Status of three great crested newt *Triturus cristatus* populations after translocation

Status av tre större vattensalamanderpopulationer Triturus cristatus efter translokering

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Abstract

The great crested newt *Triturus cristatus* has a high legal protection in Europe through the Bern Convention and Habitats Directive, which often come into conflict with human development. Translocation of populations are increasingly being used as a "solution" to this conflict, but the implications for the populations' status are not known. With the aim of investigating these effects, three translocated populations in Stockholm, Sweden were studied using a capture-mark-recapture method. The results show that both population size and body condition of the great crested newt can be affected by translocation. The results indicate a 90 % local population decrease for one of the populations, while the other two studied populations seem unaffected. The difference is probably due to the removal of drift fence for the population that had declined, while the drift fence remained for the other two populations. For the population that decreased, body condition increased after translocation, but was still lower compared to the other two populations. This study shows that translocation of great crested newt populations can negatively impact their status, possibly due to a strong "homing-behavior" when the drift fence around the receptor site has been removed. This homing-behavior likely persist for more than one and a half years after translocation. Further studies are needed to investigate factors that affect salamanders' long-term population changes and body condition after translocation, including long-term effects of drift fence around the receptor site.

Keywords: Amphibians, Caudata, capture-mark-recapture, breeding population size, body condition, conservation.

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1. Introduction

Vertebrates have suffered a 68 % average decline in population sizes globally during the last half century (WWF 2020). Included within the vertebrates are the amphibians, of which 41 % of all species are in danger of extinction (IUCN 2021), which makes them one of the most threatened vertebrate groups on the planet (Stuart et al. 2004). The causes for the declines are variable and often complex because of interactions and local-scale effects (Angelini et al. 2020). The infectious disease *Chytridomycosis* as well as habitat loss and degradation are nevertheless, often considered the most important threats for amphibian populations (Blaustein & Kiesecker 2002; Stuart et al. 2004; Denoël & Ficetola 2008; Ficetola 2015; Downie et al. 2019; Sheele et al. 2019; Angelini et al. 2020). Starting their lives as larva in water, developing through metamorphosis into air breathing adults with lungs – make amphibians (generally) dependent of two habitat types. This increases their risk of extinction since they are sensitive to damage in either system (Primack & Sher 2018).

Ponds – small freshwater bodies (Rannap et al. 2009), are essential habitats for a large proportion of amphibian species (Beebee 1997) but have exhibited a massive decline in the European countries during the 20th century with a loss of 50-90 % (Hull 1997). The remaining ponds are often isolated or have reduced quality because of overgrowth, eutrophication, contamination or invasive species (Brönmark & Hansson 2005; Rannarp et al. 2009). Amphibians that have their ranges in human dominated landscapes, mostly close to cities or towns, also compete for habitat with building- and infrastructure development (Beebee & Griffiths 2005; Price et al. 2006). One common solution to these conflicts that have increased in practice over the past decades is to translocate the affected population to another locality to be able to exploit their old habitat (Edgar et al. 2005; Germano & Bishop 2009; Germano et al. 2015).

The great crested newt *Triturus cristatus* is dependent of freshwater bodies; typically ponds with good water quality and a suitable proportion of vegetation cover (preferably 25-50 % emergent and 50-75% submerged) for its reproduction (Oldham 1994). The terrestrial environment surrounding the breeding pond should optimally consist of woodland, rough grassland, wetland, shrub or mature garden with overwintering areas, foraging opportunities and refugia (Laan & Verboom

1990; Oldham 1994; Gent & Gibson 2003). The species has a high legal protection in Europe, together with its breeding habitat, through the Bern Convention (listed in Appendix II) and Habitats Directive (listed in Annexes II and IV). Being a widely distributed species with high legal protection, the great crested newt has been subject to many translocations as compensation measures, when exploitation of their habitat is perceived as unavoidable (Edgar et al 2005; Germano et al 2015). The implication of these translocations is however often not evaluated or not monitored with relevant methods that are required for assessing population status or population comparisons pre- and post-translocation (Oldhamn & Humphries 2000; Edgar et al. 2005; Germano et al. 2015; Lewis et al. 2017).

As part of an evaluation of implications of two translocation projects of the great crested newt that were conducted as compensation measures for building development in Stockholm, Sweden, resulting in three receptor site populations - I intend to answer: (I) what the size of each breeding population post-translocation is, (II) if it is comparable to the number of translocated adults (III) and how this may influence the body condition at each receptor site. For one of the populations, I also (IV) compare breeding population size estimates pre- and post- translocation, assess the proportion of the receptor pond breeding population that consists of translocated adults and (V) if these individuals' body condition is affected by translocation.

Translocations of great crested newts have increased during the last decades (Gustafson et al. 2016) and only in the United Kingdom several hundred occasions of population translocations of the great crested newt were performed between 1990 and 2001 (Edgar et al. 2005). Therefore, the results of this thesis are very important for increasing the knowledge of conservation and implications for a globally declining amphibian – the great crested newt (IUCN 2021).

