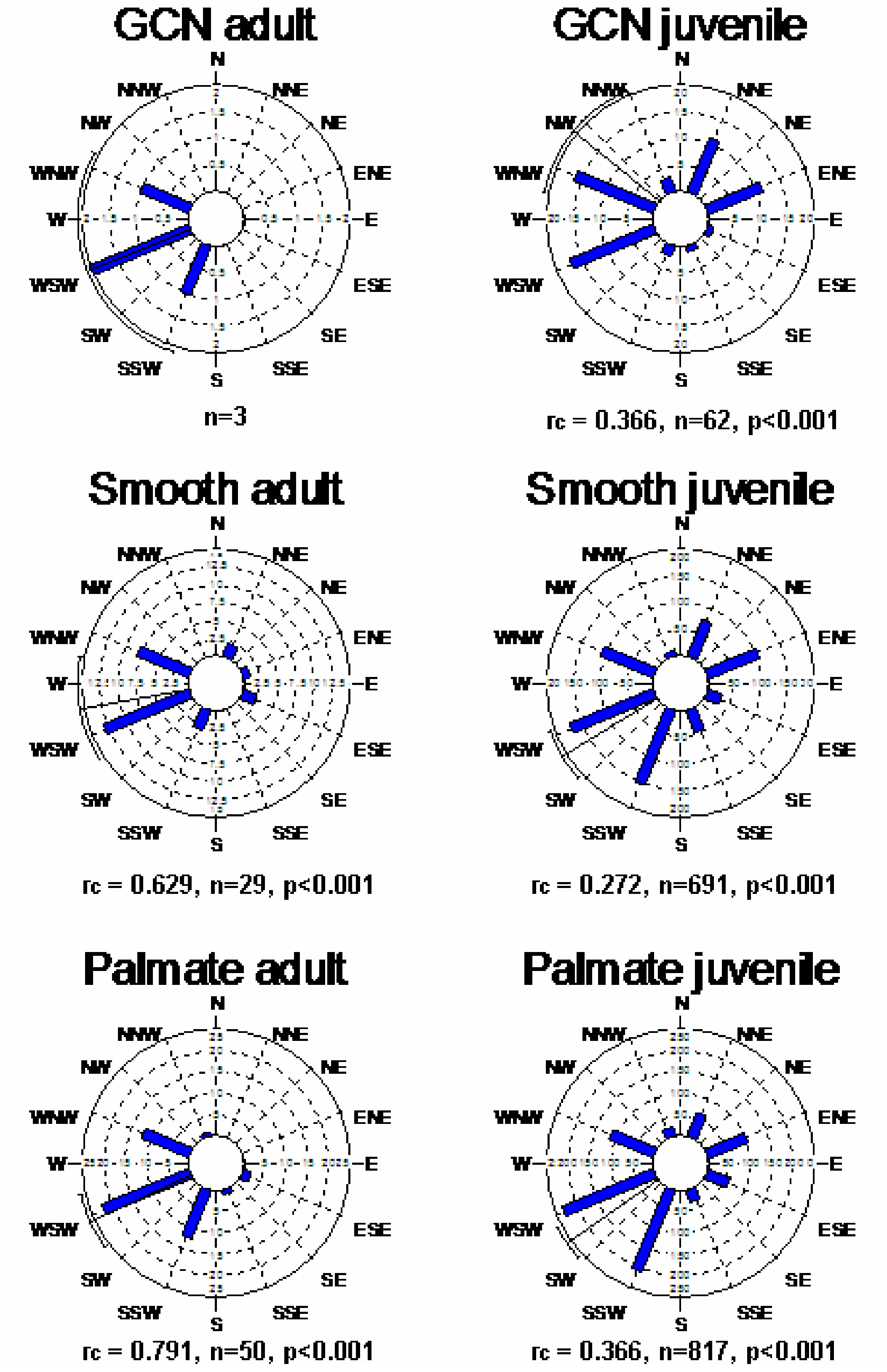
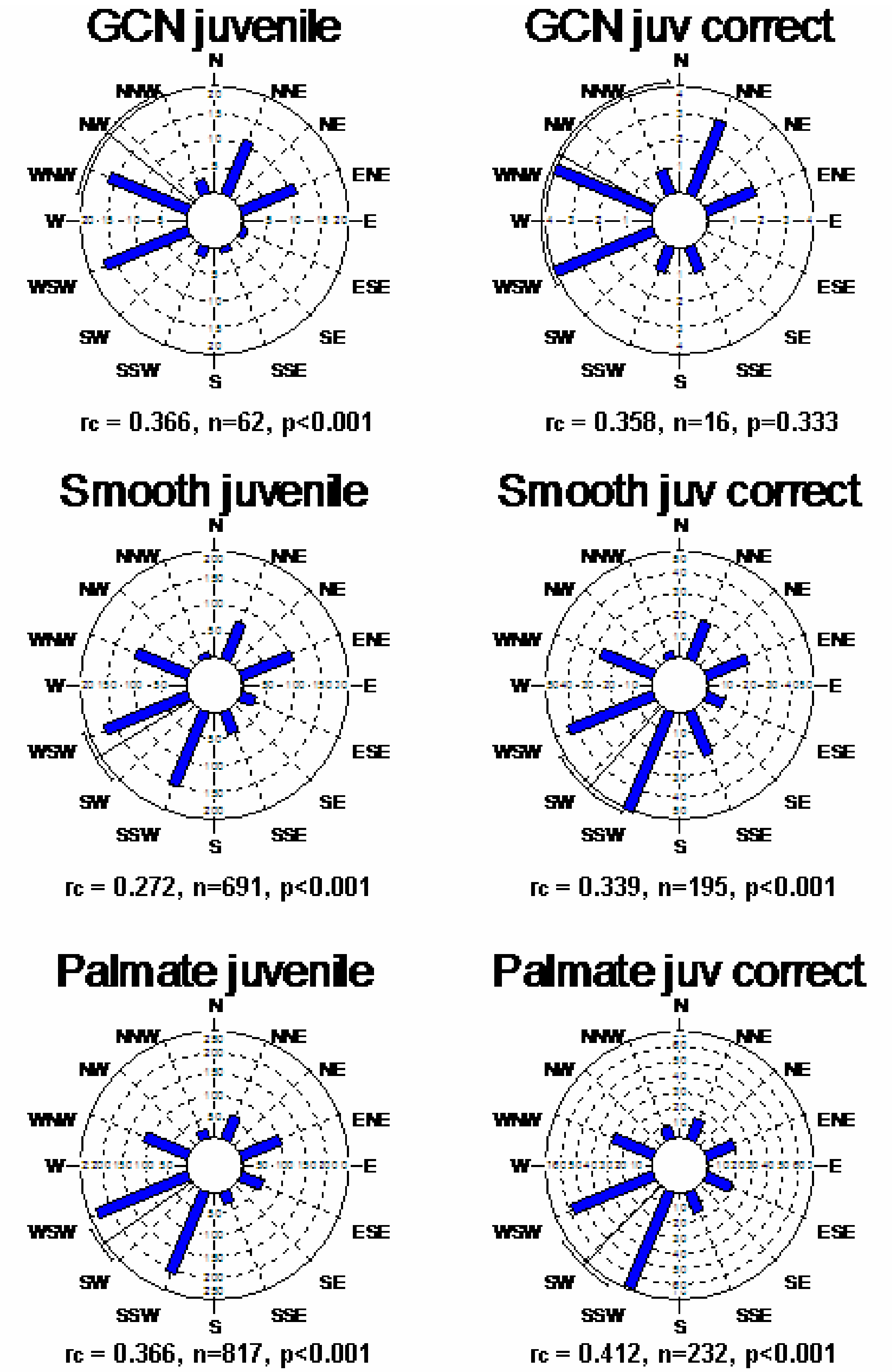


Figure 5-6: a) circular histograms showing dispersal direction in Bothlin Burn of GCN, smooth and palmate adults and juveniles during the autumn months. Data were pooled from 2006 to 2008. b) Juveniles were re-tested, correcting for potential effects of different fence lengths within each 45° section. Adult GCN counts were too low for statistical analysis, but histograms are included to indicate the directions traveled by the adults sampled.

Fig 5-6b)


GCN juvenile
rc = 0.366, n=62, p<0.001
GCN juv correct
rc = 0.358, n=16, p=0.333
Smooth juvenile
rc = 0.272, n=691, p<0.001
Smooth juv correct
rc = 0.339, n=195, p<0.001
Palmate juvenile
rc = 0.366, n=817, p<0.001
Palmate juv correct
rc = 0.412, n=232, p<0.001

Juveniles were tested for potential effects of fence length using multi-sampled Chi-Squared analysis on the grouped circular statistics data. The null hypothesis was that the populations did not differ in their distribution and that the fence therefore had no effect. As the data are grouped, a Chi-Squared test must be used, but this requires that at least 20% of the data have a frequency greater than five. This was not the case for GCN juvenile corrected, therefore could not be analysed statistically.

The null hypothesis could not be rejected for either Smooth juvenile versus corrected (X_2=8.877, df=7, p=0.262) or Palmate juvenile versus corrected (X_2=8.78, df=7, p=0.269). Adults and juveniles for both species did not differ in their distribution; therefore there was no significant effect of fence length on Smooth or Palmate migration patterns. Visual analysis of the GCN circular histogram suggests there was little difference in the preferred direction and therefore fence length was not having an effect on distribution.

5.5 Discussion

The perimeter fences were effective in providing an opportunity to sample newt juvenile lifestage but less effective for monitoring adults. There is dispute in the literature as to whether the driving force behind migration is juveniles (Gill, 1978; Breden, 1987) or adults (Perret et al., 2003). The Gartcosh data appear to support the theory that dispersal is led by migrating juveniles. Adults may have established hibernation sites within the confines of the zone to which they have headed directly. Alternatively, low counts may be related to the timing of the survey, with adults having left ponds and attempted migration earlier in the season.

An interesting finding was that both smooth and palmate juveniles were significantly more likely to move during the day than at night. A study by Himstedt (1971) observed that smooth metamorphs displayed a diurnal rhythm several weeks after becoming terrestrial. Additional survey work throughout the night is required to determine that the juveniles had not moved later in the evening as was sampled during this project. Differences in timing of movement may have been an avoidance strategy, to limit possible predation by adults of the same or other species or it could be that visual cues are important to juveniles of these species. This was not a sampling bias as it proved very easy to spot juveniles at night by torchlight. GCN juveniles and smooth and palmate adults showed a tendency towards moving at night. Only one GCN adult was observed in total, during day time sampling. In a radio-tracking experiment on *T. carnifex* (Schabetsberger et al., 2004) adults were found to move during day and night.

Dispersal routes of both adult and juvenile smooth and palmate newts displayed a strong directional bias towards the west-southwest end of Bothlin Burn during 2006 to 2008, heading towards an area of woodland just outside the perimeter fence, in the direction of the original ACA ponds (Figure 5.1). This was similar to findings by Malmgren (2002). Sample size was very low for GCN adults, although two of the three newts had moved in this direction. Juvenile GCN showed a preferred direction between west-northwest towards another small stand of woodland outside the fence boundary. Directional choice can be used as an indicator of good terrestrial habitat (Malmgren, 2002). It may be microhabitat or microclimatic conditions are more favourable within these routes, resulting in a favoured migration path. Although the analyses show the existence of migration paths, individuals of all species were observed moving in all directions throughout the zone.

RJ could not be explored in the intended detail. What was apparent was that as in BB, smooth and palmate juveniles showed a strong preference to orientate towards the ACA, in this instance following a north-north west bearing. This was a particularly noteworthy direction choice due to the existence of woods to the south end of the zone.

The presence of the amphibian- proof fencing and wall was an attempt to prevent adult newts returning to their original ponds post-translocation, as they are known to display strong fidelity to their breeding ponds (Joly & Miaud, 1993; Oldham, 1994; Latham et al., 1996; Kupfer & Kneitz, 2000; Oldham & Humphries, 2000; Pechmann et al., 2001) and to the same area of terrestrial habitat (Jehle & Arntzen, 2000). Despite the measures in place at Gartcosh to prevent this happening, the first great crested newt observed on site by this surveyor had breached the perimeter at BB and was crossing the road back to the ACA. Other studies do show adults moving between ponds (Arntzen & Teunis, 1993; Miaud et al., 1993) and this was observed at Gartcosh (refer to Chapter 3). New ponds built within the Gartcosh ACA were colonised within a few years and the population translocated to the GNR showed evidence of breeding within the first year of being moved, as indicated by the presence of eggs (refer to Chapter 2).

