Short Note

Sampling efficiency, bias and shyness in funnel trapping aquatic newts

Jan W. Arntzen*, Annie Zuiderwijk

Abstract. A lightweight, collapsible funnel trap designed for crayfish was furnished with a smaller mesh and then used to study adult breeding populations of five species of newts in five ponds in France. Observations were made in spring, at the peak of breeding activity, over an 11-year period. Annual experiments involved on average 7.7 traps and 5.3 overnight sampling sessions at 2.0 day intervals. In 95 out of 171 experiments (56%) the probability for an individual to go undetected was <1%. A trend was observed for catchability to increase with body size (Lissotriton < Ichthyosaura < Triturus). The two Triturus species involved were frequently exhaustively sampled in a single overnight session. In spite of their smaller size, L. helveticus males were more readily captured than females, presumably reflecting breeding associated locomotor activity. The numbers captured decreased over time suggesting ‘trap shyness’ to operate. We noted some predation by diving beetles (family Dytiscidae) affecting L. helveticus males in particular.

Keywords: catchability, detectability, France, Ichthyosaura, Lissotriton, mortality, predation, Triturus.

Surveying and monitoring are essential components to the study of wildlife for conservation and research. Amphibian surveys over larger areas are mostly carried out with the traditional dip-net, yielding data per visit instantaneously. The monitoring of aquatic amphibians is increasingly carried out with traps. However, the use of traps requires at least two visits, for positioning and for inspection, with the trade-off that experiments are more readily standardized and results better comparable than with dip-nets. Early studies with aquatic traps are those by Calef (1973), van Gelder (1973) and Bell (1977). By now a substantial literature exists on the design and performance of traps, from which it is apparent that they generally perform well (Skelly and Richardson, 2010; Kronshage et al., 2014). However, for research into demography and population processes, high sampling efficiencies are advantageous. For example, to unambiguously identify adults that skip one or more annual breeding opportunities requires that all animals that engage in breeding are actually observed, over a range of years. We here describe the functioning and sampling efficiency of lightweight, collapsible funnel traps that we use to study European newts. The traps were originally designed for catching crayfish, but are for amphibian monitoring manufactured with a smaller, 4 × 4 mm mesh. The traps consist of a framework of one large semi-circular (diameter 48 cm) and three smaller circular metal loops (diameter 29 cm), to which the funnel and the collection chamber are attached (fig. 1). The actual funnel is cone-shaped, 30 cm deep and has the apex removed to create a funnel opening of 7 × 7 cm. A rectangular 45 × 97 cm extension leading towards the trap opening enlarges the catchment area. The total length of the traps is 207 cm and the weight is ca. 600 g. The traps were purchased at Casa Galo, Avenida Palo-mares 26, 41100, Coria del Rio, Sevilla, Spain.

The study was carried out in the French ‘departments’ Pas-de-Calais (pond 1, located near...
Figure 1. Funnel trap used to capture newts during the breeding season. Traps were positioned with the diagonal of the semi-circular funnel flat to the pond bottom. The position of the narrow opening in between the two chambers is indicated by line ‘a’. Line ‘b’ indicates the section of the trap that stays above the water surface, if so needed with the help of a polystyrene floater. The anterior chamber can be opened for inspection at position ‘c’. The iron poles at either side are M10 threaded rods, so that the tension applied to the cords is easily adjusted. The sheet of paper is of A4 size. One functional difference with most other funnel traps is the extension at the front that enlarges the catchment area.
(S) as implemented in FSA software (Ogle, 2016). The Moran method estimates a constant probability of capture across all sampling sessions ($p_M$), whereas the Schnute method accounts for a different probability of capture for the first sample ($p$) and a constant probability of capture for all ensuing samples ($p_{1S}$). The S-method was preferred over the M-method if catchability significantly differed between the first sample and the other samples, as determined from negative log-likelihoods by the chi-square test statistic (Ogle, 2016). The parameters $p_M$, $p_S$ and $p_{1S}$ are catchabilities at the first ($p$) and subsequent visits ($p_1$) for the Moran ($p_M$) and Schnute methods ($p_S$ and $p_{1S}$). For analyses across the data set $p_M$ was used to ensure the comparability of the results. The overall probability of being detected (and not being missed in an annual experiment) is detectability ($D$), which here is the number of different animals encountered ($N_{diff}$) divided by the estimated population size ($\hat{N}$). Ninety-five percent confidence intervals (CI95) are derived from $\hat{N}$ and based on likelihood ratio theory as described in Schnute (1983). Experiments with $N_{diff} < 5$ were not analyzed and results with CI95 covering the zero to unity range were ignored. A special case are capture histories such as ($x$, 0, 0, etc.) that have $x$ individuals caught at the first sampling session and none at two or more sessions afterwards. Such data are not accommodated by the Moran and Schnute methods and results were interpreted as $x = N_{diff} = \hat{N}$, with $p_M$ and $D$ at unity. This type of analysis we refer to as the count method (c). Population parameters were estimated per pond, year and species for either sex in the period 2009-2019. The number of study years was one for pond 1, three for pond 5 and 11 for ponds 2, 3 and 4. Data statistical analysis was with SPSS (IBM SPSS v. 20, 2016).

