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Cost-effectiveness of two monitoring strategies for the great crested newt (*Triturus cristatus*)

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Abstract. Designing cost-effective monitoring protocols is a fundamental prerequisite for amphibian conservation. Here, we report a comparison of flashlight survey and trapping (with and without light sticks as trap baits) in order to determine flashlight detectability and trap detectability of great crested newts (*Triturus cristatus*). Twelve ponds were surveyed in Switzerland where *T. cristatus* had been known to occur. We measured covariates affecting both flashlight detectability and trap detectability. Newt flashlight detectability using 20 min long flashlight surveys was on average $\pm$ SE $=$ 39% $\pm$ 10%). Flashlight detectability was mostly influenced by surface and submerged vegetation density, as well as by water temperature. Newt trap detectability during one night using six funnel traps per pond was on average$\pm$SE $=$ 41%$\pm$10%. Trap detectability was mainly affected by trap position in the pond, with traps lying on the pond floor being more likely to attract newts. The use of light sticks did not enhance the trap detectability. Estimates of flashlight detectability and trap detectability were used to define how many times the sites have to be visited to be 95% certain of not missing *T. cristatus* in ponds where they are present. In both cases multiple visits (7 flashlight surveys or 6 trapping sessions) have to be performed. Flashlight surveys are the most easily applied and most cost-effective method to use in large scale programs.

Keywords: flashlight survey, funnel trap survey, light sticks, occupancy, Switzerland.

Introduction

Amphibian population declines have been observed all around the world (Houlahan et al., 2000; Stuart et al., 2004) resulting in many species being threatened, endangered or even facing extinction (Stuart et al., 2004). Switzerland is affected by this decline too, with 70% of all native amphibians being red-listed (Schmidt and Zumbach, 2005). The evidence for a global amphibian decline points to the need for efficient monitoring programs to keep records of species occurrence and population changes (Bailey et al., 2004). Common investigation methods for amphibians include flashlight surveys (Griffiths, 1985), funnel traps (Weddeling et al., 2004; Maritz et al., 2007), drift fences (Ortmann et al., 2006) often combined with pitfall traps (Weddeling et al., 2004; Maritz et al., 2007), dip netting (Willson and Dorcas, 2003) and call surveys (Pellet and Schmidt, 2005) for anurans. The data needed strongly depend on the objective of a program. For large scale monitoring programs, presence/absence data might be sufficient (Royle and Nichols, 2003). For conservation decisions reflecting local population trends and ecological patterns, estimations of relative species abundances have to be included (Balmer, 2002; Schmidt et al., 2002). Only if we understand which factors lead to persistence and to decline, can successful conservation strategies be developed to avoid extinctions (Schmidt and Pellet, 2005). Species detection is defined as the probability of detecting at least one individual during the sampling period assuming that the species is present (Bailey et al., 2004; Schmidt and Pellet, 2009). However, most species are not conspicuous enough to be detected at each survey (MacKenzie et al., 2002). This is especially true for newts. This means that a species will not always be detected, even if it is present (MacKenzie and Royle, 2005). If detection indicates that a species is present, non-detection on the other hand does

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not prove that the species is absent (false absences) (MacKenzie et al., 2003). If detectability is estimated, the minimum number of visits to reach a defined level of certainty about the absence of a species can be calculated (Pellet and Schmidt, 2005). Without taking imperfect detectability into account, occupancy studies will inevitably underestimate population occupancy (MacKenzie and Royle, 2005). Therefore a focus on detection probabilities is worthwhile if a quantification of the extent of amphibian decline has to be done (Schmidt, 2004).

In our study, we compare the efficiency of both flashlight surveys and trapping on *Triturus cristatus* in breeding ponds. We ask whether different sampling covariates affect flashlight detectability and trap detectability. Traps baited with light sticks have been used in previous studies to investigate the distribution and ecology of fish larvae (Marchetti et al., 2004). Here, we tested whether unbaited traps are as efficient in capturing amphibians as traps baited with light sticks.

