RESEARCH ARTICLE

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Nocturnal variation in population size estimate counts of male palmate and smooth newts (*Lissotriton helveticus* and *L. vulgaris*)

ERIK PATERSON

College of Medical, Veterinary & Life Sciences, Graham Kerr Building, University of Glasgow, Glasgow, G12 8QQ, UK
Present address: 205 Telford Road, East Kilbride, South Lanarkshire, G75 0DG, UK
Author Email: erikpaterson@virginmedia.com

ABSTRACT - Of the three native species of newt in the United Kingdom, the smooth and palmate newts are the most widespread and abundant. Despite this, there is a dearth of guidelines on sampling for these common species due to the highly protected status of the great crested newt. However, as amphibians can serve as useful bioindicators, recording schemes exist to collect data on the widespread species. This paper reports on an observational study of the peak times for detection of smooth and palmate newts by torchlight at a nature reserve in north Lanarkshire, Scotland. Smooth newts were found to be crepuscular and palmate newts followed a more nocturnal pattern of maximum population size counts. For both species, water temperature seemed to be more relevant for obtaining peak counts than air temperature. I propose that from sunset to approximately 150 minutes after would be the optimal time to sample for both of these species via torchlight.

INTRODUCTION

Mainland United Kingdom has only three native species of newt, the highly protected great crested newt (*Triturus cristatus*), as well as the abundant and more widespread smooth and palmate newts (*Lissotriton vulgaris* and *L. helveticus*; Wilkinson & Arnell, 2011). National surveys such as the Amphibian and Reptile Conservation (ARC) Trust's National Amphibian and Reptile Recording Scheme (NARRS) generate citizen science data on widespread species' distribution and abundance which can serve as a tool for monitoring population status (Wilkinson & Arnell, 2011). To generate more comparable data for small newts between sites, a tailored and standardised effort should be designed and undertaken and one important factor is the optimal time during which to undertake surveys.

As a result of its relative rarity throughout its range, the great crested newt has strict legal safeguards as a European protected species. However, smooth and palmate newts (hereafter small newts) have much more limited protection, safeguarded only from sale and related activity under schedule 5 of the Wildlife & Countryside Act 1981 (as amended). Due to their strict protection status much more documentation and research have been undertaken in maximising detection rates of great crested newts (e.g. Oldham et al., 2000; Sewell et al., 2013; Biggs et al., 2015; Paterson, 2018) than for small newts (Griffiths et al., 1996; Deeming, 2008; Baker, 2013; Sewell et al., 2013). However, given the value of amphibians as indicators of biodiversity and ecosystem health (Wyman, 1990) it is also of value to monitor common species (Wilkinson & Arnell, 2011; Petrovan & Schmidt, 2016).

Several studies exist already which have explored the diel rhythms of smooth newts, these have predominantly shown them to be crepuscular (Himstedt, 1971; Dolmen, 1983a & 1983b; Griffiths 1985; Dolmen 1988). However, little is currently known about the diel rhythms of the palmate newt although Beebee & Griffiths (2000) state that they are crepuscular. The great crested newt has been shown to have a variable pattern of maximal counts via torchlight relative to sunset, with a statistical peak between 60 and 180 minutes following sunset (Paterson, 2018). This showed that great crested newt populations could be underestimated or undetected if sampled at the wrong time and this may also be true of small newts. This study sought to determine the changes in relative abundance of small newts via torchlight sampling across time relative to sunset. Samples were undertaken throughout the breeding season in order to determine whether smooth or palmate newts showed a similar pattern of differential abundance throughout the survey period as exhibited by great crested newts (Paterson, 2018).

METHODS

The sample site chosen was Gartcosh Nature Reserve in north Lanarkshire (NS 70 68) as it is known that both target species occur there alongside great crested newts (McNeill, 2010; McNeill et al., 2012). Owing to a road development to the north-east of the reserve, access could only be attained to the Bothlin Burn complex of ponds (Fig. 1). This cluster of eight ponds was visited on 17 March 2017 at night and sampled by torchlight to ascertain their suitability for sampling by assessment of accessibility, water clarity, and estimation of small newt numbers. All ponds with the exception of pond B6 which had a thick ring of emergent macrophytes were carried forward for this study.