Safe navigation of the terrestrial terrain and location of habitat suitable for feeding and overwintering is crucial for the survival of amphibians. Studies on metamorph dispersion (Franklin 1993; Hayward et al., 2000) found that metamorphs followed migratory directional cues of adults, who, to have survived, must have successfully dispersed in previous years. This was contradicted by Malmgren (2002) who found that metamorphs had a wider dispersal range than adults. This was suggested as a mechanism to reduce competition for resources between the lifestages. In Gartcosh, palmate and smooth metamorphs followed the same migration path as adults. Further study is required to determine whether the juveniles were following adult cues or share a preferred habitat corridor. Low adult GCN counts prevented comparisons with juvenile dispersal.

What effect does translocation have on adults that have learned orientation cues within the context of an old habitat? Translocation to a new habitat appears to have a disorientating effect, limiting movement in radio-tracked newts (Jehle, 2000). Failure to find suitable refuge within the GNR could have serious implications for adult survival through the winter and for the long term future of the population due to effects on subsequent breeding and recruitment. The intent had been that between years comparisons of preferred dispersal choice would provide some evidence as to the impact of translocation on migration patterns of adults. Overall counts were too low to establish any annual changes. However, there is a relationship between the direction travelled by adults and juveniles when looking at the three years of data pooled. Assuming that this relationship existed across the three years, we can look to juvenile dispersal as a proxy for adult dispersal. There was a significant orientation choice in 2006, the final year of the translocation. Direction of orientation did not vary significantly in the subsequent years, after the newts had time to adapt to their new surroundings. The sampled adults would have been a mix of translocated adults and adults that had matured within the GNR, therefore not all adults surveyed would have a potential homing instinct for the ACA.

When designing habitat suitable for supporting newt populations, the minimum requirement is that terrestrial habitat extends 100 m beyond the ponds (English Nature, 2001) and that this should continue to the dispersal limit of 500 m (Oldham & Nicholson, 1986; Franklin, 1993; Baker & Halliday, 1999; Oldham & Humphries, 2000). Dispersal within any one site may be unimodal; therefore a 500m dispersal limit may not be required in all directions. Knowledge of dispersal preference could be used to improve the design of nature reserves and provide evidence for the best positioning of wildlife corridors. Current preferred direction choice within BB is not in the direction of the other GNR zones, should the fences come down. Metapopulation structure within the GNR will be heavily dependant upon the channelling effect of the amphibian wall that will remain in place, separating the GNR from development works.

5.5.1 Critique of Methods

The terrestrial fence survey is a simple mechanism for surveying changes in metamorph output from year to year. This methodology can provide information on annual fluctuations and has been shown to be effective at providing migration behaviour data for juveniles, a difficult stage to survey. For robust data on metamorph counts the common methodology is to fully encircle a pond with fencing, dig in pitfall traps and monitor extensively on a daily basis, which is very resource heavy. As the traps would be positioned immediately surrounding a pond, the apparent ‘chosen’ direction of an amphibian may be a reflection of pond design and the suitability of exits points. By surveying further away from their ponds as has been possible with the perimeter fence sampling method, an amphibian would have time to orientate towards a preferred direction.

Comments on directions traveled must be treated with caution due to potential channeling effects of the fence. Literature on radio-tracking of newts suggests that movement is relatively linear (Jehle, 2000). Personal observations of juveniles attempting to repeatedly climb the fence may suggest that considerable effort is expended in attempting to move in a chosen direction. If there was a significant channeling affect, a more diffuse dispersal pattern around the perimeter may be expected.

The methodology relies on assuming that all newts could disperse equally in all directions from the pond cluster. There were no known barriers or obvious areas of newt ‘unfriendly’ habitat within the zone that would suggest this assumption was violated.

6 Conclusions

6.1 Thesis Conclusions

Reviews of translocation success have proved inconclusive due to insufficient pre and post translocation monitoring (Dodd & Siegel, 1991; Oldham et al., 1991; Edgar et al., 2005; May, 1996). Lewis et al., 2007; Gartcosh Industrial site presented an opportunity for long term monitoring, with the donor site surveyed for six years (1998 to 2003) prior to a three year translocation (2004 to 2006), with post-monitoring scheduled at the receptor site until 2015. The focus of this research project was to provide additional, in-depth monitoring during the last year of the translocation and throughout the first three years of the post monitoring period (2006 to 2009). The research was designed to test the effectiveness of the translocation procedure in its aim to produce a self-sustaining, viable population. Central to the project was a study of aquatic and terrestrial habitat use.

Has the translocation at the Gartcosh site proved successful? Peak breeding adult counts indicate that the adult population is faring well, with counts a factor of two higher than numbers recorded pre-translocation. This is supported by the CMR results. The breeding adult population is being maintained at levels comparable to the known number of adults translocated. Survival rate in BB/GQH is on a par with mean survival rates recorded in the literature. Analysis of addition rates and belly pattern photographs suggest that ‘new’ adults are being recruited into the breeding population. The analyses only allow for two years of population size estimates and one year of survival and addition rates. In RJ due to a lack of recaptures in 2007, only one year of population estimates and no survival or addition rates could be calculated. On-going analysis in this zone could prove very useful in helping to inform good practice, as would further analysis in BB/GQH but this would require a considerable investment in resources due to the size of the translocated population.

Examinations of juvenile lifestages were less positive, indicating decreased production and survival of larvae and metamorphs that will lead to a reduction in successful recruitment to the adult population. This may be an effect of the translocation or could simply be indicative of natural fluctuations in annual production. It is therefore recommended that monitoring of the juvenile stages is continued. This is not currently within the post-monitoring brief for HEL. For future projects, pre-translocation monitoring should include monitoring of juvenile stages to provide a baseline for comparisons with the post monitoring. Sampling over more than one year will provide additional information on natural fluctuations within the untouched population.

Translocation should be planned to prevent net habitat loss and where possible, promote gain. With the creation of the GNR there has been a loss of terrestrial habitat, an increase in the number of ponds but subsequent decrease in pond surface area. Much of the lost terrestrial habitat was likely of poorer quality. There requires better assessment of quality/ extent of habitat pre-translocation to compare with. Overall, the newly created habitat is of good quality, capable of supporting the existing population of GCN. Extensive pond management work was required after only three years of creation and a second bout of vegetation clearing was undertaken two years later in 2010. This suggests long term management issues due to rapid macrophyte growth reducing the suitability of the aquatic habitat.

The GNR would benefit from improved connectivity between individual zones. This would be achieved in part, by the removal of amphibian-proof fences surrounding individual zones which severely limit dispersal opportunities. This may result in pond disturbance by dogs as the area is widely used by the local community. Even with this measure, directional adult migration data suggests preferential movement towards old ponds, not in direction of the new ponds within GNR. This tendency would be expected to decline as ‘new’ adults increase in numbers. Monitoring of migration would be useful in the longer term. RJ is particularly isolated, surrounded on all sides by migration barriers. Although RJ appears to be faring well, there is an inherent problem within the zone due to the decision to move only 56 adults to this area, less than the minimum population sizes required for a viable population; 40 females (Halley et al., 1996), 100 adults (Shaffer, 1981) or 100-200 adults (Griffiths & Williams, 2000; 2001). Fully connecting RJ with the BB/GQH populations within the diverse network of ponds at the Gartcosh site would meet the criteria for a genetically viable GCN population; genetic diversity and population size are correlated (Gregory et al., 2006).

The GNR remains isolated within the context of the wider landscape. The nearest known GCN population is in Drumcavel Quarry, outwith the natural migration range and across a pre-existing barrier (busy motorway). This was not caused by the mitigation work, although redevelopment of the site has resulted in further isolation, with negligible migration opportunities available in all directions. This is potentially a significant threat to the long term survival of the Gartcosh population. Drumcavel has also been subject to mitigation work but this small population does not appear to be genetically viable in the long term. It may be appropriate to consider alternative management solutions, such as means to link the two populations providing opportunity for genetic exchange. This raises the issue as to whether money is well spent rescuing and protecting small pockets of GCN in isolation. There are believed to be many populations across Scotland and the UK yet to be detected due to lack of surveying resources. These unknown GCN ponds may subsequently be lost due to natural or manmade causes, or maintained in an increasingly fragmented landscape.

During the translocation of GCN from the Gartcosh Industrial Site to the Gartcosh Nature Reserve, a capture target of 405 adults was set for 2005, based on sampling efforts during 2004. This was greatly exceeded, with 656 adults caught and moved. In 2006, another 300 adults were captured (Kellett & Bates, 2006). At this point, translocation efforts ceased after certain conditions were met and the ponds infilled. The stopping conditions were that no newts were observed during five night's consecutive torchlight monitoring of ponds. This was carried out in October, well outwith the breeding season, suggesting that the timing was inappropriate. Despite extensive monitoring and trapping efforts based on best practice, the Gartcosh population was underestimated by at least 50%.There is a need for accurate population estimates to allow assessment of the true impact of translocation. With such large captures still being made in 2006, what proportion of the population remained at large within the Industrial Site? In 2010, North Lanarkshire Council were granted a licence to capture small numbers of amphibians including GCN, from water bodies in the Industrial Site (yet to be fully developed) and translocate these to the BB zone of GNR. The individuals may have avoided the initial translocation or could be escapees from the GNR. It may be preferable to move the adults to RJ, where translocated numbers fell below the recommended minimum viable population. It is unknown what the carrying capacity for RJ is but based on estimates of number of newts capable of being supported in one hectare of ‘newt friendly’ habitat (minimum suggested is 200 newts per hectare), RJ should be easily capable of absorbing additions. It is interesting to note that had the duration of the translocation only been one breeding season as is permitted in some translocations, less than 50% of the known population would have been captured and moved.

After three years of post monitoring, we can report that the Gartcosh translocation appears to be supporting the adult population and the recruitment of ‘new’ adults. There is evidence of on-site breeding, with eggs, larvae and metamorphs being recorded. There is a worrying decline in the output of the juvenile stages although it is not clear whether this is an effect of the translocation or a natural fluctuation. Despite this large data-set it is still not possible to fully resolve the question as to whether the translocation will be successful in the long term. We cannot determine whether survival rates have changed, if recruitment is a true gain or indicative of the ‘old’ newts having died off or whether survival and recruitment are high enough to continue to maintain the population at previous levels. Post monitoring is scheduled for the GNR until 2015, looking to simple counts of breeding adults. This will provide information on annual fluctuations but is insufficient monitoring to provide the necessary answers. There is a real opportunity at Gartcosh to produce a valuable data set, building on the work detailed within this project. Future translocations would benefit immeasurably from the inclusion of surveying population dynamics, survival, recruitment and growth rates in the pre monitoring stages. This would provide a comparative baseline with which to compare post monitoring. Fundamental questions have yet to be resolved by those working in great crested newt conservation; what is ‘favourable conservation status’ and what is the most appropriate way to measure this?

6.2 Recommendations for Gartcosh

- Extend the 10 years post translocation monitoring regime of breeding adult counts to include juvenile stages, to ascertain whether there is a true decline and if so, what measures are required to reverse this.

- Include further study of migration direction in post monitoring plans.

- Continue the CMR project in RJ. This will require additional resources but provides an excellent opportunity to assess annual estimates of population size, survival and recruitment and explore the relationship between simple torchlight counts and CMR population size estimates.

- Remove fencing and increase access to refuge in wooded areas currently outwith pond clusters, promoting exchange between the zones and re-establishing one connected population.

- Improve connectivity to the RJ zone. This may require a purpose built habitat corridor and/or pond(s) to aid dispersal to this isolated area.

- All ponds within RJ fall below the recommended minimum surface area of 100 m^2. It would be beneficial to have at least one larger pond within this zone. Preferably a new pond or alternatively, formed from the two ponds RJ5 and RJ6. Both ponds are very small, shallow and have dried out every summer during surveying.

