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Developing a methodology for the National Frog Survey of Ireland: a pilot study in Co. Mayo

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A National Frog Survey of Ireland is planned for spring 2011. We conducted a pilot survey of 25 water bodies in ten 0.25 km² survey squares in Co. Mayo during spring 2010. Drainage ditches were the most commonly available site for breeding and, generally, two 100 m stretches of ditch were surveyed in each square. The restricted period for peak spawning activity renders any methodology utilizing only one site visit inherently risky. Consequently, each site was visited three times from late March to early April. Occurrence of spawn declined significantly from 72 % to 44 % between the first and third visit whilst the overall occurrence of spawn at all sites was 76 %. As the breeding season advanced, spawn either hatched or was predated and, therefore, disappeared. In those water bodies where spawning was late, however, greater densities of spawn were deposited than in those sites where breeding was early. Consequently, spawn density and estimated frog density did not differ significantly between site visits. Future surveys should nevertheless include multiple site visits to avoid biased estimation of species occurrence and distribution. Ecological succession was identified as the main threat present at 44 % of sites.

Keywords: estimated density, EU Habitats Directive, *Rana temporaria*, spawn surveys

Introduction

Ireland has three native amphibians, the most widespread and abundant of which is the common frog (*Rana temporaria* L.) (Ní Lamhna 1979, Teacher *et al*. 2009). This species hibernates in or near water bodies, breeding synchronously after emergence in ponds, bogs, ditches and other still or slow-moving water (Arnold and Ovenden 1978, Inns 2009). Spawning occurs in shallow water usually 15 - 30 cm deep (Cooke 1975, Arnold and Ovenden 1978). One spawn clump per female is produced (Griffiths and Raper 1994) but these usually aggregate into a communal egg mass or masses (Håkansson and Loman 2004). The successful breeding of frogs can be determined at any given water body by observing spawn, tadpoles and/or metamorph froglets, and population size can be determined by counting individual spawn clumps or estimating total spawn clump area (Griffiths *et al*. 1996).

In Great Britain, the National Amphibian and Reptile Recording Scheme has been developed by Amphibian and Reptile Conservation. The project aims to establish a baseline of population and abundance data for widespread amphibians and reptiles to facilitate the assessment of Biodiversity Action Plans and identify the threats posed to each species. The common frog is

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Figure 1. Common frogs (*Rana temporaria* L.) in a garden wildlife pond in Co. Clare. Photo: Joan O'Neill.

threatened by ecological succession and loss of ponds due to agricultural intensification, introduction of fish to breeding sites and development pressures (Beebee and Griffiths 2000). However, some population losses have been offset in Great Britain by a trend for creating garden ponds (Beebee 1979) (Fig.1).

In Ireland, frogs are protected under the Irish Wildlife Act (1976, amended 2000) and are listed on Annex V of the Directive on the Conservation of Natural Habitats of Wild Fauna and Flora (92/43/EEC), hereafter referred to as the EU Habitats Directive. Article 17 of the latter requires that signatory states report regularly to the European Commission on the species' conservation status. Three surveys carried out between 1993 and 2003 suggested that the frog is present in almost every 10 km square in the Republic of Ireland and, where habitat is suitable, is frequently abundant (IPCC 2003). Nevertheless, the species was deemed to be in 'poor' conservation status in the last Article 17 report due to ongoing threats to remaining suitable habitat, principally wetland drainage and intensive urban and suburban development, resulting in anecdotal reports of local extinction (NPWS 2008a). The report also identified concerns about our level of knowledge of frog abundance and the species' ability to adapt to habitat fragmentation.

During 2010, the National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, issued a contract to develop a national survey methodology for the common frog that would meet obligations for the species under Article 11 of the EU Habitats Directive. The survey will provide necessary population and habitat data to inform the next Article 17 report (due 2013). It will also provide a baseline for future monitoring of the conservation status of the species in Ireland similar to that provided by the National Amphibian and Reptile Recording Scheme in Great Britain. Prior to full implementation of the 'National Frog Survey of Ireland 2011', this project aimed to pilot the proposed methodology.

Methods

A total of ten 1 km^2 squares was selected in Co. Mayo from those used by BirdWatch Ireland in the Common Bird Survey. In each, the most south-westerly 0.25 km^2 square was surveyed. Initially, surveyors mapped all suitable frog breeding sites, such as drainage ditches, ponds, bog pools, lakes, rivers, swamp/marsh or temporary water features. Where a square failed to contain any water bodies, an adjacent 0.25 km^2 square, beginning with the one to the north and working in a clockwise direction within the same 1 km^2 square, was surveyed. A maximum two 100 m of drainage ditch were randomly selected for spawn surveys as well as any remaining discrete water bodies, up to a maximum of three.