Ponds were visited on the evenings of 25 March, 8 April, 22 April, 13 May, 26 May, and 17 June 2017 and sampled throughout the night utilising torchlight surveys (as Griffiths et al., 1996). Each pond's accessible perimeter

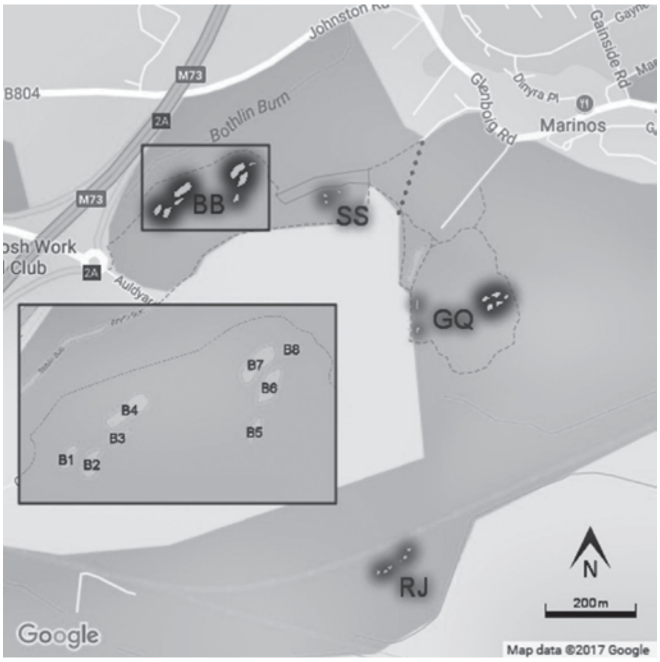

Figure 1. Gartcosh pond sets showing the six Railway Junction (RJ); seven Garnqueen (GQ); three Stepping Stone (SS); and eight Bothlin Burn (BB) pond cluster locations. Thick dotted line shows the approximate location of a road development which restricted access from the west to the GQ and RJ pond clusters. Inset: Bothlin Burn pond numbers.

was traversed on foot from the same starting point and in the same direction with the water being illuminated by a Clulite Clubman CB3 1,000,000 candlepower LED spotlight. The author undertook the torchlight surveys with an assistant annotating a recording form. This was repeated at hourly, two-hourly, and three-hourly repetition rate treatments in order to control for the effects of torchlight disturbance to the newts (Table 1). Sampling commenced from 30 minutes prior to sunset and continued until sunrise of the following morning. Ponds were visited in the order B1, B2, B3, B4, B5, B8, and B7 including subsets to ensure consistency of timing. Sunset time was determined by the table given on the website timeanddate.com (2017).

Newts (n= 2497) were identified to species and sex where possible utilising secondary sexual characteristics of males (e.g. hind feet webbing, presence and structure of crests, tail filament) to differentiate between species, although a number of records, chiefly of females, which are not distinguishable to species via torchlight, could not be reliably identified (n= 869). However, for statistical purposes, each sample was considered as a discrete unit (n= 174) for both male palmate and smooth newts and for all female small newts. Count data for females and unidentified small newts were excluded from analyses.

At the beginning of each pond sample, water temperature was read in the same approximate location of each pond approximately 10 cm from the shoreline and at approximately 15 cm depth using a TPI digital pocket thermometer. In addition, air temperature was measured approximately 50 cm from the ground at a central location between ponds B1 and B2 (Approx. NS 70575 68400) using a PeakMeter MS6508 digital thermometer. Cloud cover was estimated by the author as the percentage of visible sky obscured by cloud at the beginning of each sample, and the percentage of the visible surface of the moon on that evening was read from the table given by astronomyknowhow.com (2017).

Table 1. Example sampling repetition rate for the Bothlin Burn complex. The example shown is the visits undertaken on 16 – 17 June.

Sample start time (minutes; relative to sunset)	Hourly ponds	Two-hourly ponds	Three-hourly ponds
-30	B1, B2	-	-
+30	B1, B2	B3, B4	B5, B8
+90	B1, B2	B7	-
+150	B1, B2	B3, B4	-
+210	B1, B2	B7	B5, B8
+270	B1, B2	B3, B4	-
+330	B1, B2	B7	-
+390	B1, B2	B3, B4	B5, B8

Counts of newts were scaled for comparability whereby the maximum count of each newt species per pond per survey night was considered to be 100% of the potentially detectable population and all other counts from that pond were expressed as a percentage of that count, serving as a measure of population size detection. As sampling of the complete set of ponds lasted up to 50 minutes, visits were staggered and the start time of each can be placed in a half hour window relative to sunset providing the explanatory variable "half hour relative to sunset" as a continuous variable.