- Improve the ponds within the Stepping Stone zone. This will increase the number of suitable pond habitats available for use by GCN and promote dispersal throughout the GNR.

6.3 Future Work

A number of sub-projects were begun during the work reported in this thesis, but have not been completed or fully analysed. In addition, the work suggested some areas for further study. These are briefly outlined here.

Invertebrate Predators and Larval Distribution

Ten ponds were surveyed during summer 2007. Within each pond, four vegetation mesohabitats were present; submerged, emergent grasses, emergent rushes and floating. Each mesohabitat was netted in accordance with methodology outlined by Biggs et al. (1998). Counts and body length of GCN, smooth and palmate larvae were recorded, as was both abundance and biomass of three invertebrate predators (dragonfly larvae, diving beetles and backswimmers). The relationship between predators and positioning of the newt larvae within the ponds will be examined in the analysis of these data.

Smooth and Palmate

In addition to data collected on smooth and palmate eggs, larvae and metamorphs described in previous chapters, torchlight counts of peak breeding smooth and palmate adults were undertaken. The annual variation in peak breeding adult counts and the relationship between presence of eggs, larvae and metamorphs will be explored within species and between GCN.

Scottish Population Estimate

It is interesting to note how poorly the Scottish GCN population is represented in the scientific literature. It is often quoted that there are only approximately 1000 adult GCN in the whole of Scotland (e.g. Edgar & Bird, 2005; www.ukbap.org.uk). Yet, the translocated Gartcosh GCN population alone numbered 1,012 (Kellett & Bates, 2006). In Scotland, surveys during 1995 and 1996 revealed 85 GCN breeding ponds (Alexander, 1997; SNH, 1997). A survey of 42 Scottish GCN breeding ponds produced a mean of 41.6 to 138.8 adult newts per occupied pond (Bates & Hutcheon, 1998). Assuming a minimum of 85 ponds, Bates & Hutcheon (1998) suggest that the adult population of GCN in Scotland ranges between 3,536 and 11,798 adult newts.

A joint project between Amphibian and Reptile Conservation (ARC) and SNH is currently underway during the 2010 breeding season titled ‘Predictive model of great crested newt distribution in Scotland and field survey’ (*pers. comm. ARC)*. The project seeks to map the distribution of GCN throughout Scotland, using current occupied habitats to predict occupancy in other areas, confirming presence through field surveying. This should provide a more complete estimate of the Scottish GCN population size and location.

Genetics

There is a need to understand the implications of translocation on the genetic make-up of a population. In a study examining the genetic structure of salamanders, Noel et al. (2007) found that populations living in fragmented habitats were genetically differentiated in comparison to populations living within a continuous landscape. Translocation as a conservation method supports the development of land that may increase fragmentation of amphibian populations. This could limit dispersal and gene flow, impacting on genetic diversity and the ability of a population to adapt to change (Storfer, 1999; Frankham et al., 2002; Gregory et al., 2006). In light of increased isolation within the wider landscape, can populations survive in the long term? Genetic techniques may be used alongside or in the absence of counts to provide information on population trends, bottlenecks and fragmentation events (Storfer, 2003) and provide information on genetic distinction between populations (Gregory, 2006).

Public Engagement

The establishment of Gartcosh as a local nature reserve could be an opportunity for public education about GCN. In general, education focusing on amphibian populations is deficient. Activities such as Froglife Living Waters project are emphasising community-based, environmental education work. Gartcosh has a high local human population that utilises the GNR and would be a good centre to develop educational resources.

Overwintering

Another aspect that had to be set aside but which may have some relevance to climate change is overwintering in larvae. This could benefit from further research.

6.4 Guidelines

To enable the content of this thesis to be easily applied to future conservation projects, a series of guidelines have been produced. This incorporates lessons learned from the research undertaken at Gartcosh Industrial Site and best practice as determined from relevant published literature. There are several key texts that should be considered essential background reading for anyone seeking to undertake GCN translocation projects in the UK, including 'Great Crested Newt Mitigation Guidelines' (English Nature, 2001), 'Herpetofauna Workers' Manual' (Gent & Gibson, 2003) and 'Great Crested Newt Conservation Handbook' (Langton et al., 2001). For further advice on good practice and to learn from other projects undertaken previously 'An Evaluation of the Effectiveness of Great Crested Newts *Triturus cristatus* mitigation projects in England, 1990-2001' (Edgar & Griffiths, 2004) and for more detail on choice of survey methodology 'Evaluation of a Standard Method for Surveying Common Frogs and Newts' (Griffiths et al., 1996).

Pre and post monitoring protocols should be standardised and applied to all future translocation projects to promote best practice, allowing for meaningful comparisons between projects and increasing the number of good case studies that can be used to determine whether translocation can be an effective tool for mitigation.

6.4.1 Best Practice Principles in GCN Translocations

Great Crested Newts (GCN) are protected by UK and European law. This prohibits the deliberate killing, injuring or disturbance of GCN and damage or destruction of their habitat. Any actions likely to contravene the legislation may only be carried out under licence, granted in Scotland by Scottish Natural Heritage. Permission to develop within an area known to support a population of GCN may be given if appropriate mitigation work is proposed.

Translocation is not a proven conservation method. Previous projects have failed due to bad practice including poor provision of terrestrial or aquatic habitat, too small a founding population or presence of predators e.g. fish. With a proper understanding of GCN biology and careful planning, such mistakes can be avoided. Adoption of best practice will maximise the likelihood of successful mitigation and provide further evidence as to what measures are most beneficial. Translocation should be viewed as a method of last resort, permitted only if there is no other satisfactory solution. This must be based on sound science to minimise risk.

Pre Monitoring

- It is recommended that a project begins with pre-translocation monitoring, to provide reasonable population estimates. This will be used to inform the scope and method of intercepting the donor population, what proportion of the population has been moved and a baseline to compare against in future monitoring.

- Duration of pre monitoring as determined on a case by case basis. Ideally, pre monitoring should occur over several years to estimate annual fluctuations in population size and reproductive output. However it is acknowledged that this may not always be possible.

- Adult and juvenile life stages should be monitored as a measure of population size and reproductive output.

Habitat

- Thorough survey of the receptor site habitat and provision of detailed plans for habitat creation and/or augmentation if required.

- Recommend the use of the Habitat Suitability Index to compare between original and newly created habitat in supporting great crested newts.

- Habitat creation or augmentation work should be carried out in consultation with suitably experienced and knowledgeable people.

- A post-management plan will be required where extensive works have been undertaken. This requires an agreement on responsibility for works done and allocation of resources.

- For detail on key habitat requirements specifically for GCN, refer to 'Best Practice Principles in Habitat Creation'.

Translocation

- There should be an agreed criteria for measuring success or otherwise of a translocation project. What is 'favourable conservation status' and how best to measure this?

- The translocation period should extend over a minimum of two, preferably three breeding seasons to allow capture of adults skipping breeding seasons and newly matured metamorphs returning as adults to breed.

- Significant effort should be made to translocate juvenile lifestages (eggs, larvae and metamorphs) along with adults.

- Capture/ sampling methodology will be site-specific.

- Trapping intensity should be increased for projects of shorter capture durations.

- Standardising the use of the different sampling methods as described in Griffiths et al. (1996) will allow for comparisons with other projects that may have employed different sampling methods.

- 'Rescue' mitigations, where the population is trapped and moved within one breeding season should be avoided where possible. This excludes a significant proportion (up to 70%) of the non-breeding population from being caught and may exclude early or late breeders.

- The translocated population should have a minimum size of 40 females or 100 adults to survive long-term in isolation. Smaller populations will persist if there is a source of immigration.

- Translocation to a receptor site with a pre-existing GCN population should be avoided. If necessary, augmentation work may be required to prevent additional newts exceeding habitat carrying capacity.

- Where the donor population is not threatened by change or destruction of habitat (i.e. conservation translocations), the possibility of success may be increased by moving non-adult life stages e.g. eggs or larvae. This solves site fidelity issues where up to 70% of translocated adults have been found to leave the receptor site to locate their original ponds.

- When adults are moved, it may be necessary to erect barriers to prevent newts leaving the receptor site and attempting to migrate back to the donor site.

- Chronic stress may contribute to translocation failure by indirectly increasing mortality, vulnerability to disease or decreasing reproduction (Dickens et al., 2010). Those involved in a translocation should aim to reduce the stress by means such as minimizing handling time during capture and transportation and ensuring where possible, resources in the new habitat e.g. food, are not limited.

Post Monitoring

- If receptor site contains a pre-existing GCN population, a means of differentiating the original from the translocated population is required to gauge survival.

- Post monitoring duration should extend to a minimum of six years (2 generations) and up to 10 years where possible.

- Post monitoring should mirror pre monitoring sampling methods of adult and juvenile life stages.

- Simple counts are indicative of population fluctuations. Where feasible, capture-mark-recapture (CMR) should be used. This will provide population size estimates with confidence limits, estimates of survival and crucially, allows a measure of juvenile recruitment into the breeding adult population.

- The presence of ‘new’ adults being recruited into the breeding population should be monitored where possible.

- Ongoing habitat surveys using Habitat Suitability Index methodology to ensure ponds are maintained favourably for GCN (refer to Best Practice Principles in Habitat Creation).

- For information on monitoring methods refer to ‘Monitoring the Success of the Translocation’.

Disease

The emergence of infectious diseases in amphibians (Daszak et al., 1999) and the potential transmission of disease between populations and from captive to wild populations (Dodd & Seigel, 1991; Cunningham et al., 1996) is a very real threat associated with translocation. A 2008 UK survey confirmed chytrid infection in all native species with the exception of GCN (Cunningham & Minting, 2008) although there are unconfirmed reports that chytrid has been located in wild GCN populations in other sites (*pers. comm. John McKinnell, SNH*). Best practice for disease control must be disseminated among relevant people to avoid translocations furthering the spread of this or any other pathogen. This is especially important since GCN translocations are likely to involve the movement of other species, as occurred in Gartcosh.

6.4.2 Monitoring the Success of a Translocation

Monitoring of all Great Crested Newt (GCN) lifestages is recommended although this may not be feasible. If resources are limited, relative abundance of adult and larvae as a measure of population fluctuations and reproductive output are recommended. Capture-mark-recapture (CMR) studies of breeding adults are preferable to simple counts.

Adults

When monitoring a translocation project, presence/ absence surveying is not enough. The minimum method used should be peak adult counts. Bottle trapping or torchlight sampling can be used, in accordance with methodology described in Gent & Gibson (2003). Multiple visits throughout the breeding season (March to June) are required. English Nature (2001) recommends six, at least three between mid-April to mid-May. The Gartcosh data supports this timescale as applicable to Scottish populations.

For future great crested newt projects, Scottish Natural Heritage (SNH) should consider supporting the use of density measures as described in Griffiths et al., (1996). Counts of newts every 2m are recorded (2m transects if using torchlight or a funnel trap positioned every 2m). Standardised survey methods expressing peak counts as density measures allow for comparisons between different sampling methods and across pond sizes. This would allow for meaningful comparisons between projects/sites even if different survey methods were used. Refer to Lewis (2007) for a comparison between density measured with peak counts.

Where density measures are not used, counts can be standardised for comparison with other translocation projects by using the English Nature (2001) population size class method. Night time surveys using torchlight or bottle trapping produce peak adult counts which are classed as ‘small’ for up to 10 adults, ‘medium’ between 11-100 and ‘large’ for peak counts greater than 100. This classification may be misleading as a ‘small’ population at the edge of the distribution range of the species could be considered as important as a ‘large’ population situated elsewhere.

Drift fencing and pitfall trapping are commonly used, often situated surrounding a pond. This is a resource intensive process, requiring daily visits. It will provide information on adult and metamorph counts, timing and direction of movement.

For descriptions of possible designs, minimum trapping density and number of sampling days, refer to English Nature (2001) and Gent & Gibson (2003).

For detailed analysis on population size the use of CMR should be considered. Adult sampling methodologies already mentioned are used (bottle trapping, pit fall trapping, torchlight sampling with targeted netting as per Gartcosh project) to capture individuals. The unique belly pattern can be used as a non-invasive mark. This is photographed and compared with prior captures. CMR sampling and photographic sorting is relatively straight forward although the photographic matching can be very time consuming with larger populations. CMR will require some statistical expertise in the planning, design and analysis.