The total number of observations was 22 161 (numbers irrespective of marking status). The default M-method was applied most frequently (128 experiments, 75%). The S-method was preferred in 29 experiments (17%), mostly for *L. helveticus* (21 times), or the other species when samples were large ($N_{diff} > 30$, six times). Experiments with $p_S > p_{1S}$ and $p_S < p_{1S}$ were about equally frequent, suggesting no particular tendency for a decrease or increase in the catchability of unmarked animals over time. The c-method was applied in 14 experiments (8%) and only to Triturus, suggesting that these two species were frequently exhaustively sampled in a single overnight sampling session. We generally achieved high yields with $D \geq 0.90$ in 135 experiments (79%) and $D \geq 0.99$ in 95 experiments out of 171 (56%; table 1). Across the study catchability $p_M$ was significantly higher for males than for females in the small bodied species (related samples Wilcoxon signed rank test: *L. helveticus*, $n = 33$, $W = 479.5$, $P < 0.0001$; *L. vulgaris*, $n = 7$, $W = 28$, $P < 0.05$) and not in the large bodied species (*T. cristatus*, $n = 22$, $W = 100$, $P > 0.05$; *T. marmoratus*, $n = 20$, $W = 90$, $P > 0.05$). Overall, catchability was markedly higher for syntopic *T. marmoratus* and *T. cristatus* than for *L. helveticus* and *L. vulgaris* (supplementary table S1). Among congeneric species differences were not significant (*Lissotriton*: $n = 17$, $W = 97$, $P > 0.05$; *Triturus*: $n = 21$, $W = 135$, $P > 0.05$). In the species studied body length increases in the order *L. helveticus* – *L. vulgaris* – *I. alpestris* – *T. marmoratus* – *T. cristatus* (Griffiths, 1996; Arntzen, 2000) and we note that catchability increases in approximately the same order, but to further test this apparent relationship more data are required on *I. alpestris*. A decrease with body size highlights the position of *L. helveticus*, in which males are smaller than females, yet they have higher catchability.

In the literature, a male capture bias and no capture bias have both been reported, frequently however without reference to total population size (e.g. Griffiths, 1985). The statistical analysis of Trevor Beebee’s data, with population sizes known (Beebee, 1990), reveals a male bias for *T. cristatus* ($G$-test for independence, $G = 10.3$, $P < 0.01$) and no bias for *L. vulgaris* ($G = 1.05$, $P > 0.05$). The study also shows a higher catchability for *T. cristatus* than for *L. vulgaris* ($G = 17.5$, $P < 0.001$). The data by
Table 1. Probability of being detected (D) in annual experiments for male (M) and female (F) newts in the French departments Pas-de-Calais (pond 1) and Mayenne (ponds 2-5). 95CI is the 95% confidence interval. Methods used in the process are c (count), M (Moran) and S (Schnute); for details see text. Empty cells denote experiments for which the number of different individuals encountered was <5.