Generalised Linear Mixed Models (GLMMs) were built using lme4 (Bates et al., 2015) and lmerTest (Kuznetsova et al., 2017) packages in R V. 3.4.3 (R Core Team 2017). The dependent variable in all models was the proportional count of newts with separate models built for each of the explanatory variables incorporating half hour relative to sunset, moon percentage, cloud percentage, air temperature, and water temperature. GLMMs were then built incorporating interaction terms test the effects on proportional abundance of newts from the repetition rate treatment, cloud percentage, air temperature, and water temperature. A GLMM was also built to test whether there was any relation between the counts of smooth newt males with palmate newt males. All models included the random effects variables of date and pond number. Likelihood ratio tests were utilised to choose the best fitted models via stepwise backwards deletion of variables.

RESULTS

Both smooth and palmate newts were present in each pond within the Bothlin Burn complex (Table 2). Palmate newts were more abundant in every pond than smooth newts with the exception of B3. A significant, positive relation was found between the numbers of male palmate newts detected, and the numbers of male smooth newts detected (r^2= 0.41, $F_{(1,160)}$= 19.7, p= <0.001; Fig. 2).

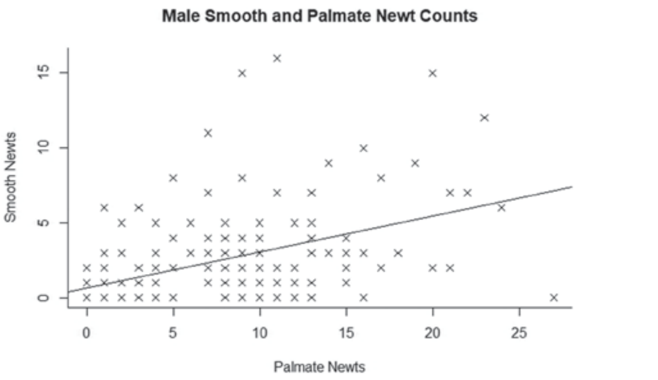

Figure 2. Counts of male smooth and palmate newts showing a significant positive relation between the counts achieved for both species (r^2= 0.41, $F_{(1,160)}$= 19.7, p= <0.001)

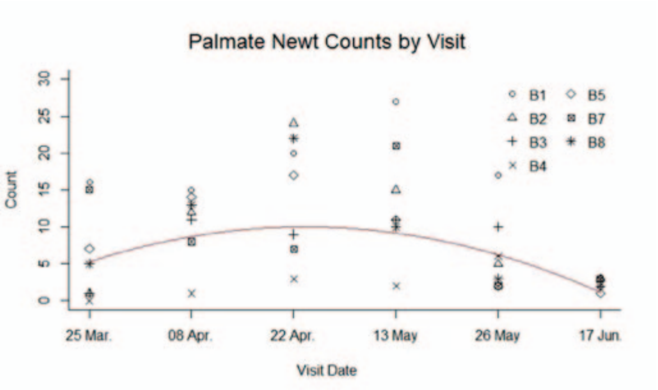

Figure 3. Maximal counts of male palmate newts by visit. Peak counts were achieved during the visit on 13th May with a peak count of 27 in pond B1. Plotted curve shows the best fit from a 2nd order polynomial model.

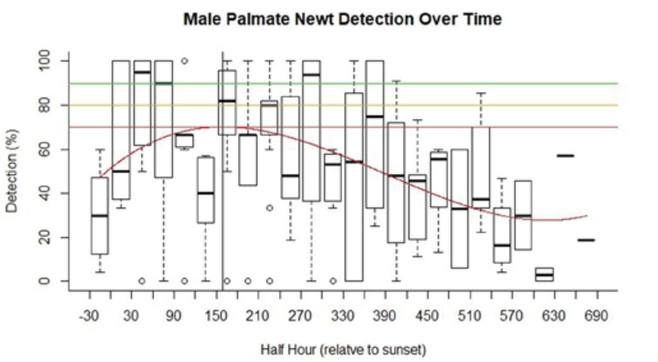

Figure 4. Palmate newt male counts expressed as a percentage of the maximum count achieved per pond per evening shown as boxplots splitting the counts in to quartiles with the thick black horizontal line at each serving as the marker of the median with boxes either side showing the range of the core 50% of data. Dotted lines represent the outer 50% of data and clear dots represent outlying data points. Horizontal lines represent 70, 80, and 90% of the maximum count achieved per evening. Detection of male palmate newts over time showed a more nocturnal pattern of activity with peak abundance at 159 minutes after sunset (vertical line) best fit by a 3rd order polynomial model (curve; r^2= 0.24, $F_{(3,32)}$= 9.54, p= <0.001).