Eggs

Presence of eggs can be used to confirm breeding has occurred. There is no correlation with population size. GCN eggs are distinguishable in the field (yellow, 4.5-6mm) from the other newt species, which are indistinguishable from each other (both species are grey-brown, 3mm). Females lay eggs individually on favoured vegetation such as water forget-me-not. The resultant concertina-like folded leaves are readily visible. Environmental conditions depending, eggs should be present from March but it may be advisable to wait until peak breeding season (April/ May) to increase likelihood of positive identification of egg presence. Presence is often easily observed during other sampling methodology e.g. torchlight surveys and may not require additional visits.

Larvae

A consistent sampling regime using netting or bottle trapping can be employed to indicate the relative abundance of newt larvae between ponds and sampling years. This will provide information on relative abundance of annual reproductive output. Larvae are likely to be present within a pond from March onwards, earlier if individuals of the previous cohort have overwintered in the pond. Peak larval counts were observed in June at the Gartcosh site. This requires verification from other Scottish populations.

Metamorphs

The production of metamorphs provides evidence that the pond is capable of supporting larval survival. This can be measured using a system of fencing and pitfall trapping encircling a breeding pond (as before, adults). The Gartcosh project utilised existing fences surrounding pond clusters to obtain a measure of relative abundance. Metamorphs were located during terrestrial vegetation searches immediately around the fences.

It is crucial that survival at all stages of the life cycle is supported. The described sampling methodologies do not answer the question as to whether metamorphs survive to mature into breeding adults. It is crucially important to ascertain this. Relic populations can return healthy annual adult counts but if conditions are unfavourable for juvenile survival, populations can appear to quickly crash as the original adults die out and there are no new adults to replace them. In Gartcosh, the use of the CRM methodology for breeding adult population estimates and survival rates could investigate this to some extent as the following criteria were met; the captured adults were photographed prior to translocation, there was no pre-existing GCN population at the donor site and immigration opportunities were negligible. The appearance of ‘new’ adults in subsequent recapture photographs was therefore indicative of on-site maturation.

For additional reading on choice of sampling methodology refer to Griffiths et al. (1996).

6.4.3 Best Practice Principles in Habitat Creation

Good quality aquatic habitat is vital to Great Crested Newts (GCN) for breeding, egg laying and larval development. Suitable terrestrial habitat is equally as important as a GCN adult will spend at least half the year on land (MacGregor, 1995; English Nature, 2001). Upon metamorphosis, a sub-adult may be entirely terrestrial until returning to ponds as a sexually mature adult to breed, two to three years later. Previously studied translocations have failed due to predictable reasons including unsuitable aquatic and terrestrial habitat or habitat provision inadequate in size (Oldham et al., 1991). Habitat creation should only be undertaken in consultation with individuals experienced in this area, with excellent knowledge of terrestrial and aquatic ecology, invertebrates and macrophytes. The following details criteria specific for GCN:

Recommendations for Good Aquatic Habitat

- Pond surface area between 100-750 m^2.
- Free of fish, potential predators of newt eggs and larvae.
- Good source of invertebrate prey items.
- Ponds may be designed to dry occasionally to reduce aquatic predators.
- Suitable egg laying substrate e.g. hairy willow herb, water mint or grasses.
- Provision of vegetation for refuge and open areas for courtship.
- Pond clusters (ponds within 250 m radius with no migration barriers), ranging in size and successional stage.
- New ponds should exceed what is being replaced in terms of number and/ or surface area.

Recommendations for Good Terrestrial Habitat

- 'Newt friendly' habitat i.e. rough grassland, woodland, wetlands, scrub and mature gardens.
- Good source of invertebrate prey items.
- Provision of suitable refugia, aestivation/ overwintering areas. For design of man-made hibernacula refer to GCN Conservation Handbook (Langton et al., 2001) or English Nature (2001).

- Habitat should extend a minimum of 100 m beyond the perimeter of the water body, preferably up to 500 m.

- Connectivity within the wider landscape is necessary for long term survival. This will only be possible if there is provision of 'newt friendly' habitat corridors linking ponds. The maximum migratory range is described as between 1000-1290m, assuming no migration barriers exist.

The Habitat Suitability Index (HSI) evaluates the suitability of both the terrestrial and aquatic habitat in combination to support a population of great crested newts. This methodology could be used to guide the creation of new habitat during a translocation, with the aim of designing a set of conditions capable of achieving a high HSI score. It could also be used as a comparative measure of newly created habitat with the original site. Habitat quality is based on ten criteria: location, pond area, age of pond, water quality, perimeter shading, and numbers of water fowl, presence of fish, pond count within a 1 km radius, terrestrial habitat quality and percentage of macrophyte cover. The method is very user-friendly and does not require specialist knowledge in macrophyte and invertebrate species identification. An HSI score ranging between 0.43-0.96 has been found to support populations of breeding GCN adults. Predictions can be made on how to increase a given HSI score by improving one or more of the criteria. For full description of methodology refer to Oldham et al. (2000). Computer software exists to calculate HSI scores and can be obtained by contacting the author (R.S. Oldham). An excellent summary of the methodology is available on the National Amphibian and Reptile Recording Scheme (NARRS) website http://www.narrs.org.uk/Documents/nasdocuments/HSI_guidance.pdf and has been included with this document for ease of use (Appendix 7).

7 Appendices

7.1 Appendix 1: Capture Mark Recapture Data Table

Railway Junction

Time of Last Capture		Time of Recapture		
	2004	**2007**	**2008**	**2009**
2004		0	9	0
2007			5	3
2008				4
Total Marked (m t)	0	0	14	7
Total Unmarked (u t)	56	10	39	34
Total Caught (n t)	56	10	53	41
Total Released (s t)	56	10	53	41

Bothlin Burn/ Garnqueen Hill

Time of Last Capture		Time of Recapture		
	2006	**2007**	**2008**	**2009**
2006		10	8	5
2007			7	1
2008				16
Total Marked (m t)	0	10	15	22
Total Unmarked (u t)	294	65	167	125
Total Caught (n t)	294	75	182	147
Total Released (s t)	294	75	182	147

7.2 Appendix 2: Pond Characteristics/ Macrophyte Biomass

Pond	Temp	Cond	pH	A wint	A summ	Emerg	Float	Sub
ACA 2	6.4	2.3	8.9	118	70	142.4	11.6	130.0
ACA 3	6.2	2.7	9.0	121	92	73.2	13.2	366.0
ACA 4	6.4	4.1	8.5	102	74	101.2	14.4	888.0
ACA 5	6.7	3.9	8.5	220	175	468.4	15.2	2078.0
ACA 6	6.2	5.0	9.2	660	dry	1546.4	0.0	0.0
ACA 7	5.9	5.1	9.0	117	dry	862.0	23.2	12.0
ACA 8	6.8	5.6	9.5	746	469	486.0	35.6	486.0
ACA C	5.6	8.8	9.3	9	dry	871.2	0.0	0.0
ACA D	6.1	4.4	8.4	520	dry	1048.8	0.0	0.0
ACA E	6.5	3.4	8.9	1886	540	712.0	88.4	232.0
ACA F	6.8	4.6	8.8	131	20	849.2	481.6	0.0
ACA G	7.3	4.0	9.8	660	420	813.2	0.0	0.0
ACA I	6.6	4.5	8.2	600	284	1355.2	100.8	0.0
BBC1	7.2	1.2	8.3	313	233	1009.2	114.0	446.0
BBC2	7.7	2.0	8.7	312	229	1038.0	356.4	384.0
BBC3	7.3	2.9	8.0	191	111	569.6	372.0	678.0
BBC4	7.6	2.7	8.3	581	515	628.8	190.4	588.0
BBC5	7.5	3.5	7.5	227	202	418.8	120.8	360.0
BBC6	7.8	2.7	8.3	317	300	384.0	196.8	710.0
BBC7	7.7	2.3	8.3	576	480	537.6	250.0	222.0
BBC8	7.8	1.7	8.0	152	124	500.8	153.2	500.0
SS1	7.2	1.2	9.0	58	48	121.6	37.2	46.0
SS2	7.3	1.3	8.0	68	56	140.0	54.4	48.0
SS3	7.2	1.3	8.7	62	46	282.8	65.2	272.0
GQH11	7.7	1.0	8.7	139	122	261.6	151.6	0.0
GQH12	7.7	0.9	8.7	88	23	375.6	68.4	20.0
GQH13	7.6	1.3	8.6	159	116	531.6	472.4	92.0
GQH14	7.1	1.1	8.5	277	210	1347.6	148.8	340.0
GQH15	7.1	1.0	8.6	202	157	654.8	64.0	242.0
GQH16	7.2	1.1	8.6	145	116	638.4	100.4	490.0
GQH17	7.4	0.9	8.5	255	227	535.2	118.0	510.0
RJ1	7.7	1.4	9.0	83	64	19.6	138.4	358.0
RJ2	7.4	1.5	9.7	34	11	68.0	9.2	148.0
RJ3	6.7	1.2	9.8	32	10	67.6	39.6	450.0
RJ4	7.0	1.1	8.7	19	12	520.4	104.0	38.0
RJ5	7.3	2.3	8.3	27	dry	x	x	x
RJ6	7.1	3.3	9.0	34	dry	x	x	x

Temperature (ºC), Conductivity (mS), Awint is the maximum surface area as determined by the winter drawdown level, Asumm is the pond surface area as measured in the summer 2006, Emerg/Float/Sub are the emergent, floating and submerged macrophyte biomasses (g dry weight m^{-2}).

7.3 Appendix 3: Invertebrate Family List

Common Name	Scientific Family	BB 1	BB 2	BB 3	BB 4	BB 5	BB 6	BB 7	SS 1	SS 2	SS 3	GQ 11	GQ 13	GQ 15
Mayfly	**Ephemeroptera**													
	Batediae	1	1	1	1	1	1	1	1	1	1	1	1	1
	Caenidae	1	1	1	1	1	1	1						1
Water bugs	**Hemiptera**													
Riffle bugs/ Water cicket	Veliidae		1			1		1	1	1		1	1	1
Pond skater	Gerridae	1	1	1	1	1	1	1	1	1	1	1	1	1
Water measurer	Hydrometridae					1								
Saucerbug	Naucoridae									1				
Backswimmer	Notonectidae	1	1	1	1	1	1	1	1	1	1	1	1	1
Lesser waterboatmen	Corixidae	1	1	1	1	1	1	1	1	1	1	1	1	1
Water Scorpion	Nepidae													
Spider	**Arachnida**													
Water spider	Agelenidae						1	1	1		1		1	
Mite	**Hydracarina**													
Water mite	Hygrobatidae	1	1	1	1	1	1	1	1		1		1	1
Water Fleas	**Cladocera**													
	Daphniidae												1	
Isopods	**Isopoda**													
Water Slater/hog louse	Asellidae	1	1			1	1	1				1	1	1
Dragon & Damselflies	**Odonata**													
Hawkers	Aeshnidae	1	1	1	1	1	1	1	1	1	1	1	1	1
Golden ringed	Cordulegasteridae		1											
Darters & Chasers	Libellulidae	1	1	1	1	1	1	1	1	1	1	1	1	1
Emerald Damselflies	Lestidae	1	1	1	1	1	1	1	1	1	1	1	1	1
Red and Black/Blue Damsels	Coeangrionidae/ Coenagriidae	1	1	1	1	1	1	1	1	1	1	1	1	1
Caddisflies	**Goeridae**	1	1	1	1	1	1	1	1	1	1	1	1	1
	Rhyacophilidae													
	Phryganeidae		1			1						1	1	1
	Limnephilidae		1			1		1		1		1	1	1
	Leptoceridae	1	1							1		1	1	1
	Polycentropidae													
Moth Larvae	**Lepidoptera**													
	Pyralidae	1	1	1	1	1	1	1	1	1	1	1	1	1
True flies larvae	**Diptera larvae**													
Craneflies	Tipulidae		1			1	1			1				
Meniscus midges	Dixidae	1	1	1	1	1	1	1	1	1	1	1	1	1
Ghost/ Phantom midge	Chaoboridae	1	1	1		1	1	1	1	1	1	1	1	1
Mosquito & gnats	Culicidae	1	1		1	1	1	1		1	1	1	1	1
Biting midges	Ceratopogonidae		1	1								1		1