| Locality  | Year | Number | Sex | Lissotriton helveticus | Lissotriton vulgaris | Ichthyosaura alpestris | Triturus cristatus |
|-----------|------|--------|-----|------------------------|---------------------|------------------------|-------------------|
|           |      | Capture sessions | Funnel traps | D (95CI), method | D (95CI), method | D (95CI), method | D (95CI), method |
| Pond 1    |      |                  |               |                        |                      |                        |                   |
|           | 2012 | 4                 | 5              | M                      | 0.42 (0.33-0.68), M | 0.51 (0.33-0.86), M | 0.83 (0.63-0.94), M |
|           |      |                    |                | F                      | 0.33 (0.00-0.62), S | 0.33 (0.33-0.92), S | 0.33 (0.00-0.60), M |
|           |      |                    |               |                        |                      |                        |                   |
| Pond 2    |      |                  |               |                        |                      |                        |                   |
|           | 2009 | 5                 | 8              | M                      | 0.40 (0.33-0.65), M | 1.00 (0.94-1.00), M |                    |
|           |      |                    |                | F                      | 0.33 (0.33-0.64), M | 0.45 (0.33-1.00), M |                    |
|           | 2010 | 6                 | 5              | M                      | 1.00 (0.96-1.00), M | 1.00 (0.95-1.00), M |                    |
|           |      |                    |                | F                      | 0.99 (0.91-1.00), M | 1.00, c               |                    |
|           | 2011 | 5                 | 6              | M                      | 0.99 (0.95-1.00), S | 1.00 (0.35-1.00), M |                    |
|           |      |                    |                | F                      | 0.99 (0.95-1.00), M |                        |                    |
|           | 2012 | 4                 | 8              | M                      | 0.95 (0.75-0.99), S | 1.00, c               |                    |
|           |      |                    |                | F                      | 0.97 (0.92-1.00), S |                        |                    |
|           |      |                    |               |                        |                      |                        |                   |
|           | 2013 | 5                 | 6              | M                      | 0.93 (0.81-0.98), S | 1.00 (0.86-1.00), M |                    |
|           |      |                    |                | F                      | 0.87 (0.65-0.95), S | 1.00 (0.65-1.00), M |                    |
|           | 2014 | 6                 | 8              | M                      | 0.94 (0.84-0.99), S | 1.00 (0.85-1.00), M |                    |
|           |      |                    |                | F                      | 0.91 (0.77-0.98), S |                        |                    |
|           | 2015 | 4                 | 10             | M                      | 0.88 (0.81-0.94), M | 1.00, c               |                    |
|           |      |                    |                | F                      | 0.94 (0.84-0.98), S | 1.00, c               |                    |
|           | 2016 | 4                 | 9              | M                      | 0.92 (0.33-0.97), S | 1.00 (0.95-1.00), M |                    |
|           |      |                    |                | F                      | 0.92 (0.86-0.97), M | 1.00, c               |                    |
|           | 2017 | 4                 | 6              | M                      | 0.86 (0.73-0.94), M | 1.00 (0.86-1.00), M |                    |