Table 2. Maximum counts of small newts of the Bothlin Burn ponds complex. Small newt females are either smooth or palmate newts which could not be identified to species and were excluded from further analyses.

Pond no.	Palmate male	Smooth male	Small newt female
B1	27	9	15
B2	24	15	28
B3	11	16	14
B4	6	3	8
B5	17	8	9
B7	21	7	10
B8	22	7	8

Detection of male palmate newts

Palmate newts were present in broadly similar numbers on every visit with the exception that on 17 June very few were encountered. The peak count was achieved in pond B1 on 13 May (Fig. 3). Palmate newt counts showed a non-linear relationship with time relative to sunset best fitted by a 3rd order polynomial with a peak of abundance at 159 minutes following sunset (r^2= 0.24, $F_{(3,32)}$= 9.54, p= <0.001; Fig. 4).

Palmate newt males showed peak counts at an air temperature of 6.2 °C (r^2= 0.36, $F_{(2,14)}$= 11.55, p= <0.001) and were best fitted by a 2nd order polynomial model (Fig. 5a); the peak counts for three of the sample ponds were achieved below 5 °C, though peak counts per pond were distributed over a range of air temperatures (Fig. 5b). Water temperature also impacted on detection rates of palmate newts with a peak of detection at 12.8 °C (r^2=0.38, $F_{(4,13)}$= 9.42, p= <0.001; Fig. 5c) best fitted by a 4th order polynomial model; peak palmate newt counts per pond were all achieved above 10 °C and clustered around the 12.8 °C peak (Fig. 5d).

No significant relation was found between the relative abundance of male palmate newts and the percentage visible sky covered by cloud (r^2= 0.38, $F_{(1,22)}$= 0.78, p= 0.39) or by the percentage phase of the moon (r^2= 0.39, $F_{(1,11)}$= 0.44, p= 0.52). No interaction was found between the best-fitted 3rd order polynomial for abundance of palmate males over time with air temperature (r^2= 0.26, $F_{(3,36)}$= 0.84, p= 0.48), water temperature (r^2=0.23, $F_{(3,151)}$= 0.81, p=0.49), or repetition rate treatment of the ponds (r^2= 0.26, $F_{(3,147)}$= 0.65, p= 0.59).

Detection of male smooth newts

Smooth newts showed a distinct peak of presence within the pond during April, with the peak count from pond B3 on 8 April. No smooth newts were recorded during the June visit (Fig. 6). Smooth newts showed a distinct crepuscular pattern of maximal counts with a peak abundance at 62 minutes after sunset followed by a low count at 396 minutes after sunset best fit by a 3rd order polynomial (r^2= 0.37, $F_{(3,113)}$= 4.42, p= <0.01; Fig. 7).

Smooth newts were most abundant at an air temperature of 3.8 °C (r^2= 0.38, $F_{(2,20)}$= 5.28, p= <0.05) and were best fitted by a 2nd order polynomial (Fig. 8a). Peak counts of