A total of three return visits was made during early spring 2010 to survey spawn. The first visit was made shortly after the first appearance of spawn locally (about 26 March) with the second (about 1 April) and third (about 7 April) being made approximately 7 and 14 days after the first. This method was taken from Griffiths *et al.* (1996) as it standardizes comparisons between sites and allows for the swelling of the clumps that occurs after deposition. Later site visits increase the risk that spawn may become camouflaged by algal growth and/or begin to disintegrate after hatching (sensu Beebee and Griffiths 2000). Similarly, earlier visits may not detect all clumps but may help to identify the days of peak spawning. The dimensions (length and width) and estimated depth of each potential breeding site were recorded and marked on a 1:10 000 scale Ordnance Survey map prior to digitization on ArcGIS 3.3 (ESRI, California, USA). During spawn surveys, the total cumulative spawn mat area (cm^2) was recorded.

Griffiths *et al.* (1996) demonstrated that cumulative spawn mat area (x) exhibits a linear relationship with the number of discrete spawn clumps (y_1) originally deposited (where $y_1 = 2.27 + 0.007x$). This equals the number of breeding females as each female deposits only one clump per season. Assuming an effective sex ratio of 1:1, the estimated frog density (y_2), expressed as frogs m^{-2} per surveyed breeding site, can be calculated using the formula:

$$y_2 = \frac{2(2.27 + 0.007x)}{LB}$$

where L equals the length of the water body and B equals its width (m^2). The majority of surveyed water bodies were roughly oblong in shape, but the formula can be easily adapted to accommodate the calculated surface area of a roughly circular pond or pool (πr^2).

Environmental data were also collected for each water body including information on surrounding landscapes, habitats (Fossitt 2000) and terrestrial refuges (Marnell 1998) as well as water quality. Perceived threats or pressures were also noted using the EU Habitat Directive's categories listed in NPWS (2008b).

Descriptive statistics were used to clarify trends in species occurrence, mean spawn density ($cm^2\ m^{-2}$) and mean estimated frog density (frogs m^{-2}) during each site visit, including the overall mean of the maximum values recorded for each water body. Changes in the occurrence of spawn between site visits were tested statistically using χ^2 tests of association. 95 per cent confidence intervals were generated for percentage occurrence data by 1000 iteration resample bootstrapping using the RSXL Resampling Stats add-in for Excel v4.0, whilst confidence intervals for standard means were calculated from the standard deviation. Variance in spawn density and estimated frog density were examined using Linear Mixed Models (LMMs) fitting 'Water body ID' nested within 'Square ID' as a random factor and 'Visit number' and 'Water body type' as fixed factors. Mean spawn density and frog density calculated from the raw data for each water body type would be biased by variance due to multiple site visits. Therefore, we present the estimated marginal mean which statistically accounts for variance within 'Water body ID' nested within 'Square ID'. Environmental parameters associated with frog presence were investigated using logistic regression.

Results

A total of 25 potential breeding sites was surveyed for spawn within the ten 0.25 km^2 survey squares. A total of fifteen 100 m stretches of drainage ditch were surveyed while the remaining ten water bodies were composed of various types, including bog pools, lake edges, rivers, swamp/marsh and temporary water features.

Occurrence of spawn did not differ between the first and second site visit (χ^2 (1 d.f.) = 0.10, p=0.758), but there was a significant decline from 72 per cent to 44 per cent occurrence between the first and third visit (χ^2 (1 d.f.) = 4.02, p = 0.045; Table 1). Overall occurrence (76 %) was similar to that recorded during the first site visit.

Neither the spawn density nor estimated frog density varied significantly between site visits (F (2,26 d.f.) = 0.271, p = 0.794 and F (2,23 d.f.) = 0.276, p = 0.761 respectively; Table 1). There was, however, a general positive trend in both spawn and frog density when negative sites were excluded (Table 1).

Accounting for the number of site visits, estimated marginal mean spawn density did not vary significantly between water body types (F (5,18 d.f.) = 1.621, p = 0.205). However, calculated frog density did vary significantly (F (5,19 d.f.) = 7.978, p <0.001), albeit with wide 95 per cent confidence intervals due to small sample sizes (Table 2). The greatest density of frogs was recorded at a single temporary

Table 1. Summary of spawn occurrence, maximum spawn density and maximum estimates of frog density ± 95 % confidence intervals at 25 breeding sites surveyed in ten 0.25 km^2 survey squares in Co. Mayo during spring 2010.

Visit	Median date	% occurrence of spawn ± 95%CI	Including negative sites		Excluding negative sites	
			Spawn mat area ± 95%CI (cm^2 m^{-2})	Frog density ± 95%CI (frogs m^{-2})	Spawn mat area ± 95%CI (cm^2 m^{-2})	Frog density ± 95%CI (frogs m^{-2})
1	26-Mar	72 ± 16	27.7 ± 12.9	0.53 ± 0.29	38.5 ± 15.3	0.74 ± 0.35
2	1-Apr	68 ± 18	31.7 ± 18.0	0.58 ± 0.37	46.6 ± 23.4	0.85 ± 0.50
3	7-Apr	44 ± 20	26.8 ± 17.8	0.50 ± 0.38	61.0 ± 30.4	1.14 ± 0.71
Mean maxima per site		**76 ± 18**	**42.3 ± 20.1**	**0.74 ± 0.39**	**55.7 ± 23.5**	**0.97 ± 0.47**

Table 2. Summary of water body types surveyed with spawn occurrence and the marginal estimated mean spawn density and frog density ± 95 % confidence intervals accounting for multiple site visits.