Material and methods

Study sites

During spring 2008, 12 ponds were surveyed where *Triturus cristatus* were known to occur in 2007 (B. Lüscher, personal communication). During the study, the presence of *T. cristatus* could be confirmed in all the ponds except one. The study sites belong to the nature reserves Elfenau (central coordinates 46°55′48 N, 7°28′08 E, three ponds), Belpau (central coordinates 46°55′03 N, 7°29′59 E, five ponds), Märchligenau (central coordinates 46°54′34 N, 7°30′49 E, 2 ponds), Flühli (coordinates 46°54′19 N, 7°31′17 E, one pond) and Wehrliau (coordinates 46°55′36 N, 7°29′09 E, one pond). All sites are located three to nine kilometres up the river Aare from Bern (Switzerland). They all belong to the humid-temperate central European climate and are situated at an elevation of around 500 m a.s.l. Water levels are strongly linked with the Aare water level and most ponds dry up annually, with the exception of two of our ponds (Wehrliau and Elfenau 1). Sizes and shapes of the examined ponds thus varied during the investigation period. The ponds in Märchligenau, Flühli and Belpau were surrounded by mixed forest and the ponds in Wehrliau and Elfenau 1 were partly surrounded by deciduous trees and shrubs. Elfenau 1 is located in an intensively used agricultural landscape.

Data collection

In order to compare the detection probabilities of *Triturus cristatus* based on different methods, each site was visited four times between March 3rd and May 27th 2008. On each visit, we tried to detect *T. cristatus* using both flashlight surveys and funnel traps. Our surveys resulted in two detection matrices (one for the flashlight survey and one for trapping) with sites in rows and survey dates in columns. Each cell in the matrices was filled with either 1 (at least one newt detected) or 0 (no newts detected).

The flashlight surveys were carried out (before traps were set) by a single person walking systematically along the shoreline for 20 minutes per pond. This was done between 21:00 and 01:00 because adults of *T. cristatus* show mostly crepuscular and nocturnal activity (Dolmen, 1988). Because all ponds had comparable shoreline lengths, this resulted in a roughly constant survey effort. A powerful flashlight (MagCharger, MAG Instrument, Inc., CA, USA) was used to detect *T. cristatus* in the ponds. We define flashlight detectability as the probability of observing at least one *T. cristatus* in a pond where it is present.

Following the flashlight survey, six funnel traps were placed in each pond and emptied the following morning between 09:00 and 12:00. The collapsible, rectangular-shaped funnel traps ($24 \times 24 \times 55$ cm) were made of metal wire with a nylon mesh (2 mm gauge). Each funnel trap contained two funnel shaped entrances with an opening of 7 centimetres (Koederfischreuse Art.-Nr. 61-09250, Cormoran, Gröbenzell, Germany). All traps included a plastic bottle (0.5 l) filled with air so that the top of the trap was above the water level, thus allowing trapped amphibians to breathe (Willson and Dorcas, 2004). The traps were positioned along the accessible shoreline (at least 1.5 m apart). It was ensured that both trap entrances were underwater. The traps were held in place with a bamboo cane.

Three out of the six funnel traps contained one light stick (20×0.5 cm), while the other traps contained none. We used the same light sticks as Grayson and Roe (2007). *T. cristatus* was recorded by photographic identification of their individual belly patterns (Arntzen and Teunis, 1993) in order to obtain the total number of caught newts. Trap detectability is defined as the probability of catching at least one great crested newt in a pond where it is present.

To estimate the relative cost-effectiveness of both methods, effort needed to be systematically estimated for each survey. The survey effort was estimated by summing the total time used per person for one visit divided by the number of ponds surveyed. The estimation for flashlight survey and trapping effort include one way travelling time, which averaged 40 minutes, plus an average 10 minutes to walk from one pond to the next. Furthermore, it includes the time used to disinfect field equipment, to prevent the spread of disease (e.g. chytridiomycosis) (Schmidt et al., 2009). Completing the flashlight survey and filling in the protocol sheet took 35 minutes per pond excluding travelling time.

For trap surveys, traps had to be folded and packed into the car before the visit. Afterwards, we had to lay out the traps in a storage room to dry them (as a chytridiomycosis disinfection strategy). Altogether this took around 40 minutes per visit. To set the traps and fill the protocol sheet, we spent 30 minutes per pond at night. Emptying the traps the following morning took an average of 35 minutes per pond excluding travelling time.