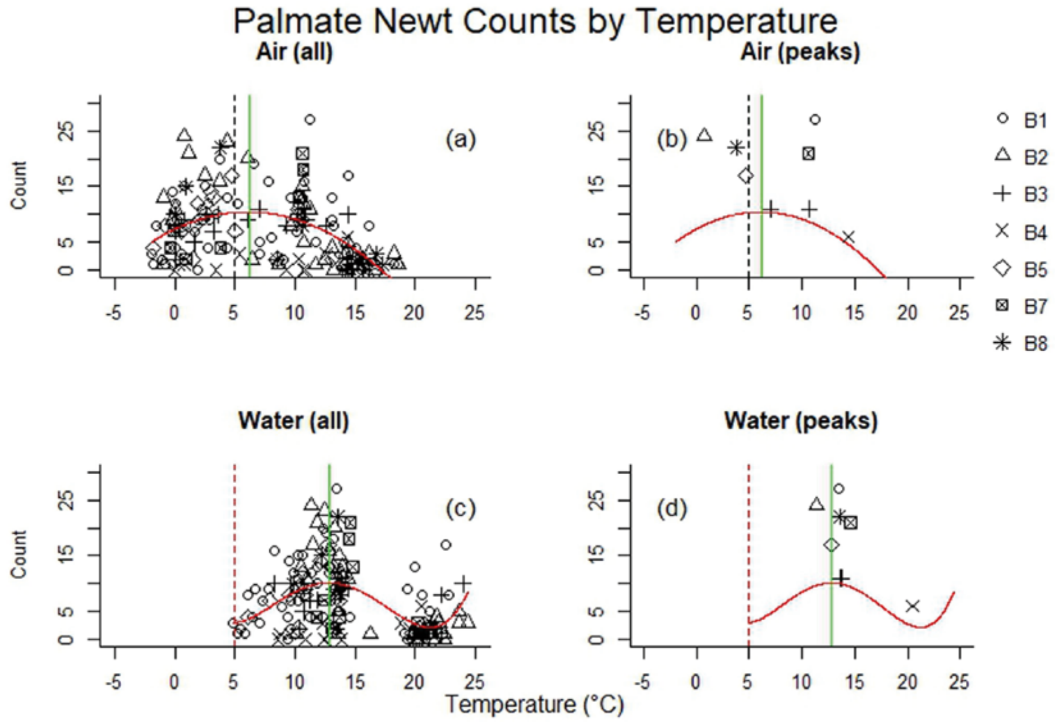

Figure 5. Counts of male palmate newts by temperature. Male palmate newts were statistically most abundant at an air temperature of 6.2 °C (a,b: solid vertical line) and a water temperature of 12.8 °C (c,d: solid vertical line); hashed vertical line shows the 5 °C reported critical minimum for newt activity (Verrell & Halliday, 1985). Plot **(a)** shows all palmate newt counts plotted against air temperature best fitted by a 2nd order polynomial (curve) peaking at 6.2 °C (r^2= 0.36, $F_{(2,14)}$= 11.55, p= <0.001); **(b)** shows the peak counts achieved for each pond plotted against the air temperature with the polynomial fit from (a) shown; **(c)** shows all palmate newt counts plotted against water temperature best fitted by a 4th order polynomial (curve) peaking at 12.8 °C (r^2=0.38, $F_{(4,13)}$= 9.42, p= <0.001); and **(d)** shows the peak counts of palmate newts achieved at each pond plotted against the water temperature with the curve showing the polynomial fit from (c).