Nonbiting midges/ blood worm	Chironomidae	1	1	1		1	1	1	1	1	1	1	1	1
Horseflies	Tabanidae													
Beetles	**Coleoptera**													
Whirligig	Gyrinidae		1			1		1				1		
crawling water beetle	Haliplidae	1	1			1	1	1		1	1	1	1	1
diving beetle	Dytiscidae	1	1	1	1	1	1	1	1	1	1	1	1	1
Scavenger	Hydrophiliidae	1				1				1		1	1	
Riffle	Elmidae		1					1						
Leaf beetle	Chrysomelidae											1		
Weevils	Curculionidae		1			1	1					1	1	
Snails	Mollusca													
Ramshorn snail	Planorbidae		1			1		1					1	1
Pond snail	Lymnaeidae	1	1		1	1	1	1	1	1	1	1	1	1
Clams	Sphaeriidae													
Pea/ orb mussel	Sphaeriidae	1	1	1	1	1	1	1		1	1	1	1	1
Mussel	Unionoida													
fw mussel	Unionoida						1							1
Leech	Hirudinidae			1										
worm	Oligochaeta	1			1				1				1	

		RJ	RJ	RJ	RJ	AC	AC	AC	AC	AC	AC	AC	AC
Common Name	**Scientific Family**	**1**	**2**	**3**	**4**	**2**	**3**	**4**	**5**	**7**	**8**	**E**	**F**
Mayfly	**Ephemeroptera**												
	Batediae	1	1	1	1	1	1	1	1	1	1	1	1
	Caenidae	1	1	1	1		1		1	1	1	1	1
Water bugs	**Hemiptera**												
Riffle bugs/ Water cicket	Veliidae	1	1	1	1	1	1						
Pond skater	Gerridae	1	1	1	1	1	1	1	1	1	1	1	1
Water measurer	Hydrometridae												
Saucerbug	Naucoridae				1								
Backswimmer	Notonectidae	1	1	1	1	1	1	1	1	1	1	1	1
Lesser waterboatmen	Corixidae	1	1	1	1	1	1	1	1	1	1	1	1
Water Scorpion	Nepidae		1	1						1		1	1
Spider	**Arachnida**												
Water spider	Agelenidae		1	1		1	1	1	1	1	1		1
Mite	**Hydracarina**												
Water mite	Hygrobatidae	1		1							1	1	
Water Fleas	**Cladocera**												
	Daphniidae												
Isopods	**Isopoda**												
Water Slater/hog louse	Asellidae								1	1	1	1	1
Dragon & Damselflies	**Odonata**												
Hawkers	Aeshnidae	1		1	1	1	1	1	1	1	1	1	1
Golden ringed	Cordulegasteridae												
Darters & Chasers	Libellulidae	1				1		1	1		1	1	
Emerald Damselflies	Lestidae	1	1	1	1	1	1	1	1	1	1	1	1

Red and Black/Blue Damsels	Coeangrionidae/ Coenagriidae	1	1	1	1	1	1	1	1	1	1	1	1
Caddisflies	**Goeridae**	1	1	1	1	1	1	1	1	1	1	1	1
	Rhyacophilidae				1								
	Phryganeidae	1											
	Limnephilidae	1			1								
	Leptoceridae	1											
	Polycentropidae												
Moth Larvae	**Lepidoptera**												
	Pyralidae	1	1	1	1		1					1	1
True flies larvae	**Diptera larvae**												
Craneflies	Tipulidae						1			1	1	1	1
Meniscus midges	Dixidae	1	1	1	1	1	1	1	1	1	1	1	1
Ghost/ Phantom midge	Chaoboridae	1	1	1	1					1	1	1	1
Mosquito & gnats	Culicidae	1			1		1	1	1	1		1	1
Biting midges	Ceratopogonidae	1		1						1		1	1
Nonbiting midges/ blood worm	Chironomidae	1	1	1	1					1	1	1	1
Horseflies	Tabanidae				1								
Beetles	**Coleoptera**												
Whirligig	Gyrinidae	1			1	1	1		1				
crawling water beetle	Haliplidae	1	1	1	1					1	1		1
diving beetle	Dytiscidae	1	1	1	1					1	1	1	1
Scavenger	Hydrophiliidae				1	1	1	1	1	1		1	1
Riffle	Elmidae												
Leaf beetle	Chrysomelidae												
Weevils	Curculionidae	1			1								
Snails	Mollusca												
Ramshorn snail	Planorbidae									1	1	1	
Pond snail	Lymnaeidae	1	1	1	1	1				1	1	1	1
Clams	Sphaeriidae												
Pea/ orb mussel	Sphaeriidae		1	1	1					1		1	
Mussel	Unionoida												
fw mussel	Unionoida			1									
Leech	Hirudinidae									1		1	1
worm	Oligochaeta		1							1			1

1 denotes the presence of an invertebrate family within a pond.

7.4 Appendix 4: Macrophyte Species List

	AC 2	AC 3	AC 4	AC 5	AC 6	AC 7	AC 8	AC C	AC D	AC E	AC F	AC G	AC I
Sagittaira saggitofolia													
Equisetum fluviatile	1	1	1	1	1	1	1			1		1	1
Eleocharis palustris	1	1	1	1	1	1	1		1	1		1	1
Juncus effusus	1	1	1	1	1	1	1	1	1	1	1	1	1
Juncus conglomeratus	1	1			1	1	1	1	1	1	1	1	1
Juncus acutiflorus													1
Juncus compressus									1				
Iris pseudocarus	1												
Carex pendula	1	1											
Mysotis scorpioides	1	1	1	1	1	1	1	1	1	1	1	1	
Carex rostrata	1	1	1	1	1	1	1	1	1	1	1	1	1
Glyceria fluitans	1	1	1	1	1	1	1			1	1		1
Eriophorum angustifolium	1	1					1			1			
Rannunculus flammula	1	1		1		1	1	1	1	1		1	
Potamogeton natans	1	1	1	1	1	1	1			1	1		1
Myriophyllum sp	1	1	1	1		1	1			1			
Typha latifolia		1	1		1		1		1	1	1	1	1
Sparganium erectum					1	1		1		1	1		
Ranunculus lingua					1	1	1		1				
Equisetum fluviatile													
Veronica anagallis-aquatica													
Epilobium palustre													
Alisma lanceolatum							1						

	BB 1	BB 2	BB 3	BB 4	BB 5	BB 6	BB 7	BB 8	SS 1	SS 2	SS 3
Sagittaira saggitofolia											
Equisetum fluviatile	1			1	1	1		1	1		1
Eleocharis palustris	1				1	1		1		1	1
Juncus effusus	1	1	1	1	1	1	1	1	1	1	1
Juncus conglomeratus	1	1	1	1	1	1	1	1	1	1	1
Juncus acutiflorus	1	1	1	1	1	1	1	1			1
Juncus compressus											
Iris pseudocarus											
Carex pendula	1	1		1		1	1				
Mysotis scorpioides	1	1	1	1	1	1	1	1	1	1	
Carex rostrata	1	1	1	1	1	1	1	1	1	1	1
Glyceria fluitans	1	1	1	1	1	1	1	1			
Eriophorum angustifolium	1	1		1	1	1	1	1	1	1	1
Rannunculus flammula	1	1	1	1	1	1	1	1	1	1	1
Potamogeton natans	1	1	1	1	1	1	1	1	1	1	1
Myriophyllum sp	1	1			1		1	1	1	1	1
Typha latifolia	1	1	1	1	1		1	1			
Sparganium erectum	1	1	1	1	1		1	1			1
Ranunculus lingua					1		1	1	1	1	1
Equisetum fluviatile					1		1	1	1	1	1
Veronica anagallis-aquatica											
Epilobium palustre											
Alisma lanceolatum											

	GQ 11	GQ 12	GQ 13	GQ 14	GQ 15	GQ 16	GQ 17	RJ 1	RJ 2	RJ 3	RJ 4	RJ 5	RJ 6
Sagittaira saggitofolia													
Equisetum fluviatile	1				1		1		1			1	1
Eleocharis palustris	1	1	1	1	1	1	1	1	1		1	1	1
Juncus effusus	1	1	1	1	1	1	1	1	1	1	1	1	
Juncus conglomeratus	1	1	1	1	1	1	1	1	1	1	1	1	
Juncus acutiflorus	1	1	1	1	1	1	1			`			
Juncus compressus						1							
Iris pseudocarus													
Carex pendula						1	1						
Mysotis scorpioides	1	1	1	1	1	1	1	1	1		1	1	1
Carex rostrata	1	1	1	1	1	1	1	1	1	1	1	1	1
Glyceria fluitans	1		1	1	1	1	1	1		1	1	1	1
Eriophorum angustifolium			1	1	1	1	1	1		1			
Rannunculus flammula	1		1	1	1	1	1	1	1	1	1	1	1
Potamogeton natans	1	1	1	1	1		1	1	1	1	1		
Myriophyllum sp			1	1	1	1	1		1	1	1		
Typha latifolia	1		1	1	1	1	1	1	1			1	1
Sparganium erectum	1		1	1	1	1					1		
Ranunculus lingua	1	1	1	1	1	1	1	1		1	1	1	
Equisetum fluviatile	1	1	1	1	1	1	1						
Veronica anagallis-aquatica	1	1			1	1							
Epilobium palustre	1		1		1	1							
Alisma lanceolatum													

7.5 Appendix 5: PSYM Sample Data Sheet

Pond PSYM Datasheet (Long)

SITE AND SAMPLE DETAILS

Site name		Code no.	
Location		Grid ref.	
Surveyor		Survey date	
Site access details			

Notes

Altitude (m)		pH	
Shade: % pond overhung		% emergent plant cover	
Inflow: absent=0, present=1		Pond area (m^2)	
% of pond margin grazed			

Pond base: categorise into one of three groups: 1 = 0% - 32%, 2 = 33% - 66%, 3 = 67% - 100%

Clay / silt		Sand, gravel, cobbles		Bed rock	
Peat		Other			

MACROINVERTEBRATE LIST: Enter 1 if group is present; remember to fill in ASPT, OM and Cole boxes

Group 1 taxa (BMWP:	ASPT	OM	Cole.
Siphlonuridae			
Heptageniidae			
Leptophlebiidae			
Ephemerellidae			
Potamanthidae			
Ephemeridae			
Taeniopterygidae			
Leuctridae			
Capniidae			
Perlodidae			
Perlidae			
Chloroperlidae			
Aphelocheiridae			
Phryganeidae			
Molannidae			
Beraeidae			
Odontoceridae			
Leptoceridae			
Goeridae			
Lepidostomatidae			
Brachycentridae			
Sericostomatidae			
No. of taxa	0		

Group 2 taxa (BMWP: 8)	ASPT	OM	Cole.
Astacidae			
Lestidae			
Calopterygidae (Agriidae)			
Gomphidae			
Cordulegasteridae			
Aeshnidae			
Corduliidae			
Libellulidae			
Philopotamidae			
Psychomyiidae			
No. of taxa	0	0	

Group 3 taxa (BMWP: 7)	ASPT	OM	Cole.
Caenidae			
Nemouridae			
ecophilidae (Glossomatidae)			
Polycentropodidae			
Limnephilidae			
No. of taxa	0		

Group 4 taxa (BMWP: 6)	ASPT	OM	Cole.
Neritidae			
Viviparidae			
Ancylidae (Acroloxidae)			
Hydroptilidae			
Unionidae			
Corophiidae			
ammaridae (Crangonyctidae)			
Platycnemididae			
Coenagriidae			
No. of taxa	0	0	

Group 5 taxa (BMWP: 5)	ASPT	OM	Cole.
Planariidae (Dugesiidae)			
Dendrocoelidae			
Mesoveliidae			
Hydrometridae			
Gerridae			
Nepidae			
Naucoridae			
Notonectidae			
Pleidae			
Corixidae			
Haliplidae			
Hygrobiidae			
Dytiscidae (Noteridae)			
Gyrinidae			
Hydrophilidae (Hydraenidae)			
Dryopidae			
Elmidae			
Hydropsychidae			
Tipulidae			
Simuliidae			
No. of taxa	0		0