To quantify the shape of the ponds, the following shore development index was applied: $SHAPE = Perimeter/2 \cdot \sqrt{\pi \cdot Area}$. This index qualifies the sinuosity of the pond. It is equal to one for a circular pond and goes up as the sinuosity of the shore increases (Pellet et al., 2004). We measured pond water temperature at 10 cm depth during the flashlight survey as the mean of three measurements taken at the time of the survey. Accessibility was measured as the percentage of walkable shoreline. The percentage of surface vegetation was estimated visually as well as the percentage of submerged vegetation. We measured water temperature on trapping night as the average of six water temperature measurements (three taken in the evening, and three in the morning) per pond. In order to test the effect of trap detectability based on moon phases, we created a covariate based on the number of days to and from the closest full moon (full moon $=0$, days before and after full moon ranging from 1 to 14). We also discriminated between free floating traps (not touching the pond floor) and grounded traps (touching the pond floor). For each trapping session, we define a covariate describing the percentage of free floating traps (a subset of the 6 traps we set) (table 1).

We used occupancy models as implemented in program PRESENCE (see MacKenzie et al., 2003 to investigate which model explained our detection and trapping data best. In the first step of analysis, we constructed a single model based on the complete dataset and incorporated the method used (flashlight survey or trapping) as a covariate. In a second analytical step, we constructed a set of models for each method used, each time incorporating relevant covariates in order to explore the parameters affecting flashlight detectability and trap detectability independently.

For our flashlight detection data, we tested for constancy of flashlight detectability ($\psi(\cdot)p(\cdot)$). Second, we tested whether the shape index of the pond influenced newt flashlight detectability ($\psi(\cdot)p(\text{SHAPE})$). We tested the influence of the water temperature during the survey on the flashlight detectability ($\psi(\cdot)p(\text{WATERTEMPNIGHT})$). The fourth covariate was the accessibility of the pond ($\psi(\cdot)p(\text{ACCESSIBILITY})$). Next we tested if the percentage of vegetation in the pond had an influence on flashlight detectability ($\psi(\cdot)p(\text{VEGETATION})$). To investigate if the survey date and consequently the season when the survey was carried out had an impact on flashlight detectability, we constructed the model $\psi(\cdot)p(\text{DAY} + \text{DAY}^2)$, assuming a quadratic relationship between survey date and flashlight detectability. Furthermore, we tested if the percentage of pond surface covered by vegetation had an influence on flashlight detectability with model ($\psi(\cdot)p(\text{SURFACECOVER})$).

Trapping data were analysed in a similar fashion. We first tested whether trap detectability was constant ($\psi(\cdot)p(\cdot)$). Second, we tested whether the water temperature influenced trap detectability ($\psi(\cdot)p(\text{WATERTEMP})$). Further, we tested the influence of pond area on trap detectability ($\psi(\cdot)p(\text{PONDAREA})$). The fourth covariate we tested was the moon phase ($\psi(\cdot)p(\text{MOONPHASE})$). Furthermore, we tested if the position of the traps in the pond (percentage of free floating traps) influenced the trap detectability ($\psi(\cdot)p(\text{TRAPPOSITION})$). To test for seasonal differences we used the model $\psi(\cdot)p(\text{DAY} + \text{DAY}^2)$.

Parameters were estimated by maximum likelihood in program PRESENCE (MacKenzie et al., 2003). We used the log-likelihood to perform model selection based on the AICc using the formula $AICc = -2\log + 2K(n/(n - K - 1))$ with $n =$ sample size and $K =$ number of estimated parameters. The use of $AICc$ is recommended when K exceeds $n/40$ (Johnson and Omland, 2004). To determine the evidence ratios we used the formula: Evidence ratio $= w_j/w_i$ where the best model j is compared to model i (Mazerolle, 2006). We used model averaging (Burnham and Anderson, 2004) to calculate the unconditional average detectability.

Because the number of newts trapped was not normally distributed, we ran a Wilcoxon's paired sample signed rank

Table 1. Sampling covariates for flashlight detectability and trap detectability.

