The Glasgow Naturalist (online 2016) Volume 26, Part 3, xx-xx

Annual variation in the numbers of breeding common frog *Rana temporaria* at a cluster of sites in the west of Scotland

Paterson, E

205 Telford Road, East Kilbride, G75 0DG

E-mail: erikpaterson@virginmedia.com

ABSTRACT
The common frog is a pool-breeding anuran widely regarded as the most common amphibian in the United Kingdom. However, the species has seen widespread decline due to habitat loss, degradation, and pollution. Long-term population studies are useful for determining the overall trend for species abundance and presented here are interim results of a population monitoring study in East Kilbride, South Lanarkshire. The study populations showed high variation in annual numbers of breeding frogs at all sample sites, and average population size appeared to have little influence on the variation in numbers. There was a moderate correlation observed between the area of the breeding pool and the average spawning number. However, pool size cannot be considered the only factor which affects relative spawning numbers and requires further investigation.

INTRODUCTION

The common frog *Rana temporaria* Linnaeus,1758 is a pool-breeding anuran common throughout much of Europe and Asia (Savage, 1961). Often regarded as the most common amphibian in the United Kingdom (Arnold, 1995; Wilkinson & Arnell, 2011), this species has however been noted to experience declines throughout the country (Cooke, 1972; Beebee, 1973; and Cooke & Ferguson, 1976).

Amphibians have been noted to be useful indicators of biodiversity and ecosystem health (Wyman, 1990) and long-term monitoring studies can be useful in regards to characterising the health of amphibian populations (Blaustein *et al*., 1994), biodiversity monitoring, and influencing management decisions for conservation. Kuzmin *et al*. (2009) note that population monitoring of the common frog is key to determining the overall status of this species. Independent projects alongside national monitoring schemes such as the UK's National Amphibian and Reptile Recording Scheme (NARRS) co-ordinated by the Amphibian and Reptile Conservation Trust (ARC) can assist with monitoring herpetofauna populations (Wilkinson & Arnell, 2011). Terrestrial habitat disturbance and loss as well as pollution are regarded as major causes of decline in amphibian species (Cooke, 1972). Local knowledge and familiarity with amphibian populations can help to ensure that these effects are mitigated appropriately at the earliest available opportunities. Amphibian populations are noted to be highly variable in the number of breeding adults annually (Savage, 1961; Haapanen, 1982; Loman & Andersson, 2007; O'Brien, 2015) and it is also known that temporary local extinctions are commonplace (Green, 2003). A survey of a cluster of water bodies in the South Lanarkshire town of East Kilbride in the west of Scotland was undertaken between 2011 and 2016 with the aim of monitoring the status of the wider amphibian population, and the results are presented here.

METHODS

A 56 km^2 study area encompassing the town of East Kilbride in South Lanarkshire was chosen as the sample area extending approximately from Thorntonhall in the west to Calderside Road in the east, Auldhouse in the south to Nerston in the north. Potential breeding sites of the common frog were found within the sample area using Ordnance Survey 1:25,000 maps, online mapping tools such as Google Earth, local knowledge of the author, and gathered by communication with members of the public via local press.

Ponds of sufficient size are easily noted via mapping tools, but common frog breeding sites are known to be highly variable in their nature (Savage, 1961; Cooke, 1975). Walk-overs of areas deemed to have potentially suitable habitat due to their location or vegetation structure were undertaken by the author when breeding frogs and spawn first began appearing at previously identified sites and potential breeding pools were noted. Fig. 1. shows the extents of the survey area and the 33 sites that have been identified and to which access can be gained.

Identified potential breeding sites were visited by the author annually from 2011 to 2016 inclusive from mid-March to mid-April during the day to determine whether frogs were using them for breeding. Each site was then visited one to two weeks after all spawn had been deposited and spawn mat area was estimated and plotted against the relationship given by Griffiths *et al*. (1996). Individual clumps were counted where present and the numbers combined to give a measure of the number of spawn present. Spawn mat area calculations and comparisons were undertaken by the author alone to mitigate for potential recorder variability.