|           |      |                    |                | F                      | 0.66 (0.42-0.81), M |                        |                    |
|           | 2018 | 5                 | 9              | M                      | 0.97 (0.93-0.99), S | 1.00 (0.99-1.00), M |                    |
|           |      |                    |                | F                      | 0.93 (0.85-0.98), S | 1.00 (0.96-1.00), M |                    |
|           | 2019 | 4                 | 6              | M                      | 0.97 (0.93-0.99), S | 1.00 (0.74-1.00), M |                    |
|           |      |                    |                | F                      | 0.96 (0.91-0.99), M | 1.00 (0.96-1.00), M |                    |
| Pond 3    |      |                  |               |                        |                      |                        |                   |
|           | 2009 | 8                 | 10             | M                      | 0.87 (0.33-1.00), M | 1.00 (0.33-1.00), M |                    |
|           |      |                    |                | F                      | 1.00 (0.57-1.00), M | 1.00 (0.74-1.00), M |                    |
|           | 2010 | 6                 | 4              | M                      | 1.00 (0.70-1.00), M | 1.00 (0.95-1.00), M | 1.00 (0.89-1.00), M |
|           |      |                    |                | F                      | 1.00 (0.83-1.00), M | 1.00 (0.95-1.00), M | 1.00 (0.95-1.00), M |
|           | 2011 | 4                 | 7              | M                      | 1.00 (0.88-1.00), M | 1.00, c               |                    |
|           |      |                    |                | F                      | U                    | 1.00 (0.98-1.00), M |                    |
|           | 2012 | 6                 | 10             | M                      | 1.00 (0.87-1.00), M | 1.00 (0.92-1.00), M |                    |
|           |      |                    |                | F                      | 1.00 (0.87-1.00), M | 0.99 (0.89-1.00), M |                    |
|           | 2013 | 5                 | 6              | M                      | 0.78 (0.33-1.00), M | 1.00 (0.88-1.00), M | 1.00 (0.85-1.00), M |
|           |      |                    |                | F                      | 0.92 (0.33-1.00), M | 1.00 (0.97-1.00), M |                    |
|           | 2014 | 8                 | 7              | M                      | 0.71 (0.33-0.90), M | U                    | 0.82 (0.33-1.00), M |
|           |      |                    |                | F                      | 0.33 (0.33-0.68), M | 0.33 (0.00-0.75), S | 0.77 (0.42-0.94), M |
|           | 2015 | 6                 | 6              | M                      | 0.90 (0.64-1.00), M | 0.90 (0.60-1.00), M | 0.99 (0.81-1.00), M |
|           |      |                    |                | F                      | 0.54 (0.00-0.94), S | 0.79 (0.33-1.00), M |                    |
|           | 2016 | 6                 | 9              | M                      | 0.98 (0.91-1.00), M | 1.00 (0.99-1.00), S | 1.00 (0.96-1.00), S |
|           |      |                    |                | F                      | 0.80 (0.38-0.97), M | 0.84 (0.40-1.00), M | 0.95 (0.84-1.00), M |
|           | 2017 | 6                 | 6              | M                      | 0.88 (0.33-1.00), M | 0.97 (0.63-1.00), M | 0.69 (0.33-0.93), M |
|           |      |                    |                | F                      | 0.75 (0.33-0.99), S |                        | 0.94 (0.83-1.00), M |
|           | 2018 | 5                 | 9              | M                      | 0.99 (0.94-1.00), M | 0.95 (0.60-1.00), M |                    |
|           |      |                    |                | F                      | 0.97 (0.88-1.00), M | 0.99 (0.85-1.00), S |                    |
Table 1. (Continued.)