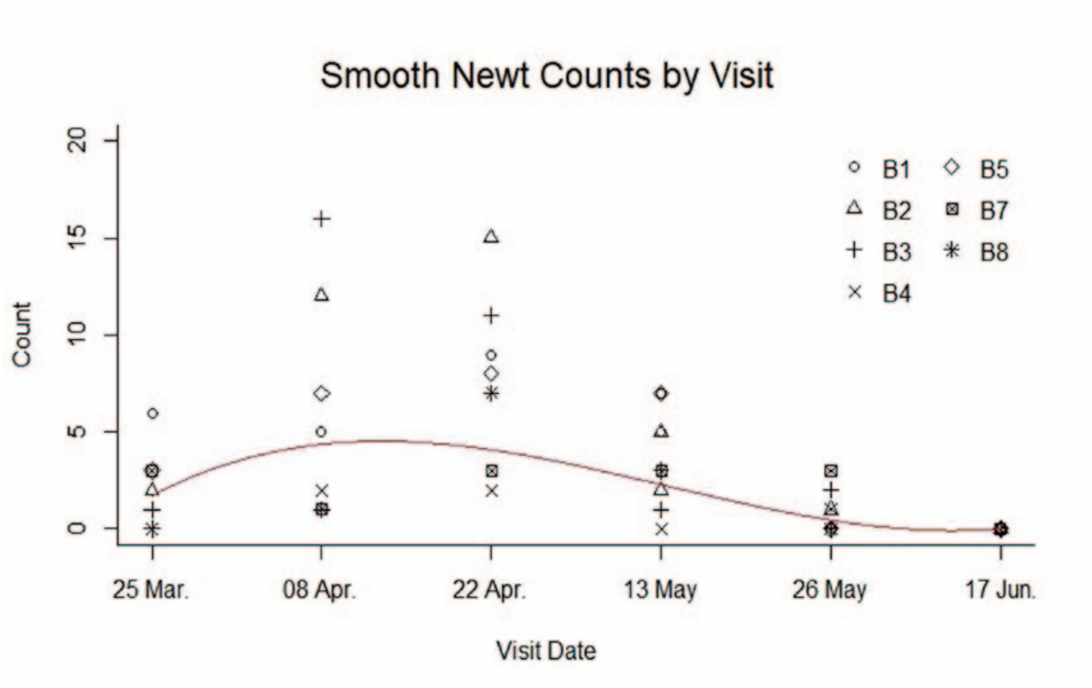

Figure 6. Smooth newt males were most abundant in April with a peak of 16 males counted in pond B3 on 8th April. Residence in ponds was for a short time period and no smooth newts were recorded in June. Plotted curve shows the best fit of a 3rd order polynomial.

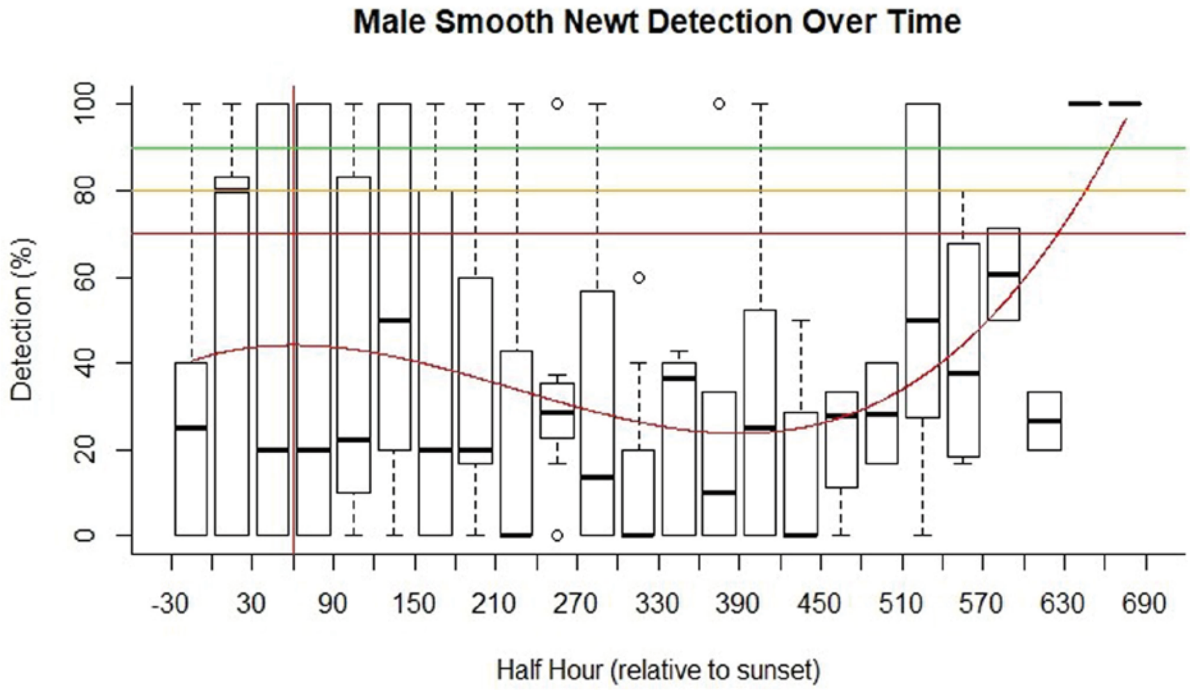

Figure 7. Smooth newt male counts expressed as a percentage of the maximum count achieved per pond per evening shown as boxplots splitting the counts in to quartiles with the thick black horizontal line at each serving as the marker of the median with boxes either side showing the range of the core 50% of data. Dotted lines represent the outer 50% of data and clear dots represent outlying data points. Horizontal lines represent 70, 80, and 90% of the maximum count achieved per evening. Smooth newt males displayed a slightly more crepuscular pattern of abundance with two peaks occurring shortly after sunset and again at sunrise with a statistical low of detection at 396 minutes after sunset and peak at 62 minutes after sunset (vertical line). Plotted curve shows the best fit from a 3rd order polynomial (r^2= 0.37, $F_{(3,113)}$= 4.42, p= <0.01).