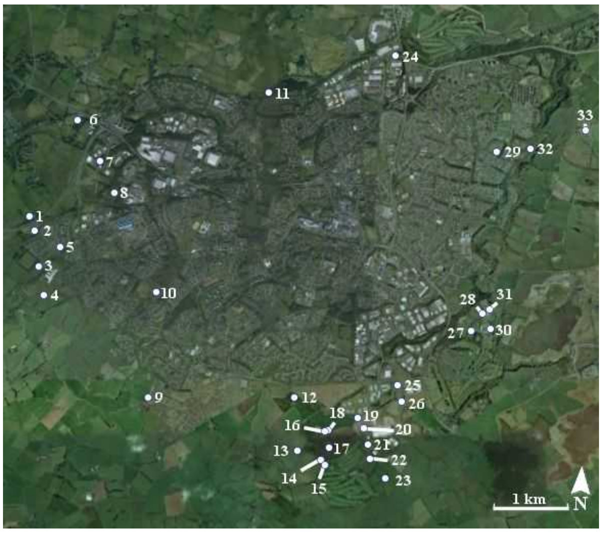

Fig. 1. The extent of the survey area and the location of identified sample sites labelled 1-33 from west to east. The corresponding pond for each number can be found in Table I. (Map adapted from Google Earth, DigitalGlobe).

Spawning numbers appeared at first to be more variable from year to year at higher densities and so an attempt to quantify this was made by comparing the percentage of the peak site count that each site varied by. This was calculated by determining the percentage of the maximal achieved count that the difference between the average number of spawn at any site was, to the maximum and minimum counts achieved for that site.

Potential breeding site size was estimated by the author to the nearest 50m^2 at large sites and where possible, more accurately, by use of in-field walkovers and utilising mapping tools to generate estimates. The square root of these values was taken in order to provide a linear measure of pond area and this was plotted against the average spawn numbers and Pearson's correlation was used to ascertain whether there was a relation between the two values, the significance threshold was set at 0.05.

RESULTS

A total of 33 sites were visited between 2011 and 2016 (Fig. 1, Table I). Site access limitations resulted in not every site being visited in each season.

Average spawn counts were compared with maximum and minimum counts expressed as a percentage of the maximum count (Fig. 2.). Spawning numbers varied from the average count each season by a mean (±SD) of +45±17.9% to -32.3±11.9%. The variation in this figure is large and there is no obvious correlation between average spawning number and the variation observed; large populations appeared to vary in proportionally the same manner as small populations.

Table II displays the average spawn count for each pond during the survey period alongside the pond size. Average spawn counts were plotted against the square root of pond area (Fig. 3.) and showed a moderate positive correlation (Pearson's correlation $r = 0.55$, $P < 0.001$).

DISCUSSION

Common frogs have been recorded breeding at 32 of the 33 monitored sites across the East Kilbride area and a peak spawn clump estimation of 578 clumps in one pond was achieved in 2016. However, these numbers were found to be highly variable between breeding seasons.

For several sites (e.g. Thornton Road SUDs, Peel Road SUDs etc.) 2014 represented a peak in the numbers of breeding frogs (Table I), but this was not the case across the survey area, with some sites showing a decline from 2013 (e.g. Calderglen Wildlife Pond, Hairmyres Woods) which cannot be explained without examining multiple factors affecting each individual site. In the case of both Hairmyres Woods and Lindsayfield SUDs there is ongoing anthropogenic disturbance evident: terrestrial habitat degradation from quad bike usage, and residential development respectively. Cooke (1972) suggests that terrestrial habitat loss and disturbance is one of the primary causes of amphibian decline. It is unclear in both cases whether frogs are being disturbed and relocating, suffering fatally from this disturbance, or simply failing to recruit larval cohorts. Harper *et al*. (2008) note that pond breeding amphibians generally remain within 300m of their breeding site and Kovar *et al*. (2009) notes that 75% of common frogs breeding at ponds in the Czech Republic undertook their spring migration from within 346m of the pond suggesting that the bulk of the population of this species would be affected by habitat loss or disturbance near the pond. However, Kovar *et al.* also note that 95% of the overall breeding population travelled annually from within 2214m of their pond which suggests that the common frog is able to disperse over considerable distances, potentially rendering them capable of moving to new and suitable habitat to evade disturbance.