Water body type	Sample size (n)	Mean depth (m)	Surface area surveyed (m^2)	% occurrence	Marginal estimated mean spawn mat area ± 95%CI (cm^2/m^{-2})	Marginal estimated mean frog density ± 95%CI(frogs m^{-2})
Bog pool	4	0.43	142	75	45.1 ± 35.7	0.70 ± 0.55
Drainage ditch	15	0.29	106	80	19.5 ± 18.4	0.31 ± 0.29
Lake	1	?	167	100	8.9 ± 71.4	0.15 ± 1.10
River	2	0.6	200	50	13.5 ± 50.5	0.21 ± 0.78
Swamp/marsh	2	0.2	131	50	56.4 ± 50.5	0.98 ± 0.78
Temporary feature	1	0.15	2	100	97.0 ± 71.4	3.62 ± 1.10

feature.

Due to low sample sizes, logistic regression analysis failed to find any significant relationships between frog presence and any landscape, habitat or terrestrial refuge features. A total of 24 breeding sites (96 %) were associated with various threats or pressures; ecological succession represented the greatest threat to the future occurrence of breeding sites, however, drying and/or silting up, mechanical peat extraction, development, forestry and canalization were also recorded frequently (Table 3).

Discussion

The methods piloted here appear adequate for recording the occurrence and density of frogs at likely breeding sites. Species occurrence, determined by the presence of spawn, varied significantly between breeding sites and successive site visits. As a consequence of the harsh 2009-10 winter, surveys commenced late (19 March 2010), however, it appears that peak breeding activity was recorded during the first site visit. While spawn and estimated frog density did not differ between successive site visits, a survey methodology based on a single site visit may be vulnerable to a biased estimate of species occurrence and, therefore, distribution.

In those water bodies where spawning was late, a greater density of spawn was deposited than in those sites where breeding was early. Consequently, the decline in the percentage occurrence of spawn was compensated for by an increase in spawn area in positive sites; suggesting that late spawning activity was more concentrated than earlier spawning activity which was more widespread. Increases in spawn area can be attributed to new spawning as freshly-laid clumps reach their maximum size (through water absorption) within 24 hours of being laid (Frazer 1983). Spawning has been shown to be influenced by various factors (Savage 1961). Frogs may spawn later in less favourable habitats, for example where the algal flora is immature (Smith 1951, Savage 1961). It may also be that the late onset of spring during 2010 resulted in a less protracted overall spawning period with initial spawning delayed, thus truncating the start of the season. This is probably why there was no significant difference between visits 1 and 2. Otherwise an increase may have been expected and this emphasizes the need for multiple visits.

Little information of value can be taken from

Table 3. Summary of recorded threats at each breeding site surveyed using the EU Habitats Directive classification of pressures. Threats present at >10 % of sites are highlighted in bold.

Threat	Number of sites	% occurrence
Cultivation (A01)	0	0
Intense grazing (A04.01)	0	0
Abandonment (A04.03)	**4**	**16**
Removal of hedgerows/scrub (A10.01)	0	0
Forestry (B02)	**5**	**20**
Mechanical peat extraction (C01.03.02)	**5**	**20**
Development (E)	**5**	**20**
Recreational activities (G01)	0	0
Pollution (H01)	3	12
Invasive species (I01)	0	0
Infilling (J02.01.03)	0	0
Canalization (J02.03)	**5**	**20**
Drying/silting (K01.02/03)	**7**	**28**
Ecological succession (K02)	**11**	**44**
Predation (K03.04)	1	4
Other (O)	0	0
No threat (X)	1	4
Total	**25**	**96**

differences in densities of spawn or frogs between water body types due to small sample sizes.

Ecological succession was the greatest threat to breeding sites indentified in this pilot study. However, the total range of apparent threats recorded reflects those recorded by Beebee and Griffiths (2000), though further data from the 'National Frog Survey of Ireland 2011' will be required to elucidate how these threats might affect the frog population throughout Ireland. Changes in land management (or lack of it) leading ultimately to water body loss, appear to constitute the greatest danger. Fortunately, frog behaviour is sufficiently plastic for them to exploit new water bodies, including temporary features, when these are created (Beebee 1997). A National Frog Survey of Ireland will provide data consistent with that from the National Amphibian and Reptile Recording Scheme in Great Britain and will provide a means by which to report to the EU Commission on the conservation status of our most widespread amphibian.

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