Group 6 taxa (BMW	ASPT	OM	Cole
Baetidae			
Sialidae			
Piscicolidae			
No. of taxa	0	0	

Group 7 taxa (BMWP: 3)	ASPT	OM	Cole
Valvatidae			
ydrobiidae (Bithyniidae)			
Lymnaeidae			
Physidae			
Planorbidae			
Sphaeriidae			
Glossiphoniidae			
Hirudinidae			
Erpobdellidae			
Asellidae			
No. of taxa	0		

Group 8 taxa (BMWP: 2)	ASPT	OM	Cole
Chironomidae			
No. of taxa	0		

Group 9 taxa (BMWP: 1)	ASPT	OM	Cole
Oligochaeta			
No. of taxa	0		

	ASPT	OM	Cole
TOTAL NO. OF TA	0		
TOTAL BMWP SC	0		
ASPT	0		
NO. OF OM TAXA		0	
NO. COLEOPT. TAXA			0

PLANT LIST

R = Rarity Score, T = Trophic Ranking Score (TRS)

Enter 1 if species present

	R	T	Emergent Plants
	1		Achillea ptarmica
	1		Acorus calamus
	1		Agrostis canina
	1		Agrostis stolonifera
	#		Alisma gramineum
	2		Alisma lanceolatum
	1	9	Alisma plantago-aquatica
	2		Alopecurus aequalis
	4		Alopecurus borealis
	1		Alopecurus geniculatus
	2		Anagallis tenella
	2		Andromeda polifolia
	1		Angelica archangelica
	1		Angelica sylvestris
	2		Apium graveolens
	1	10	Apium nodiflorum
	#		Apium repens
	2		Baldellia ranunculoides
	2	10	Berula erecta
	2		Bidens cernua
	1		Bidens connata
	1		Bidens frondosa
	2		Bidens tripartita
	2		Blysmus compressus
	2		Bolboschoenus maritimus
	2		Butomus umbellatus
	2		Calamagrostis canescens
	2		Calamagrostis epigejos
	8		Calamagrostis purpurea
	8		Calamagrostis stricta
	#		Calamagrostis scotica
	1		Calla palustris
	1	7	Caltha palustris
	1		Cardamine amara
	1		Cardamine pratensis
	2		Carex acuta
	1	10	Carex acutiformis
	4		Carex appropinquata
	2		Carex aquatilis
	2		Carex curta
	2		Carex diandra
	1		Carex disticha
	1		Carex echinata
	2	10	Carex elata
	4		Carex elongata
	1		Carex flacca
	1		Carex hostiana
	2		Carex laevigata
	2	4	Carex lasiocarpa
	2	4	Carex limosa
	1	5	Carex nigra
	1		Carex oedocarpa
	1		Carex otrubae
	1		Carex panicea
	2	10	Carex paniculata
	1		Carex pendula
	2	10	Carex pseudocyperus
	1		Carex pulicaris
	1	10	Carex riparia
	1	5.3	Carex rostrata
	2		Carex spicata
	2		Carex vesicaria
	1		Carex viridula
	#		Carex vulpina
	1		Carex sp.
	2		Catabrosa aquatica
	4		Cicuta virosa
	2		Cirsium dissectum
	1		Cirsium palustre
	2		Cladium mariscus
	1		Conium maculatum
	1		Crassula helmsii
	1		Crepis paludosa
	#		Cyperus fuscus
	4		Cyperus longus
	2		Dactylorhiza sp (undet.)
	#		Damasonium alisma
	1		Deschampsia cespitosa
	2		Drosera anglica
	1		Drosera binata
	1		Drosera capensis
	2		Drosera intermedia
	1		Drosera rotundifolia
	#		Dryopteris cristata
	2		Eleocharis acicularis
	8		Eleocharis austriaca
	2		Eleocharis multicaulis
	1		Eleocharis palustris
	2		Eleocharis quinqueflora
	2		Eleocharis uniglumis
	2		Epilobium alsinifolium
	2		Epilobium anagallidifolium
	1		Epilobium brunnescens
	1		Epilobium ciliatum

Enter 1 if species present

	R	T	Emergent Plants (con
	1		Epilobium hirsutum
	1		Epilobium obscurum
	1		Epilobium palustre
	1		Epilobium parviflorum
	2		Epilobium tetragonum
	2		Epipactis palustris
	1		Equisetum fluviatile
	1		Equisetum palustre
	1		Erica tetralix
	1	3	Eriophorum angustifolium
	#		Eriophorum gracile
	2		Eriophorum latifolium
	1		Eriophorum vaginatum
	1		Eupatorium cannabinum
	1		Filipendula ulmaria
	2		Galium boreale
	8		Galium constrictum
	1		Galium palustre
	2		Galium uliginocountif
	1		Geum rivale
	2		Glyceria declinata
	1		Glyceria fluitans
	1	10	Glyceria maxima
	2		Glyceria notata
	1		Gnaphalium uliginocountif
	1		Hydrocotyle vulgaris
	2		Hypericum elodes
	1		Hypericum tetrapterum
	4		Hypericum undulatum
	2		Impatiens capensis
	1		Impatiens glandulifera
	4		Impatiens noli-tangere
	1		Iris pseudacorus
	1		Isolepis setacea
	1		Juncus acutiflorus
	1		Juncus articulatus
	1		Juncus bufonius agg.
	1	5	Juncus bulbosus
	2		Juncus compressus
	1		Juncus conglomeratus
	1		Juncus effusus
	2		Juncus foliosus
	1		Juncus inflexus
	#		Juncus pygmaeus
	2		Juncus subnodulosus
	4		Lathyrus palustris
	#		Leersia oryzoides
	#		Liparis loeselii
	1		Lotus pedunculatus
	1		Luzula luzuloides
	2		Luzula sylvatica
	1		Lychnis flos-cuculi
	1		Lycopus europaeus
	1		Lysimachia nummularia
	1		Lysimachia terrestris
	4		Lysimachia thyrsiflora
	2		Lysimachia vulgaris
	#		Lythrum hyssopifolium
	2		Lythrum portula
	1		Lythrum salicaria
	1	7	Mentha aquatica
	#		Mentha pulegium
	1	5	Menyanthes trifoliata
	1		Mimulus guttatus
	1		Mimulus luteus
	#		Minuartia stricta
	1		Molinia caerulea
	1		Montia fontana
	1	8	Myosotis laxa
	1	9	Myosotis scorpioides
	1		Myosotis secunda
	4		Myosotis stolonifera
	1		Myosotis sp (undet.).
	2		Myosoton aquaticum
	1		Myrica gale
	1		Narthecium ossifragum
	2		Oenanthe aquatica
	1		Oenanthe crocata
	2		Oenanthe fistulosa
	2		Oenanthe fluviatilis
	2		Oenanthe lachenalii
	2		Oenanthe pimpinelloides
	4		Oenanthe silaifolia
	2		Osmunda regalis
	2		Parnassia palustris
	1		Pedicularis palustris
	1	10	Persicaria hydropiper
	1		Persicaria maculosa
	2		Persicaria minor
	4		Persicaria mitis
	1		Petasites hybridus
	1		Petasites japonicus
	4		Peucedanum palustre
	1	9	Phalaris arundinacea

Enter 1 if species present

	R	T	Emergent Plants (cont'd)
	1	7	Phragmites australis
	4	6	Pilularia globulifera
	2		Pinguicula lusitanica
	1		Pinguicula vulgaris
	1		Potentilla erecta
	1	5	Potentilla palustris
	1		Pulicaria dysenterica
	#		Pulicaria vulgaris
	1		Ranunculus ficaria
	1		Ranunculus flammula
	2	10	Ranunculus hederaceus
	2		Ranunculus lingua
	2		Ranunculus omiophyllus
	#		Ranunculus ophioglossifolius
	#		Ranunculus reptans
	1	10	Ranunculus sceleratus
	2		Rhynchospora alba
	4		Rhynchospora fusca
	2		Rorippa amphibia
	8		Rorripa islandica
	2	10	Rorippa microphylla
	1	10	Rorippa nasturtium-aquaticum
	1	10	Rorippa (undet.).
	1		Rorippa palustris
	2	10	Rumex hydrolapathum
	2		Rumex maritimus
	2		Rumex palustris
	1		Sagina procumbens
	1		Sagittaria subulata
	2		Samolus valerandi
	2	8	Schoenoplectus lacustris
	#		Schoenoplectus pungens
	2		Schoenoplectus tabernaemonta
	#		Schoenoplectus triqueter
	#		Schoenus ferrugineus
	2		Schoenus nigricans
	#		Scorzonera humilis
	1		Scrophularia auriculata
	1		Scutellaria galericulata
	1		Senecio aquaticus
	1		Senecio fluviatilis
	#		Senecio paludosus
	4		Sium latifolium
	1	10	Solanum dulcamara
	4		Sonchus palustris
	1	9	Sparganium erectum
	1		Stachys palustris
	2		Stellaria palustris
	1		Stellaria uliginosa
	1		Symphytum officinale
	#		Teucrium scordium
	2		Thalictrum flavum
	4		Thelypteris palustris
	2		Tofieldia pusilla
	1		Trichophorum cespitocountif
	1		Triglochin palustre
	2	10	Typha angustifolia
	1	9	Typha latifolia
	2		Valeriana dioica
	1		Vallisneria spiralis
	1		Veronica anagallis-aquatica
	1	10	Veronica beccabunga
	2		Veronica catenata
	1	6	Veronica scutellata
	1		Veronica sp. (undet.)
	1		Viola palustris
	#		Viola persicifolia
	1		Unknown exotic

	R	T	Floating-leaved Plants
	1		Azolla filiculoides
	2		Hydrocharis morsus-ranae
	1		Hydrocotyle ranunculoides
	2		Lemna gibba
	1	9	Lemna minor
	1		Lemna minuta
	1	10	Lemna trisulca
	4		Luronium natans
	1		Menyanthes trifoliata
	1		Nuphar advena
	2	9	Nuphar lutea
	4	7	Nuphar pumila
	2	7	Nymphaea alba
	1		Nymphaea sp. (exotic)
	4		Nymphoides peltata
	1	9	Persicaria amphibia
	1		Potamogeton natans
	1	4	Potamogeton polygonifolius
	2		Riccia fluitans
	2		Ricciocarpus natans
	2		Spirodela polyrhiza
	4		Wolffia arrhiza