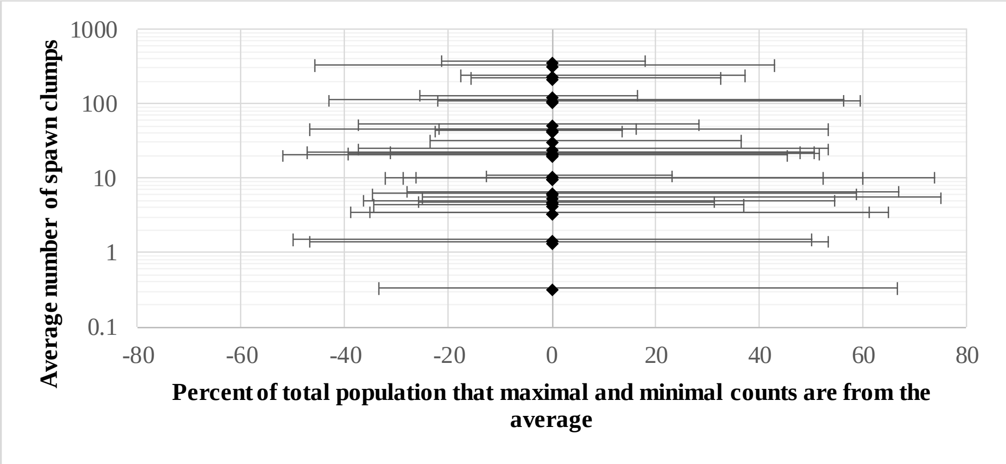

Fig. 2. Showing the percentage variance in population of the common frog at each of the sample sites where frogs have been noted to breed. Where ♦ represents the average spawn count per site (standardised to 0), bars indicate the percentage of the maximum (m) count from the average that the lowest (L) and highest (H) counts for any given site are. ($\left[+\% = \frac{H - \blacklozenge}{m} \times 100\right]$ and $\left[-\% = \frac{\blacklozenge - L}{m} \times 100\right]$). The position of ♦ relative to the extents of the bar indicates whether the average count is high or low in comparison to the maximum count and shorter bars indicate more stable breeding numbers annually at a given site.

Pond No.	*Pond Name*	*Grid reference*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
1	Thornton Road SUDs	NS 59444 54170	-	100	50	272	50	78
2	Peel Road SUDs	NS 59492 63976	-	1	17	37	9	37
3	Ocein Pond	NS 59546 53473	-	-	1	0	0	39
4	Jackton SUDs	NS 59592 53112	-	-	-	278	391	459
5	Disraeli Pond	NS 59766 53659	-	-	0	0	0	0
6	G.S.O. Business Park SUDs	NS 60085 55429	-	1	1	15	7	7
7	Peel Park Pond	NS 60427 54956	-	2	60	95	254	145
8	Hairmyres Woods	NS 60495 54470	-	45	41	17	7	1
9	Lindsayfield SUDs	NS 60680 51918	-	35	97	69	25	0
10	Mossneuk Park	NS 61055 53180	-	4	-	21	6	9
11	Heritage Loch	NS 62637 55773	-	90	155	130	143	-
12	Langlands West Pond	NS 62923 51727	-	-	65	514	159	578
13	Crosshill Pond	NS 62976 51061	-	-	50	32	42	49
14	Langlands Road Ditch	NS 63269 50935	-	-	10	0	4	0
15	Langlands Golf Course Pond	NS 63319 50876	-	-	0	22	0	0
16	Langlands Woods Pond	NS 63341 51362	1	1	0	0	0	0
17	Langlands Main Ditch	NS 63401 51142	2	7	1	11	6	3
18	Langlands Woods Ditch	NS 63430 51315	-	6	3	7	4	4
19	Langlands Path Ditch	NS 63690 51419	-	4	2	5	7	4
20	Langlands Square Ditch	NS 63782 51417	2	25	-	9	10	4
21	Langlands Golf Course Ditch	NS 63898 51114	-	5	-	7	32	53
22	Amphibian Site	NS 63903 60984	225	200	173	289	383	173
23	Field by the Calder	NS 64064 50664	-	1	1	4	7	20
24	B&Q SUDs	NS 64175 56228	-	3	0	3	1	0
25	Greenhills Road Sub Station	NS 64226 51942	-	-	3	0	-	-
26	Sainsbury's Small Pond	NS 64272 51503	-	-	9	9	14	11
27	Calderglen Old Duck Pond	NS 65251 52642	-	-	25	63	73	48
28	Calderglen Fire Pond	NS 65413 52864	-	-	170	190	328	196
29	Glen Esk Marsh	NS 65500 54981	-	4	-	23	44	14
30	Calderglen Wildlife Pond	NS 65514 52657	-	-	9	0	3	2
31	Calderglen Bottom Field	NS 65532 52966	-	20	-	50	21	36
32	Fred's Pond	NS 65847 54715	-	40	55	52	49	34
33	Calderside Road Disused Pit	NS 66761 55257	-	9	16	32	43	12

Table I. The annual count of frog spawn clumps at each site. Usage of "–" denotes a year in which the site was not visited. (SUDs = Sustainable Urban Drainage System.)