Covariate	Explanation	Mean ± SD	Min.	Max.
SHAPE	$SHAPE = Perimeter/2 \cdot \sqrt{\pi \cdot Area}$	1.9 ± 0.39	1	2.6
WATERTEMPNIGHT	Mean of three water temperature measurements (°C) taken during the flash light survey	12.1 ± 3.91	7	21
ACCESSIBILITY	Percentage of accessible shoreline	74 ± 25	20	100
VEGETATION	Percentage of pond covered by submerged vegetation	24 ± 18	5	65
$\text{DAY} + \text{DAY}^2$	Day of the survey (day 1 = March 3rd)	1080 ± 1034	2	3080
SURFACECOVER	Percentage of surface vegetation cover	18.6 ± 26	0	95
WATERTEMPNIGHT	Mean of six water temperature measurements (°C) (three in the evening and three in the morning)	11.5 ± 3.81	6	20
PONDAREA	Surface (m^2)	60.3 ± 37	10	160
MOONPHASE	Number of days to and from the closest full moon	7.6 ± 4	0	13
TRAPPOSITION	Percentage of free floating traps (not touching the pond floor)	34.6 ± 35	0	100

test to see whether traps baited with a light stick attracted more newts than traps without a light stick.

The minimal number of surveys to be 95% confident that a species is absent was calculated with the formula $N_{min} = \log(0.05)/\log(1 - p)$ (Pellet and Schmidt, 2005) where p is the flashlight detectability or trap detectability.

Results

The first step of our analysis demonstrated that there was no difference between the detectability obtained by each survey method, with flashlight detectability ± SE being 39% ± 10% and trap detectability ± SE being 41% ± 10%.

Flashlight detectability was best predicted by the percentage of the pond covered by surface vegetation (QAICc weight = 0.361). The model including water temperature comes second best with a weight of 0.193. Third, but with a much lower weight of 0.110, comes the model assuming a relationship between flashlight detectability and submerged vegetation. The first model has an evidence ratio of 1.9 compared to the second best, and of 3.3 compared to the third (table 2).

We found that two models explain trap detectability best. The first one assumes a relationship between trap detectability and the position of traps (with a high percentage of free floating traps decreasing trap detectability). The model assuming constant trap detectability is second best (QAIc weight = 0.346). The first model has an evidence ratio of 1.2 compared to the second best, and of 4.5 compared to the third (table 3).

We caught 55 *Triturus cristatus* in the 141 traps that included a light stick (mean ± SE = 0.39 ± 1.52, maximum = 14 individuals per trap). In those 141 traps without light sticks 39 individuals were trapped (mean ± SE = 0.28 ± 1.16, maximum = 10 individuals per trap). We found no difference in trap attractiveness (Wilcoxon's paired sample signed rank test P-value = 0.71). If *T. cristatus* were in the trap, there were on average ± SE = 2.75 ± 3.18 individuals in the traps with light and on average ± SE = 2.63 ± 2.16 individuals in those without light. The Wilcoxon's paired sample signed rank test resulted in a P-value of 0.75.

Table 2. Candidate model selection for *Triturus cristatus* flashlight detectability using 20 min flashlight survey. Models are ordered by decreasing Aikake weights (w_{AICc}). n is the sample size, K is the number of parameters. Model averaged flashlight detectability ± SE = 36% ± 34%.

Model	n	K	QAICc	w_{QAICc}	Intercept	Slope	Slope2
7 $\psi(\cdot)p$(SURFACECOVER)	12	3	49.773	0.361	−0.091 ± 0.571	−0.032 ± 0.024	
3 $\psi(\cdot)p$(WATERTEMPNIGHT)	12	3	51.024	0.193	0.897 ± 1.319	−0.121 ± 0.105	
5 $\psi(\cdot)p$(VEGETATION)	12	3	52.157	0.110	−1.067 ± 1.245	0.017 ± 0.031	
4 $\psi(\cdot)p$(ACCESSIBILITY)	12	3	52.287	0.103	−0.864 ± 1.113	0.005 ± 0.013	
2 $\psi(\cdot)p$(SHAPE)	12	3	52.340	0.100	−0.211 ± 1.935	−0.135 ± 0.964	
1 $\psi(\cdot)p(\cdot)$	12	3	52.360	0.099	−0.472 ± 0.509		
6 $\psi(\cdot)p(\mathrm{DAY} + \mathrm{DAY}^2)$	12	4	54.493	0.034	−0.824 ± 0.939	0.095 ± 0.028	−0.002 ± 0.001

Table 3. Candidate model selection for *Triturus cristatus* trap detectability using funnel traps. Models are ordered by decreasing Aikake weights (w_{AICc}). n is the sample size, K is the number of parameters. Model averaged trap detectability ± SE = 47% ± 17%.