| Locality | Year | Number | Sex | Capture sessions | Funnel traps | *Lissotriton helveticus* | *Lissotriton vulgaris* | *Triturus marmoratus* | *Triturus cristatus* |
|-----------|------|--------|-----|------------------|--------------|-------------------------|----------------------|----------------------|----------------------|
| Pond 4    |      |        |     |                  |              | 0.85 (0.52-0.99), M    | 1.00 (0.94-1.00), M  | 0.99 (0.93-1.00), M |                     |
|           |      |        |     |                  |              | 0.87 (0.60-0.99), M    | 0.97 (0.95-1.00), M  |                      | 1.00 (0.94-1.00), S |
|           | 2009 | 6      | 8   | M                |              | 1.00 (0.98-1.00), M    | 1.00 (0.91-1.00), S  | 1.00 (0.96-1.00), S |                     |
|           |      |        |     |                  |              | 0.97 (0.89-1.00), M    | 0.88 (0.33-1.00), M  | 0.99 (0.86-1.00), M |                     |
|           | 2010 | 6      | 6   | M                |              | 0.98 (0.93-1.00), M    | 1.00 (0.99-1.00), M  | 1.00 (0.98-1.00), M |                     |
|           |      |        |     |                  |              | 0.92 (0.81-0.98), M    |                      | 1.00, c              | 1.00 (0.99-1.00), M |
|           | 2011 | 5      | 6   | M                |              | U                      | 1.00 (0.91-1.00), M  | 1.00 (0.87-1.00), M |                     |
|           |      |        |     |                  |              | 0.86 (0.56-0.98), M    | 0.97 (0.50-1.00), M  | 1.00 (0.94-1.00), M |                     |
|           | 2012 | 5      | 4   | M                |              | NS                    | 1.00 (0.63-1.00), M  | 0.94 (0.40-1.00), M |                     |
|           |      |        |     |                  |              | NS                    | 0.74 (0.33-1.00), M  | 1.00 (0.67-1.00), M |                     |
|           | 2013 | 9      | 7   | M                |              | 1.00 (0.96-1.00), M    | 0.99 (0.75-1.00), M  | 1.00 (0.90-1.00), M |                     |
|           |      |        |     |                  |              | 0.33 (0.33-0.75), M    | 1.00 (0.60-1.00), M  | 0.33 (0.00-0.88), M |                     |
|           | 2014 | 9      | 8   | M                |              | 0.99 (0.95-1.00), M    | 1.00 (0.97-1.00), M  | 0.92 (0.43-1.00), M |                     |
|           |      |        |     |                  |              | 0.93 (0.84-0.98), M    | 1.00 (0.82-1.00), M  | 1.00 (0.90-1.00), M |                     |
|           | 2015 | 4      | 13  | M                |              | 0.99 (0.33-1.00), S    |                      | 1.00, c              | 1.00 (0.97-1.00), M |
|           |      |        |     |                  |              | 0.99 (0.97-1.00), M    |                      | 1.00, c              | 1.00 (0.90-1.00), M |
|           | 2016 | 6      | 10  | M                |              | 0.90 (0.33-0.95), S    | 1.00 (0.87-1.00), M  | 0.98 (0.59-1.00), M |                     |
|           |      |        |     |                  |              | 0.86 (0.78-0.92), M    | 1.00 (0.79-1.00), M  | 1.00 (0.95-1.00), M |                     |
|           | 2017 | 5      | 8   | M                |              | 0.98 (0.91-1.00), S    |                      | 1.00, c              | 1.00 (0.96-1.00), M |
|           |      |        |     |                  |              | 0.94 (0.82-0.99), S    |                      | 1.00 (0.95-1.00), M |                     |
|           | 2018 | 6      | 13  | M                |              | 1.00 (0.99-1.00), M    |                      | 1.00, c              | 1.00 (0.94-1.00), M |
|           |      |        |     |                  |              | 0.91 (0.78-0.97), S    |                      | 1.00, c              | 1.00 (0.98-1.00), M |
|           | 2019 | 5      | 13  | M                |              | 1.00 (0.99-1.00), S    | 1.00 (0.98-1.00), M  | 1.00 (0.96-1.00), M |                     |
|           |      |        |     |                  |              | 0.91 (0.81-0.97), M    |                      | 1.00, c              | 1.00, c             |
| Pond 5    |      |        |     |                  |              | 0.90 (0.51-0.90), M    | 0.98 (0.97-0.98), M  |                     |                     |
|           | 2010 | 3      | 6   | M                |              | 0.92 (0.55-0.94), M    | 0.99 (0.98-0.99), M  |                     |                     |
|           |      |        |     |                  |              | U                      | 0.97 (0.77-1.00), M  |                     |                     |
|           | 2011 | 3      | 6   | M                |              | 0.37 (0.00-0.99), M    | 1.00 (0.96-1.00), M  |                     |                     |
|           | 2016 | 5      | 8   | M                |              | NS                     | 1.00 (0.94-1.00), M  |                     |                     |
|           |      |        |     |                  |              | NS                     | 0.93 (0.72-1.00), M  |                     |                     |