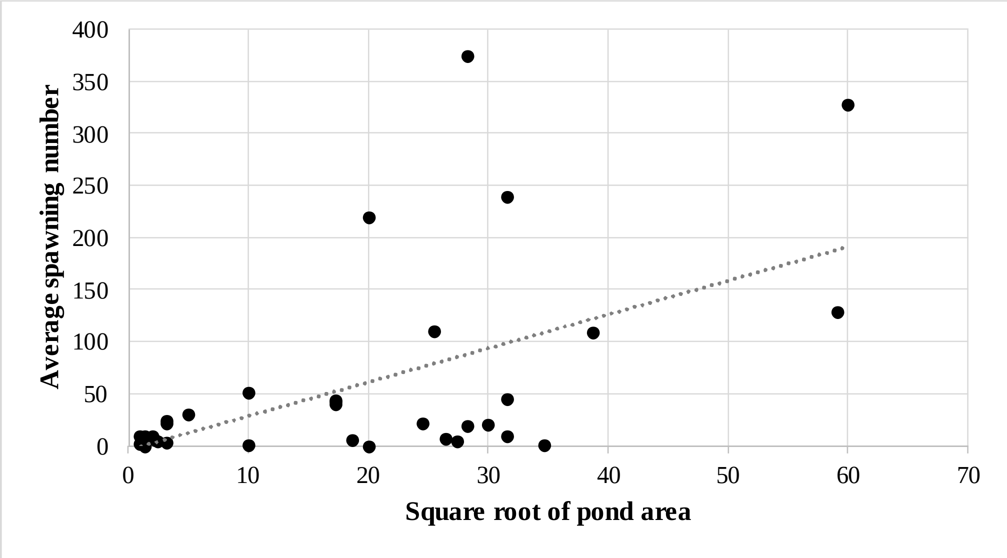

Fig. 3. Showing the square root of pond area (estimated to nearest $50m^2$ where pond area exceeds $100m^2$) plotted against the average spawn number for each site. The values show a moderate positive correlation with an observed *r* value of 0.55 ($P < 0.001$).

Pond Name	*Average Spawn No.*	*Pond Area (m^2)*	$\sqrt{Pond\ Area}$
Thornton Road SUDs	110.0	1500	38.7
Peel Road SUDs	20.2	800	28.3
Ocein Pond	10.3	1000	31.6
Jackton SUDs	376.0	800	28.2
Disraeli Pond	0.0	400	20.0
G.S.O. Business Park SUDs	6.2	350	18.7
Peel Park Pond	111.2	650	25.5
Hairmyres Woods	22.2	10	3.2
Lindsayfield SUDs	45.2	300	17.3
Mossneuk Park	10.0	4	2.0
Heritage Loch	129.5	3500	59.2
Langlands West Pond	329.0	3600	60.0
Crosshill Pond	43.3	300	17.3
Langlands Road Ditch	3.5	2	1.4
Langlands Golf Course Pond	5.5	750	27.4
Langlands Woods Pond	0.3	2	1.4
Langlands Main Ditch	5.0	6	2.4
Langlands Woods Ditch	4.8	2	1.4
Langlands Path Ditch	4.4	10	3.2
Langlands Square Ditch	10.0	1	1.0
Langlands Golf Course Ditch	24.8	10	3.2
Amphibian Site	240.5	1000	31.6
Field by the Calder	6.6	5	2.2
B&Q SUDs	1.4	100	10.0
Greenhills Road Sub Station	1.5	1200	34.6
Sainsbury's Small Pond	10.8	2	1.4
Calderglen Old Duck Pond	52.3	100	10.0
Calderglen Fire Pond	221.0	400	20.0
Glen Esk Marsh	21.3	900	30.0
Calderglen Wildlife Pond	3.5	1	1.0
Calderglen Bottom Field	31.8	25	5.0
Fred's Pond	46.0	1000	31.6
Calderside Road Disused Pit	22.4	600	24.5

Table II. The estimated area of each pond, the square root of that value, and the average number of spawn clumps for each site.

Despite a considerable capacity for dispersal, Blab (1986) found that in one study population, 92% of females would return to their ancestral site annually in contrast to Elmberg (1990) who found that an average of only 16% of females would return, site fidelity is consistent with many other anurans (Sinsch, 1990). However, Laan & Verboom (1990) note that common frogs were typically the first amphibian colonisers of new ponds with 72% of their study ponds being colonised within two years.

Spawning number variation

High variation in the number of frogs was noted annually and at first inspection appeared to vary more greatly in larger populations. However, from analysis of the percentage of the peak count that the maximal and minimal spawning number recorded for each population differed from the average revealed that this was not the case. Populations with smaller numbers were observed to be more likely to experience a complete loss of breeding frogs than those with larger overall populations (Table I). However, it is seen that common frog spawning numbers appeared to vary greatly and that this variation can be of a similar proportion irrespective of the average spawn number (Fig. 2.). The observed variation over the study period was relatively large for both maxima and minima but this may be an effect of using a small dataset in respect of monitoring period and pond number. Population studies over longer periods of time, or that utilise a larger number of breeding site samples may reduce variance and exploring this will be one of the aims as this study continues. The observed level of variability suggests that spawning frog numbers can proportionally vary equally with no obvious effect from population size.