Model	n	K	QAICc	w_{QAICc}	Intercept	Slope	Slope2
5 $\psi(\cdot)p$(TRAPPOSITION)	12	3	56.359	0.405	0.335 ± 0.58	−0.022 ± 0.012	
1 $\psi(\cdot)p(\cdot)$	12	2	56.671	0.346	−0.403 ± 0.435		
2 $\psi(\cdot)p$(WATERTEMP)	12	3	59.340	0.091	0.592 ± 1.089	−0.092 ± 0.091	
3 $\psi(\cdot)p$(PONDAREA)	12	3	59.871	0.070	−0.011 ± 0.625	−0.006 ± 0.008	
4 $\psi(\cdot)p$(MOONPHASE)	12	3	59.896	0.069	−0.87 ± 0.826	0.057 ± 0.086	
6 $\psi(\cdot)p(\mathrm{DAY} + \mathrm{DAY}^2)$	12	4	62.468	0.019	−0.604 ± 0.687	0.061 ± 0.023	−0.002 ± 0.025

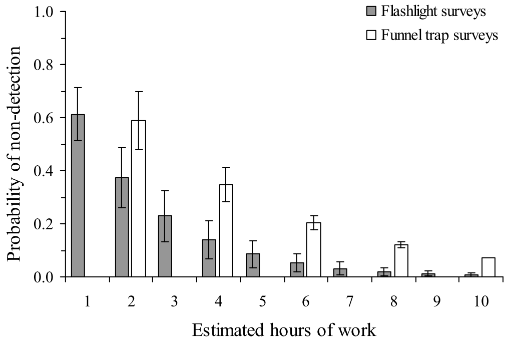

Figure 1. Flashlight detectability and trap detectability of *Triturus cristatus* versus estimated hours of work necessary. Flashlight surveys take on average one hour per pond, while funnel trap surveys take on average 2 hours per pond.

At least 7 flashlight surveys with a flashlight detectability of 39% are needed to be 95% certain that the species is absent. With a trap detectability of 41%, 6 trapping sessions are needed to reach the same level of certainty (fig. 1).

The average time needed for one flashlight survey equals to 1 hour per pond (including travelling time). The average time for setting and controlling funnel traps equates to 2 hours per pond, again including travelling time. By comparing flashlight detectability and trap detectability versus hours of work one can see that fewer hours of work for flashlight surveys are needed to get equal trap detectabilities. In other words, fewer hours of work have to be invested in flashlight surveys than in trapping sampling sessions to get similar probabilities of non-detections (fig. 1).

Discussion

The fact that a high percentage of surface cover precluded our ability to detect *Triturus cristatus* comes as no great surprise. This covariate depends on the pond vegetation itself as well as on the season (there might be more vegetation later in the season). This is especially true in eutrophic ponds where *Lemna sp*. quickly blankets the surface of the water. In order to determine if *T. cristatus* is present in a pond, flashlight surveys are therefore a reliable method, as long as surface cover is not too dense (at 80% vegetation cover, flashlight detectability drops to 7%!). We expected to find a higher flashlight detectability with increasing water temperature because the activity and accordingly the visibility of newts increase with rising temperatures (Putnam and Bennett, 1981). We found support for an effect of temperature on flashlight detectability, but contrary to our expectations, flashlight detectability appears to decrease with increasing water temperature. We have no plausible post-hoc explanation for this result. It must also be noted that we could not assess the full model $[p(t)]$ because it had more parameters ($K = 13$ sessions in total) than sample size ($n = 12$ ponds). We also recorded rainfall, but we could not use this variable because we had only 4 events of rain during our 48 surveys.

Our model including the position of traps appears best, with the trap detectability for the free floating traps being lower than that for traps which touched the floor of the pond. This might be due to the behaviour of *T. cristatus* which tend to be active directly above the ground of the pond rather than in the open water (Dolmen, 1983). Because at least part of the traps must be above water to allow newts to breathe, traps should be placed in shallow water (less than the trap's height). If the proportion of free floating traps can be minimized, then our best model indicates that newts' trap detectability can be as high as 58% ± 12% per night. Other capture techniques have been used for newts of the genera *Triturus*, *Lissotriton* and *Mesotriton*. It would be interesting to test the trapping detectability of these capture methods, such as 1.5 l bottles (Denoel and Schabetsberger, 2003; Griffiths, 1985) or dip-netting (Denoel and Schabetsberger, 2003).