Enter 1 if species present

	R	T	Submerged Plants
	2	6	Apium inundatum
	1		Aponogeton distachyos
	1		Cabomba caroliniana
	2		Callitriche brutia
	1	6	Callitriche hamulata
	2	9	Callitriche hermaphroditica
	2		Callitriche obtusangula
	2		Callitriche platycarpa
	1	7	Callitriche stagnalis
	4		Callitriche truncata
	1		C. stagnalis/platycarpa agg.
	1		C. hamulata/brutia agg.
	1		Callitriche sp. (undet.)
	2	10	Ceratophyllum demercountif
	2		Ceratophyllum submercountil
	2	7	Chara sp.
	1		Egeria densa
	4	7	Elatine hexandra
	4		Elatine hydropiper
	2		Eleogiton fluitans
	1		Elodea callitrichoides
	1	7	Elodea canadensis
	1	10	Elodea nuttallii
	8		Eriocaulon aquaticum
	1	6	Fontinalis antipyretica
	2		Groenlandia densa
	2	8	Hippuris vulgaris
	2		Hottonia palustris
	4		Isoetes echinospora
	2	5	Isoetes lacustris
	1		Lagarosiphon major
	2	7	Littorella uniflora
	2	5	Lobelia dortmanna
	8		Ludwigia palustris
	1	7	Myriophyllum alterniflorum
	1		Myriophyllum aquaticum
	2	9	Myriophyllum spicatum
	4		Myriophyllum verticillatum
	4		Najas flexilis
	2	7	Nitella sp.
	2		Oenanthe fluviatilis
	#		Potamogeton acutifolius
	2	6	Potamogeton alpinus
	2	7	Potamogeton berchtoldii
	4		Potamogeton coloratus
	4		Potamogeton compressus
	1	10	Potamogeton crispus
	#		Potamogeton epihydrus
	4	10	Potamogeton filiformis
	2	10	Potamogeton friesii
	2	7	Potamogeton gramineus
	2	10	Potamogeton lucens
	8		Potamogeton nodosus
	2	8	Potamogeton obtusifolius
	1	10	Potamogeton pectinatus
	2	7	Potamogeton perfoliatus
	2	9	Potamogeton praelongus
	2	9	Potamogeton pusillus
	8		Potamogeton rutilus
	4	10	Potamogeton trichoides
	2	10	Ranunculus aquatilis
	2	10	Ranunculus baudotii
	2	10	Ranunculus circinatus
	2		Ranunculus fluitans
	2	7	Ranunculus peltatus
	2	9	Ranunculus penicillatus
	2	9	Ranunculus trichophyllus
	#		Ranunculus tripartitus
	1		Ranunculus sp. (undet.)
	1		Sagittaria latifolia
	1		Sagittaria rigida
	2		Sagittaria sagittifolia
	2	4	Sparganium angustifolium
	1	10	Sparganium emersum
	2		Sparganium natans
	1	3	Sphagnum sp.
	4		Stratiotes aloides
	2	4	Subularia aquatica
			Tolypella sp.
	2		Utricularia australis
	2	4	Utricularia intermedia
	2	4	Utricularia minor
	2	5	Utricularia vulgaris
	1		Vallisneria spiralis
	2	10	Zannichellia palustris

0	Number of emergent & submerged species
0	Number of uncommon species (with a rarity score
#DIV/0!	Trophic Ranking Score (TRS)

NOTES: >>> Species whose Rarity Score is in an unshaded box are uncommon species often introduced to sites (see Preston *et al* 2002). If the species is likely have been introduced, do not include it in the "Number of uncommon species" total score. You can change it by removing the rarity score for the specific species (i.e. 2, 4, 8, 16 or 32) and replacing it with 1.

PSYM PARAMETER SUMMARY (generated from pages 1 and 2)	
Site details	
Site name	
Survey date	**0-Jan-00**
Grid reference (*e.g.* SP123456 or higher precision)	**0**
Plant metrics	
No. of submerged + marginal plant species (not including floating leaved)	**0**
Number of uncommon plant species	**0**
Trophic Ranking Score (TRS)	**#DIV/0!**
Invertebrates metrics	
ASPT	**0**
Odonata + Megaloptera (OM) families	**0**
Coleoptera families	**0**
Environmental variables	
Altitude (m)	**0**
Easting	**Office Use**
Northing	**Office Use**
Shade (%)	**0**
Inflow (0/1)	**0**
Grazing (%)	**0**
pH	**0**
Emergent plant cover (%)	**0**
Base clay (1-3)	**0**
Base sand, gravel, cobbles (1-3)	**0**
Base peat (1-3)	**0**
Base rock (1-3)	**0**
Area (m^2)	**0**

7.6 Appendix 6: PSYM Scottish Caveat

PSYM PARAMETER SUMMARY (generated from pages 1 and 2)				
Site details				
Site name	Gartcosh Bothlin Burn 1			
Survey date	1-Jul-07			
Grid reference (*e.g.* SP123456 or higher	NS 2705 6685			
Plant metrics				
No. of submerged + marginal plant species (not including floating leaved)	13			
Number of uncommon plant species	0			
Trophic Ranking Score (TRS)	6.76			
Invertebrates metrics				
ASPT	5.705882353			
Odonata + Megaloptera (OM) families	4			
Coleoptera families	3			
Environmental variables				
Altitude (m)	87			
Easting	Office Use			
Northing	Office Use			
Shade (%)	0			
Inflow (0/1)	0			
Grazing (%)	0			
pH	8.3			
Emergent plant cover (%)	20			
Base clay (1-3)	3			
Base sand, gravel, cobbles (1-3)	0			
Base peat (1-3)	0			
Base rock (1-3)	0			
Area (m^2)	313			
Results				
Submerged + marginal plant species				
Predicted (SM)	17.86			
EQI (SM)	0.73			
IBI (SM)	2	Max score =3		
Uncommon plant species				
Predicted (U)	3.25			
EQI (U)	0.00			
IBI (U)	0	Max score =3		
Trophic Ranking Score (TRS)		LEAVE THIS OUT		
Predicted (TRS)	7.43	LEAVE THIS OUT		
EQI (TRS)	0.91	LEAVE THIS OUT		
IBI (TRS)	2	LEAVE THIS OUT		
ASPT				
Predicted (ASPT)	5.15			
EQI (ASPT)	1.11			
IBI (ASPT)	3	Max score =3		
Odonata + Megaloptera (OM) families				
Predicted (OM)	3.38			
EQI (OM)	1.18			
IBI (OM)	3	Max score =3		
Coleoptera families				
Predicted (CO)	3.81			
EQI (CO)	0.79			
IBI (CO)	3	Max score =3		
Sum of Individual Metrics	13	Sum of you metrics omitting the TRS (i.e. 2+0+3+3+3) = 11		
		Out of a possible max of 15 (i.e. 5x3)		
Index of Biotic Integrity (%)	72%	Omitting TRS, you get a get a % score i.e.: 11 divided by 15	times100	73%
PSYM quality category (IBI >75%=Good, 51-75%= Moderate, 25-50%=Poor, <25%=V Poor)	Good			
Priority Ponds (IBI > 75%)	Yes			

7.7 Appendix 7: Habitat Suitability Index for Habitat BPP

Great Crested Newt Habitat Suitability Index

Background

The Habitat Suitability Index (HSI) for the great crested newt was developed by Oldham *et al.* (2000). HSI scoring systems were originally developed by the US Fish and Wildlife Service as a means of evaluating habitat quality and quantity. An HSI is a numerical index, between 0 and 1. 0 indicates unsuitable habitat, 1 represents optimal habitat. The HSI for the great crested newt incorporates ten suitability indices, all of which are factors thought to affect great crested newts. These ten suitability indices are retained in this current Guidance Note.

The HSI system proposed by Oldham *et al.* (2000) is fairly easy to use. However, one suitability index (SI_9, terrestrial) involves a more lengthy measurement and calculation than the other factors. In using the HSI system with volunteer surveyors in Kent, Lee Brady substituted a simpler evaluation of terrestrial habitat quality, a four-point scale. Volunteers have found this modified HSI relatively easy to use.

Several other, local, surveys have utilised the HSI, but utilised their own variations on the original system. In 2007, a workshop was held at the Herpetofauna Workers' Meeting to evaluate the use of the HSI for the great crested newt, with the aims of:

- identifying components of the system that may need clarification or refinement
- agreeing on a standard that can be easily used by volunteers and professionals alike.

A conservative approach has been adopted in modifying the use of the original HSI suitability indices.

Use and limitations of HSI

The HSI for great crested newts is a measure of habitat suitability. It is not a substitute for newt surveys. In general, ponds with high HSI scores are more likely to support great crested newts than those with low scores. However, the system is not sufficiently precise to allow the conclusion that any particular pond with a high score will support newts, or that any pond with a low score will not do so.

There is also a positive correlation between HSI scores and the numbers of great crested newts observed in ponds. So, in general, high HSI scores are likely to be associated with greater numbers of great crested newts. However, the relationship is not sufficiently strong to allow predictions to be made about the numbers of newts in any particular pond.

HSI scoring can be useful in:

- Evaluating the general suitability of a sample of ponds for great crested newts
- Comparing general suitability of ponds across different areas
- Evaluating the suitability of receptor ponds in a proposed mitigation scheme.

How to collect data and calculate HSI

The HSI is a geometric mean of ten suitability indices:

$$HSI = (SI_1 \times SI_2 \times SI_3 \times SI_4 \times SI_5 \times SI_6 \times SI_7 \times SI_8 \times SI_9 \times SI_{10})^{1/10}$$

- The ten Suitability Indices are scored for a pond, in the field and from map work.
- The ten field scores are then converted to SI scores, on a scale from 0.01 to 1 (0.01 is used as the bottom end of the range in stead of 0, because multiplying by 0 reduces all other SI scores to 0).
- The ten SI scores are then multiplied together.
- The tenth root of this number is then calculated $(X)^{1/10}$

The calculated HSI for a pond should score between 0 and 1.

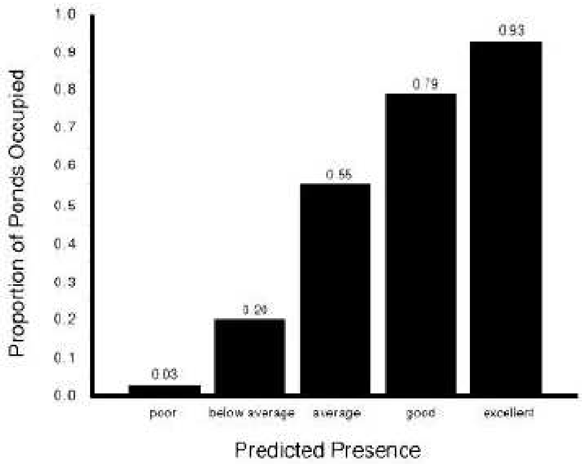
Some of the field scores are categorical, some are numerical. The numerical field scores are converted to SI scores by reading off the values from graphs produced by Oldham *et al.* (2000) reproduced in this Guidance Note.

The field scores are the data that should be collected by a surveyor. A summary of data to collect is given in *Summary of scoring system* below. More full details of the scoring system, including descriptions of the criteria used in the categorical scores are given in *Details of Suitability Indices and Definitions of Categories.* Two of the SI sores (SI_1 and SI_8) can be carried out as desktop/map exercises and so do not have to be completed in the field. The remaining SI scores should be recorded as field scores, and later converted to suitability indices, in some cases reading SI scores from the graphs provided in *Details of Suitability Indices and Definitions of Categories.*

Categorisation of HSI scores

Lee Brady has developed a system for using HSI scores to define pond suitability for great crested newts on a categorical scale:

HSI		Pond suitability
<0.5	=	poor
0.5 – 0.59	=	below average
0.6 – 0.69	=	average
0.7 – 0.79	=	good
> 0.8	=	excellent



Summary of scoring system

SI_1 Location

Field score	SI
A (optimal)	1
B (marginal)	0.5
C (unsuitable)	0.01

SI_2 Pond area

Field score	SI
Measure pond surface area (m^2) and round to nearest 50 m^2	Read off graph.

SI_3 Pond drying

Field score	SI	Criteria
Never	0.9	Never dries
Rarely	1.0	Dries no more than two years in ten or only in drought.
Sometimes	0.5	Dries between three years in ten to most years
Annually	0.1	Dries annually

SI_4 Water quality

Field score	SI	Criteria
Good	1.0	Abundant and diverse invertebrate community.
Moderate	0.67	Moderate invertebrate diversity
Poor	0.33	Low invertebrate diversity, few submerged plants
Bad	0.01	Clearly polluted, only pollution-tolerant invertebrates, no submerged plants.

SI_5 Shade

Field score	SI
Estimate percentage perimeter shaded to a least 1 m from shore.	Read off graph.

SI_6 Fowl

Field score	SI	Criteria
Absent	1	No evidence of water fowl (although moorhen may be present)
Minor	0.67	Waterfowl present, but little sign of impacts
Major	0.01	Severe impact of waterfowl

SI_7 Fish

Category	SI	Criteria
Absent	1	No records of fish stocking and no fish revealed during survey.
Possible	0.67	No evidence of fish, but local conditions suggest that they may be present.
Minor	0.33	Small numbers of crucian carp, goldfish or stickleback known to be present.
Major	0.01	Dense populations of fish known to be present.

SI_8 Ponds

Field score	SI
Count the number of ponds within 1 km of survey pond, not separated by major barriers, and divide by 3.14. This can be done from maps rather than in the field.	Read off graph.