Patterns of spawn presence and absence in successive years were seen during this study and Savage (1961) presents a similar though unquantified dataset depicting variation in presence or absence of frogs at a number of sites. Haapanen (1982) notes a similar variability of breeding population size in a small local population which varied over a five year study from 19 up to 132 breeding females. With maximal and minimal counts differing from the average by +56.5%, -29.2% of the peak count respectively, these figures fall within the annual variation presented here. Loman & Andersson (2007), surveying for a much longer period populations of *R. temporaria* and *R. arvalis* in Sweden, noted similar high variability in annual numbers of breeding frogs but found that overall, the study populations were stable. Meyer *et al.* (1998) also monitored three *R. temporaria* populations over a quarter-century and found highly fluctuating numbers with periods of depression and revival. A significant overall decline was noted only in one population possibly due to the introduction of fish. O'Brien (2015) also records annual variability in the numbers of breeding frogs in eight Sustainable Urban Drainage systems (SUDs) in Inverness, although data are presented only for three consecutive years. The results O'Brien presents yield variations of a mean (±SD) +43.9±12.6%, -35.3±11.6%, which places the dataset presented within the boundaries of the variation presented here.

The results given here and those presented by other authors suggest that annual numbers of spawning common frog are variable throughout their range. There seems to be little published explanation for this variation in the number of frogs using any given breeding site. Longer term metapopulation studies may reveal that frogs simply move between a number of nearby breeding sites in successive years and that overall population numbers remain relatively constant, such as seen by Loman & Andersson (2007). Savage (1961) also notes observed population stability over long periods of time with high annual variation. Savage notes that density-dependent factors such as dragonfly abundance and larval food availability in any given pond will result in depression and revival years of larval recruitment to the population. This cyclic variation in larval recruitment may then be reflected in the annual numbers of amphibians breeding. Additionally, depression years and years in which no amphibians breed at a site allow for recolonization of alga and microorganisms upon which the larvae feed. Larval predators will on account of the reduced food availability experience a depression in these years also, and as such these ponds are more likely to enable a successful larval cohort in successive years. Griffiths (1997) notes that absence of larval predator colonisation may be one of the factors in amphibian choice of breeding site and an evolutionary adaptation to breeding in temporary ponds. Sampling of the ponds presented within this study will be continued and investigations of possible causal factors for variation in the numbers of breeding frogs will be explored where possible.

The effects of pond area on spawning number

There was a moderate positive correlation between square root of pond area and the number of spawning frogs (Fig. 3). Larger ponds are more likely to sustain a larger number of tadpoles and support a larger population of frogs (Loman, 2004). The issue with larger pools comes from their inherent permanence allowing for potential successful colonisation by fish or other spawn and larval predators which, as shown by Meyer *et al.* (1998), can result in an overall decline in amphibian numbers. Smaller, temporary pools are less likely to be colonised by predatory species and thus more likely to recruit larval cohorts successfully (Griffiths, 1997). Loman (2004) has however shown that in ponds with a high density of tadpoles, larval failure and smaller size at metamorphosis are more likely to be encountered.

Though a moderate correlation was observed, there is still clear variation and pond size is unlikely to be the primary factor which affects the number of spawning frogs at any given site. Though not discussed at length here due to a data deficit, factors such as terrestrial habitat have been shown to be important in regards to common frog population size and breeding site choice (Marnell, 1998). The age of the breeding pool has also been shown to have an impact on the relative abundance and species composition (Laan & Verboom, 1990; Kadoya *et al*. 2004). Oldham *et al.* (2000) notes that water quality may also serve to influence amphibian usage of and survival at pools.

Acknowledgements
I would like to thank South Lanarkshire Council Countryside Ranger Service for their understanding, support, and land access agreements throughout this project; Chris Cathrine, the Clyde Amphibian and Reptile Group, Froglife, and ARC-Trust for advertisement of this work and varying levels of input during this undertaking. The East Kilbride News and Linda Fabiani for advertisement of the project, residents of East Kilbride who contacted me with details of water bodies in which frogs bred and varying levels of access to private properties to conduct spawn counts at garden ponds also. I should also like to thank Steven Allain, Gary Parsons, and Dominic McCafferty for useful commentary during preparation of the manuscript, and lastly Roger Downie for constructive review of the manuscript which has improved the content greatly.

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