NS – Not studied.
U – Undetermined because the 95% confidence interval covers the zero to unity range.

Ortmann et al. (2005), with a population size estimate available, indicate a significant male bias for *T. cristatus* in one year (*G* = 28.9, *P* < 0.001) and not the other year (*G* = 1.42, *P* > 0.05).

We also investigated if newt numbers captured would be higher at early than at late sessions within the annual experiment, irrespective of marking status. Consistently lower capture numbers at later sessions might indicate ‘trap shyness’ (or conversely ‘trap addiction’). Trap shyness is the alteration of an animal’s pattern of behavior after it has been caught for the first time (Seber, 1982). Accordingly, in the case of four or five sessions (see table 1) the pooled samples of sessions 1 and 2 were compared with pooled samples for the last two sessions; with six or seven sessions sets of three were compared, etc. Because the funnel traps were mostly up over a period confined to 1-2 weeks at the peak of the breeding season, so after immigration and prior to emigration, effects of phenology will be minor (Arntzen, 2002 and see discussion below). Across ponds we observed a significant decline in the numbers of newts captured from early to late funnel trap sessions.
Figure 2. Numbers of adult newts caught in early (vertical axis, y) versus late (horizontal axis, x) funnel trap sessions across ponds, years and species. Note the logarithmic scale. The solid line shows $x = y$. With 58 observations falling above the line, 23 below the line and one at the line the difference between ‘early’ and ‘late’ is statistically significant (G-test for equal proportions, $G = 15.12$, $df = 1$, $P < 0.001$). For species specific results and discussion see text.

Addendum
Annie Zuiderwijk passed away on January 27, 2020. In herpetology she will be best remembered for her biogeographical work (Schoorl and Zuiderwijk, 1980; Zuiderwijk, 1980; Bergmans and Zuiderwijk, 1986) and for her work on the hibernating tadpoles of Alytes obstetricans (Laurenti, 1768) which are considered unpalatable (Heusser, 1971; Peterson and Blaustein, 1991). In pond 3 some Rana dalmatina tadpoles were found dead inside the traps. The L. helveticus were invariably laterally injured, at a position just in front of the insertion of a hind leg. Injuries of this kind were not observed in the other species or outside the traps. Prime candidates for the assaults are predatory diving beetles of the family Dytiscidae. Species identified were Agabus bipustulatus (Linnaeus, 1767) and Dytiscus marginalis Linnaeus, 1758. Fish are absent in the ponds we studied and fish predation reported elsewhere (e.g. Swartz and Miller, 2018) is not an issue. Food intake by trapped newts was not studied, but some elevated predation by Triturus on Lissotriton is likely, as is the feeding by newts on larvae of the early breeding amphibian species Rana dalmatina Fitzinger, 1839, Rana temporaria Linnaeus, 1758 and Salamandra salamandra (Linnaeus, 1758). The hibernating tadpoles of Alytes obstetricans (Laurenti, 1768) are too large to be eaten and Bufo tadpoles (Bufo bufo (Linnaeus, 1758) in Pas-de-Calais and Bufo spinosus Daudin, 1803 in Mayenne) are considered unpalatable (Heusser, 1971; Peterson and Blaustein, 1991). In pond 3 some Rana dalmatina tadpoles were found dead inside the funnel traps at a spell of high temperature. Accordingly, we recommend caution in using the funnel traps later in the season and we wonder if not cases of accidental trap injury and mortality are underreported in the literature (but see Klemish, Engbrecht and Lannoo, 2013 and references therein). The very high sampling efficiency of the funnel traps here described is probably mostly achieved through their large size and large catchment area. Practical assets of the traps are their low weight and small volume when collapsed, facilitating handling and storage.
newt courtship behaviour (Zuiderwijk and Sparreboom, 1986; Zuiderwijk, 1990) and for her involvement with the Mapping Committee of the SEH. Annie also initiated the reptile monitoring program in the Netherlands (e.g. Kery et al., 2009), that is now operated by the NGO RAVON (Reptile, Amphibian and Fish Research in the Netherlands). Annie retired from her appointment as a member of the research staff at the Zoological Museum, University of Amsterdam in 2008, yet remained keen and active in herpetological research (fig. 3, see also van Diepenbeek, 2011; Evrard, 2017). A more comprehensive In Memoriam on Annie will shortly be published by her closest colleagues in the RAVON journal.

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