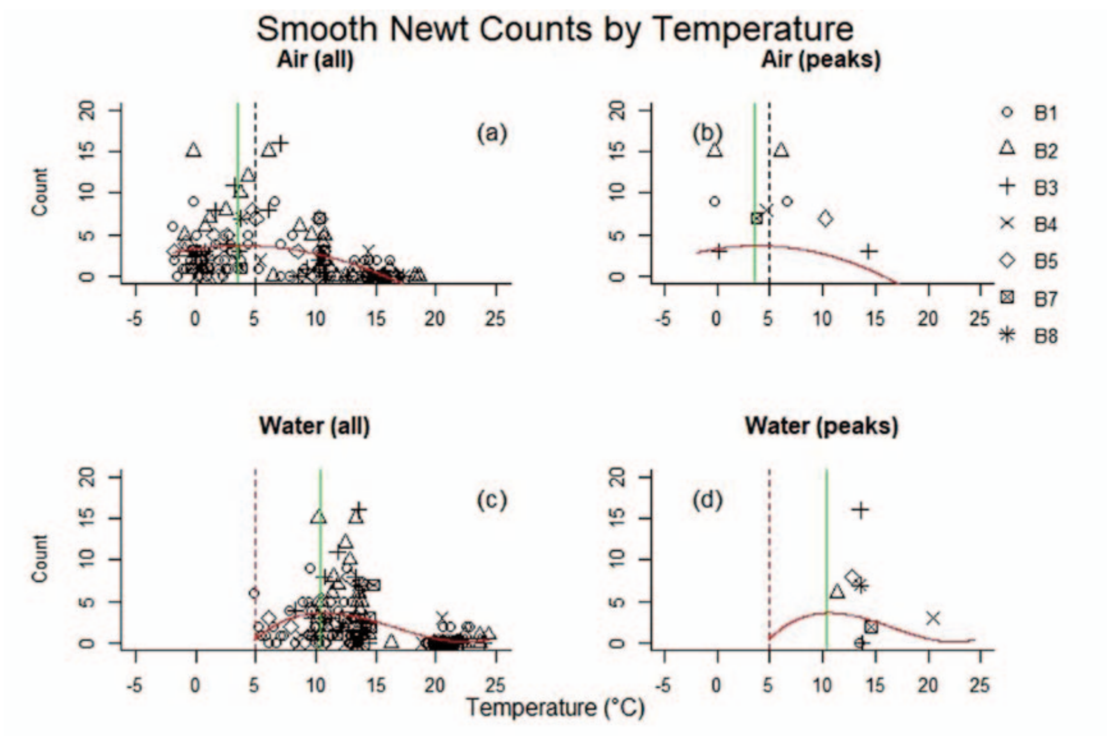

Figure 8. Counts of male smooth newts by temperature. Male smooth newts were statistically most abundant at an air temperature of 3.8 °C (a,b: solid vertical line) and a water temperature of 10.7 °C (c,d: solid vertical line), red hashed vertical line shows the 5 °C reported critical minimum for newt activity. Plot **(a)** shows all smooth newt counts plotted against air temperature best fitted by a 2nd order polynomial (curve) peaking at 3.8 °C (r^2= 0.38, $F_{(2,20)}$= 5.28, p= <0.05); **(b)** shows the peak counts achieved for each pond plotted against the air temperature with the polynomial fit from (a) shown; **(c)** shows all smooth newt counts plotted against water temperature best fitted by a 3rd order polynomial (curve) peaking at 10.7 °C (r^2= 0.49, $F_{(3,21)}$= 4.17, p= <0.05); and **(d)** shows the peak count of smooth newts achieved at each pond plotted against the water temperature with the plotted curve showing the polynomial fit from (c).

smooth newts were achieved over a range of temperatures, and multiple peak counts for three of the ponds were achieved at contrasting temperatures (Fig. 8b). Smooth newts were most abundant at 10.7 °C water temperature (r^2= 0.49, $F_{(3,21)}$= 4.17, p= <0.05) best fitted by a 3rd order polynomial (Fig. 8c) and all peak counts per pond were achieved above 5 °C though they were achieved over a wide range of temperatures (Fig. 8d).