Our results indicate no effect of pond area on trap detectability. Due to the rising water level of the study ponds, the relative number of traps per cubic meter decreased during the field season (the number of traps was kept at six per pond). Based on this fact and combined with an assumption of constant population size we expected a lower trap detectability in larger ponds.

Surprisingly, the variation between the numbers of captured *T. cristatus* per trap was sometimes very high within a pond during one session. A possible explanation for the large variation of captured individuals could be an uneven distribution of newts within a pond (Griffiths, 1985). If this is truly the case it can be concluded that the horizontal position of traps in the pond might be very important and one has to deal with a large variance in trap detectability, especially when sample size is small.

Our results demonstrate that there was no effect of light sticks on trap detectability of *T. cristatus*. This conclusion stands in contrast with Grayson and Roe (2007) who described light sticks "to be extremely effective at increasing capture efficiency of aquatic amphibians in funnel traps". However their study concentrated on *Notophthalmus viridescens* and *Rana catesbeiana* tadpoles. Based on our results, we suggest that generalizations about the positive effect of light sticks on trap detectability of aquatic amphibians should be avoided. Unfortunately, hardly any other studies have been done on the application of light sticks as bait in funnel traps for amphibians. We propose further investigations including tests regarding the effects of size and colour of the light sticks.

The average single-session trap detectability was slightly higher than the average single-session flashlight detectability. This leads to the conclusion that, given our sampling method, fewer sampling sessions are needed with traps to achieve the same confidence about the absence of a species than with flashlight surveys.

Another advantage of trapping is the possible standardisation of sampling effort (Maritz et al., 2007) that is highlighted by the fact that our two best models translate into standardisable sampling schemes (trap position) or incorporate a constant trap detectability. The performance of the latter model (constant trap detectability) is supported by the fact that the skills and the experience of an observer is not determinant on capture success (Adams et al., 1997). However a large disadvantage of trap surveys is the fact that each site must be visited twice per survey (once in the evening to set the traps and once in the morning to empty them). This disadvantage strongly increases as both travelling and survey time increase. Furthermore, many traps are needed which might be expensive (Adams et al., 1997). A possible solution to this problem is the use of funnel traps built from PET bottles (Griffiths, 1985). However, mortality in those traps might be increased due to warming of the water and lack of air (Adams et al., 1997). Additionally, a storage room is needed to dry the traps or they must be disinfected after usage in order to prevent dispersal of chytridiomycosis (Schmidt et al., 2009).

In contrast, the only material needed for flashlight survey is a strong flashlight (which admittedly can be quite expensive too). Moreover, each site has to be visited only once per survey. The disturbance to animals and vegetation caused by walking around the pond is likely to be less than for trap setting (which includes the same path but additional stops to set the traps).

The goal of the monitoring program strongly influences choice of the most appropriate method. Site occupancy has good potential as a state variable in large scale amphibian monitoring programs (Bailey et al., 2004) and accordingly presence/absence data might be sufficient. However, in cases of low detection probabilities, studies based on occupancy methods might not be worthwhile (Bailey et al., 2004). In order to make decisions reflecting real ecological patterns frequencies and estimations of relative species, a measure of population abundances has to be included (Balmer, 2002). Moreover, appraisals of life history parameters might be important too. To collect such detailed data, we conclude that trap survey is the most appropriate method, because captured newts can be clearly identified and data can be used in standardized classic capture-mark-recapture (CMR) experiments (Schmidt et al., 2002). One has to take into account that trap survey data might be biased like those of Griffiths (1985) who found disproportionately large numbers of male *T. vulgaris* in traps. Sex bias in trap detectability can be tested by CMR studies. A problem is the immense time investment required for CMR or detailed studies, which make them unrealistic for large scale monitoring programs.

The choice of an appropriate method for a *T. cristatus* monitoring program strongly depends on the objectives and the available resources. As long as presence/absence data are sufficient, the flashlight survey is the most cost-effective method and most easily applied in large scale programs. If ecologically relevant decisions have to be made based on population abundance, then we advocate the use of funnel traps, associated with capture-mark-recapture estimates of population size. In both cases, however, multiple visits (7 flashlight surveys or 6 trapping sessions) have to be made to be 95% certain of not missing great crested newts in ponds where they are present. Only by applying a rigorous approach accounting for detectability is it possible to design an evidence-based protocol that reduces the risk of false-absences.

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