SI_9 Terrestrial habitat

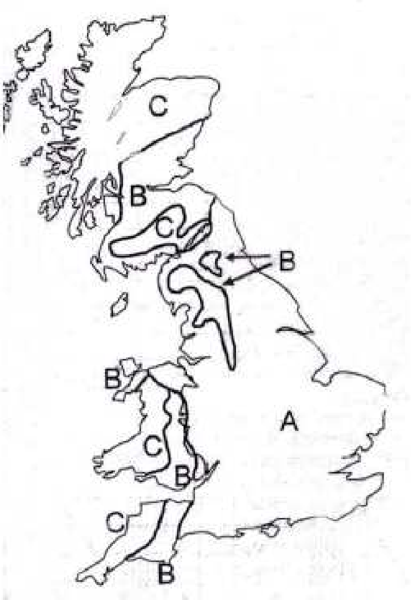
Field score	SI
Good	1
Moderate	0.67
Poor	0.33
None	0.01

SI_{10} Macrophytes

Field score	SI
Estimate the percentage of the pond surface area occupied by macrophyte cover (between May and the end of September)	Read off graph.

Details of Suitability Indices and Definitions of Categories

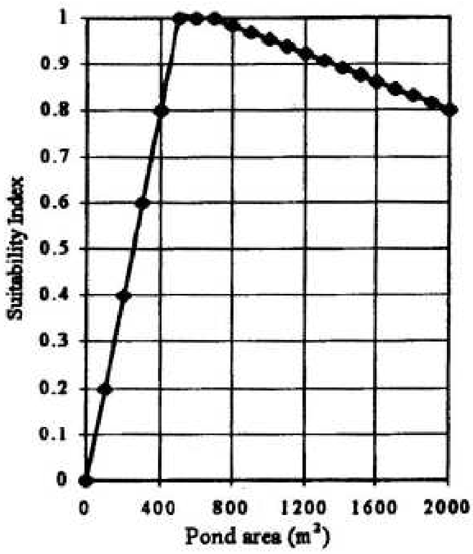
Factor 1. Geographic location (SI_1)



Sites should be scored according to the zone in which they occur. This scoring can be carried out either in the field, or as part of a desktop exercise.
Zone A, location is optimal, SI = 1
Zone B, location is marginal, SI = 0.5
Zone C, location is unsuitable, SI = 0.01.

Some sites will fall on boundary lines between zones. In such cases, select medium-value scores i.e. Zone B.

Factor 2. Pond area



Pond area is the surface area of the pond when water is at its highest level (excluding flooding events). This is usually in the spring. If the pond is being measured at another time of year, the springtime area should still be evident from vegetation types and evidence of a draw down zone around the pond.

Pond area should be measured as accurately as possible. There are several ways of doing this, for example by measuring axes of regularly shaped ponds, either by pacing out in the field, or using a map. Irregularly shaped ponds may have to be treated as a series of geometrical shapes, calculating the area for each and adding together.

Since it can be difficult reading off SI scores from graph, pond area should be rounded to nearest 50 m.

It can be particularly difficult to read off SI scores for very small ponds. For ponds smaller than 50 m^2a score of 0.05 should be used.

Factor 3. Permanence

Pond permanence should be deduced from local knowledge and on personal judgement. A landowner may know how often a pond dries. However, if not, the surveyor should make a judgement based on water level at the time of the survey, and taking seasonality into consideration. For example, a pond that is already dry by late spring is likely to dry out every year, etc.

Category	SI	Criteria
Never dries	0.9	Never dries.
Rarely dries	1.0	Dries no more than two years in ten or only in drought.
Sometimes dries	0.5	Dries between three years in ten to most years.
Dries annually	0.1	Dries annually.

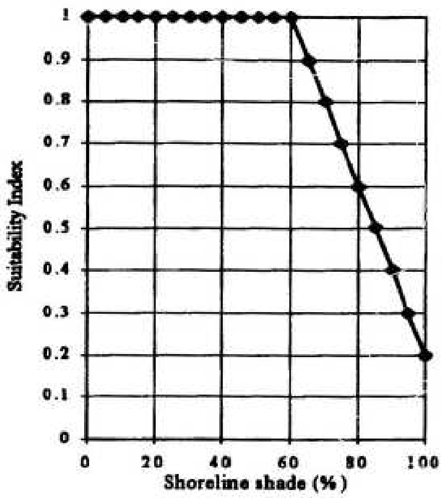
Factor 4. Water quality.

The assessment of water quality is subjective and should be based primarily on invertebrate diversity. Hence, water quality should not be confused with water clarity. Sometimes clear water can be devoid of invertebrates, and turbid ponds can support a wealth of invertebrates. There is no quick and simple invertebrate index of water quality. However, some species are indicators of water quality.

Category	SI	Criteria
Good	1.0	Water supports an abundant and diverse invertebrate community. Netting reveals handfuls of diverse invertebrates, including groups such as mayfly larvae and water shrimps.
Moderate	0.67	Moderate invertebrate diversity
Poor	0.33	Low invertebrate diversity (e.g. species such as midge and mosquito larvae. Few submerged plants.
Bad	0.01	Clearly polluted, only pollution-tolerant invertebrates (such as rat-tailed maggots), no submerged plants.

Other cues may also provide information about water quality. For example, ponds subject to agricultural inputs are likely to have poor water quality.

Factor 5. Shade



Estimate percentage pond perimeter shaded, to at least 1m from the shore. Shading is usually from trees, but can include buildings but should not include emergent pond vegetation. Estimate should be made during the period from May to the end of September.

Factor 6. Fowl

This factor is concerned with the impact of waterfowl upon a pond. At high densities, as created when waterfowl are encouraged to use a pond, by provision of food, the birds can remove all aquatic vegetation, pollute water and persistently stir sediments. Score as one of three categories.

Category	SI	Criteria
Absent	1	No evidence of waterfowl impact (moorhens may be present).
Minor	0.67	Waterfowl present, but little indication of impact on pond vegetation. Pond still supports submerged plants and banks are not denuded of vegetation.
Major	0.01	Severe impact of waterfowl. Little or no evidence of submerged plants, water turbid, pond banks showing patches where vegetation removed, evidence of provisioning waterfowl.

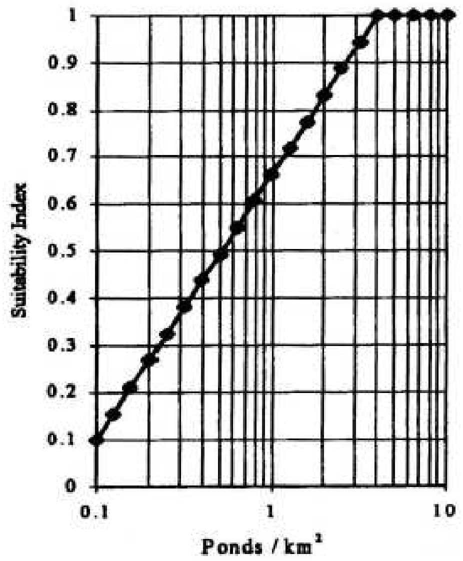
'Waterfowl' includes most water birds, such as ducks, geese and swans. Moorhens should be ignored because almost every pond has at least one or two.

Factor 7. Fish

Information on fish should be gleaned from local knowledge and the surveyor's own observations. Pond owners will usually be aware of stocking with fish for commercial or aesthetic reasons. However, stickleback (which can be significant predators of great crested newt larvae, when present in large numbers) are unlikely to be deliberately introduced to a pond, but may arrive through other means. Netting is useful in detecting smaller fish, such as sticklebacks, or the fry of larger species.

Category	SI	Criteria
Absent	1	No records of fish stocking and no fish revealed by netting or observed with torchlight.
Possible	0.67	No evidence of fish, but local conditions suggest that they may be present.
Minor	0.33	Small numbers of crucian carp, goldfish or stickleback known to be present.
Major	0.01	Dense populations of fish known to be present.

Factor 8. Pond count



This is the number of ponds occurring within 1 km of survey pond. Do not count the survey pond itself. Ponds on the far side of major barriers, such as main roads, should not be counted. Use 1:25,000 scale O.S. data, such as Explorer maps, GIS or web-based mapping sources. Pond counts can be carried out a by a survey coordinator and so do not necessarily have to be performed by surveyors.

Getamap	www.ordnancesurvey.co.uk/oswebsite/getamap/
Magic	www.magic.gov.uk/site_map.html
Digimap	edina.ac.uk/digimap/

Divide the number of ponds by Pi (3.14) to calculate the density of ponds per km^2, and read off graph.

Factor 9. Terrestrial

Scoring terrestrial habitat depends on the surveyor's understanding of newt habitat quality. Good terrestrial habitat offers cover and foraging opportunities and includes meadow, rough grassland, hedges, scrub and woodland. Terrestrial habitat should be considered only on the near side of any major barriers to dispersal (e.g. main roads or large expanses of bare habitat).

Category	SI	Criteria
Good	1	Extensive area of habitat that offers good opportunities for foraging and shelter completely surrounds pond (e.g. rough grassland, scrub or woodland).
Moderate	0.67	Habitat that offers opportunities for foraging and shelter, but may not be extensive in area and does not completely surround pond.
Poor	0.33	Habitat with poor structure that offers limited opportunities for foraging and shelter (e.g. amenity grassland).
None	0.01	Clearly no suitable habitat around pond (e.g. centre of large expanse of bare habitat).

Great crested newts do not have specific habitat requirements. However, good quality terrestrial habitat has structure. The presence of rabbit borrows, small mammal holes, proximity to old farm buildings, stone walls, piles of loose stone/rock all contribute towards 'good' terrestrial habitat. Note that it is rare to encounter a pond with a terrestrial habitat category of 'none'.

Factor 10. Macrophytes

Estimate the percentage of the pond surface area occupied by macrophyte cover. This includes emergents, floating plants (excluding duckweed) and submerged plants reaching the surface. Make estimate during the newt breeding season (March to May). Read off SI value from graph.

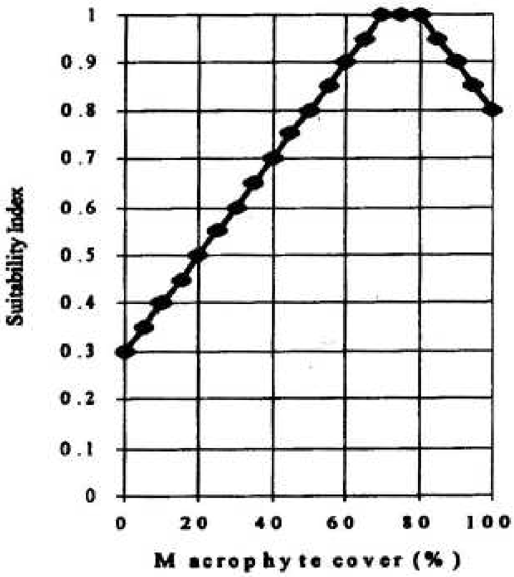
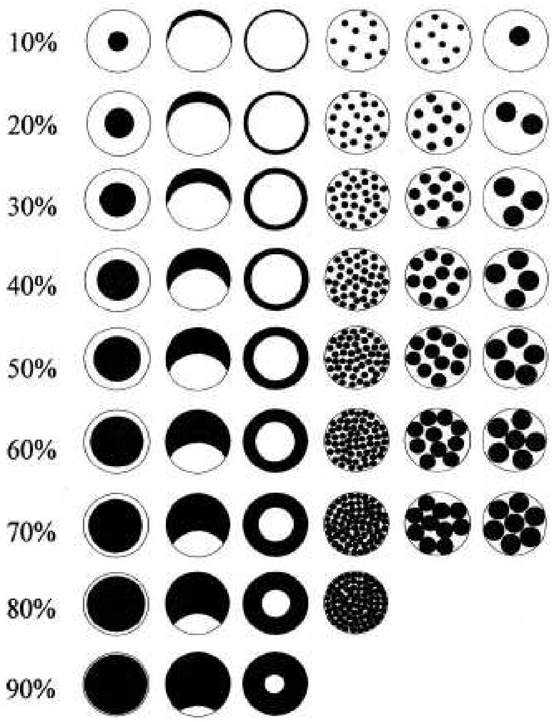


Fig. Guide for use in assessment of the proportions of vegetation cover in a pond. The areas of dark shading simulate a variety of vegetation dispersion patterns.



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