No significant relation was found between proportional smooth newt abundance and percentage cover of cloud (r^2= 0.30, $F_{(1,81)}$=0.13 , p= 0.73), nor percentage of moon (r^2= 0.45, $F_{(1,10)}$= 0.08, p= 0.78). No interaction was found between the best-fitted detection polynomial with air temperature (r^2= 0.36, $F_{(3,96)}$= 0.51, p= 0.68) or water temperature (r^2= 0.36, $F_{(3,107)}$= 0.81, p= 0.49), and the repetition rate of surveys also had no significant interaction with relative detection period (r^2= 0.38, $F_{(3,148)}$= 0.63, p=0.59).

DISCUSSION

That there was a significant relation between the counts of palmate and smooth newts (Fig. 2) is suggestive that there may be no temporal partitioning of shared resources. However, smooth newts were most abundant during early to late April (Fig. 6) and palmate newts in late April through May (Fig. 3) which may be evidence of a seasonal partitioning of pond use. As other authors have shown high overlap in food resource and habitat use (Griffiths, 1987), there may be a lack of partitioning owing to a “prey-unlimited” situation wherein there is enough prey for all the predators to successfully exploit a shared resource (Akani et al., 2008; Griffiths, 1986). However, as no niche modelling was undertaken, this aspect cannot be explored further. Future studies should aim to model niche breadth and occupancy with a view to ascertaining how segregation occurs.

The data presented here on the crepuscular nature of smooth newts accords with observations by other authors (Himstedt, 1971; Dolmen, 1983a & 1983b; Griffiths, 1985; Dolmen, 1988). However, there continued to be high counts achieved throughout the night (Fig. 7) which may be suggestive of behavioural changes. This could be explained if newts were most visible whilst displaying in the open at dusk and dawn, but continued to be active as they fed throughout the night amongst vegetation where they may be obscured (Griffiths, 1985). Palmate newts showed a more nocturnal pattern of abundance, though there was distinct variability in detection proportion throughout the evening. However, this cannot be explained by this experimental protocol and would warrant further exploration wherein recording of behaviour and spatial distribution may provide further explanation. Palmate newts achieved highest counts between sunset and approximately 240 minutes following (Fig. 4) and smooth newts achieved highest counts between sunset and 150 minutes following (Fig. 7). As such, I propose that surveys for small newts take place between sunset and approximately 150 minutes after sunset.

Griffiths (1984) showed that air temperature had a significant relation to finding smooth newts under rocks, with a peak between 9-11 °C. This shows a strong similarity to the water temperature of peak smooth newt detection in this study (10.7 °C; Fig. 8). However, air temperature of peak detection was 3.8 °C which may suggest that air temperature is less relevant to newt activity when they are in the aquatic phase as when the water temperature dropped towards 5 °C abundance fell (Fig 8). A similar relation was found for palmate newts wherein the peak counts were achieved at a water temperature of 12.8 °C and an air temperature of 6.2 °C, with activity appearing to remain high below 5 °C air temperature, but dropping as the water temperature fell towards 5 °C.

Neither smooth nor palmate newts showed any relation between cloud cover and percentage of visible moon surface unlike that which was shown by Deeming (2008). This may suggest that small newt activity rhythms could be controlled by some other cue than moonlight, for example circadian clocks have been shown to alter with temperature and day length (Majercak et al., 1999).

These data were collected close to the northern fringe of the range for both smooth and palmate newts. It has been found in several other amphibian species at the fringes of their populations that they can show differential developmental and behavioural responses to conditions which differ from core range populations (Brattstrom, 1968; Orizaola & Laurila, 2009; Orizaola et al., 2010, Muir et al., 2014a; Muir et al., 2014b). As a consequence of this, it would be advantageous to repeat this study in southern or central parts of both species ranges. Additionally, great crested newts have been shown to have differing abundance peaks for males and females (Paterson, 2018). However, in this study females were not assessed and so it is possible that female small newts could also show differing peak count periods than males.

Through standardisation of data collection by means of a standardised survey window and by standardised count method, then data collected between ponds at different sites could be comparable and thus provide an overview of the relative importance of breeding pools (Paterson, 2018). The author would propose that surveyors seeking to achieve optimal counts of small newts via torchlight sampling should seek to visit their pond of interest between sunset and c. 150 minutes after sunset during mid April on evenings where water temperatures could be expected to be at least 10 °C.

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