2. Study site descriptions and methods

2.1. The Djurgården translocation

Djurgården is part of the Royal national city park in Stockholm; a continues green area including a mixed landscape of pastures, meadows, old deciduous woodland and parks. The area also includes houses, smaller roads as well as historical and commercial buildings. Loudden is a headland at Djurgården, that currently is used as an oil harbor but is to be redeveloped for housing and workplace opportunities. As part of the planning process for the redevelopment, an investigation was conducted 2017-2018 by a consultant company Calluna AB, where two breeding ponds of the great crested newt were found between some petroleum tanks. This investigation involved a capture-mark-recapture study based on two capture occasions (the 19th of May and 15th of June 2018) using 10 funnel traps. According to their study, the breeding population at Loudden 2018 consisted of 584 adults with a 95% confidence interval [Ci] between 189 and 1141 adults (Sterenborg & Koffman 2020). The Chapman estimator in the recapr package (version 0.4.3) in program R (R Core Development Team 2021) was used for the calculations (cf. Sterenborg & Koffman 2019). Since the grounds had to be decontaminated, the destruction of the ponds was regarded as unavoidable. In compensation, new breeding habitat was constructed for the newts - Brunnslättsdammen. This pond is located in a former horse paddock, 800 meters from the newts old breeding pond and 600 m from the nearest other known breeding pond for great crested newt. Boulders, logs, fallen leaves, branches and roofing tiles were added to create refuge and overwintering opportunities. A total of 1202 great crested newts were translocated from Loudden to Brunnslättsdammen during 2019-2020, including 348 males, 306 females and 548 juveniles. The newts were captured using pit-fall and Ortmann's funnel traps (Drechsler et al. 2010). In the first year, captures and translocations were carried out from the 5th of April until the 2nd of June, which resulted in 528 adults and 443 juveniles being translocated to the new pond. In the second year, the captures and translocations started the 11th of March and ended the 26th of June. This year 126 adults and 105 juveniles were translocated. In both years, each captured adult newt was weighed and measured (snout-vent length), and their abdomen photographed (since great crested newts have individual markings that make recognition possible). Larvae were captured with dip-nets and vegetation containing eggs were collected and moved to the new location (Sterenborg et al. 2021). In 2019, before the first newts arrived, a 50 cm high plastic panel (drift fence) was constructed around the pond as well as 0.25 hectares of terrestrial area and remained until disassembled the 19th of October 2020. This was done to avoid initial homing behavior; the attempt of an animal to return to its original home range following displacement (Ward et al. 2013). The translocation also included the smaller smooth newt *Lissotriton vulgaris*, that were also found in the two ponds at Loudden.

2.2. The Värmdö translocation

Värmdö is an island, the sixth largest in Sweden, and is located in the inner archipelago of Stockholm County. It is connected to the mainland by a bridge, suitable for cars, and constitutes of many residential areas, more urban parts as well as forest and pastures. In the area Charlottendal; a part of the county town Gustavsberg on Värmdö, plans were made to construct a kindergarten, an elementary school and parking lot at a site where at that time, a great crested newt breeding pond and wetland were located. To make the redevelopment possible, two new great crested newt breeding ponds were built in the nearby area, as compensation measures. The new ponds, here called Bukettvägen and Farsta slottsväg, were built in 2018 and 2019. Bukettvägen is located in a residential area with four other known great crested newt breeding ponds within migration distance and right next to a mixed forest. Farsta slottsväg is nearer the coast, with one additional pond inhabited by the great crested newt within migration distance. This pond is surrounded by grassland, a smaller road mostly used for walking and close to deciduous as well as pine forest. Refuge and hibernation habitats were constructed at both sites using boulders, branches and dead wood. In spring 2020 a total of 257 great crested newts were captured in or close to the pond in Charlottendal - 159 (43 males, 82 females, 34 juveniles) of these newts were translocated to Bukettvägen and 98 (40 males, 38 females, 20 juveniles) to Farsta slottsväg. Both drift fences and pit-fall traps were used for capturing newts during breeding migration and Ortmann's funnel traps were used for captures in the pond. Captured smooth newts were also translocated to the new sites. A drift fence was constructed around each receptor pond before translocations started, hindering initial homing behavior. These drift fences had not yet been dismounted during monitoring 2021 of this study.

2.3. Post-translocation study 2021

To estimate the breeding population sizes in the three receptor ponds (Brunnslättsdammen, Bukettvägen and Farsta slottsväg) post-translocation, a capture-mark-recapture study was performed at each site during the newts' peak breeding season. The study included eight capture occasions every third night in May 2021 (except at one occasion in Brunnslättsdammen when six days had passed since the last capture). At Brunnslättsdammen the capture occasions were performed between the 1st – 25th, at Bukettvägen the 1st – 22nd and at Farsta slottsväg the 13th – 31st. A varying number of Ortmann's funnel traps (Drechsler 2010) were used at each site depending on approximate pond size. One umbrella shaped version of a collapsible nylon fish trap (Houser 1960) was also used at Bukettvägen. In total, 20 traps were used in Brunnslättsdammen, nine at Bukettvägen and eight at Farsta slottsväg. The traps were placed approximately at the same spot every night, with some flexibility depending on water level. The traps were put out the day before each trap night and emptied in the following morning. For each great crested newt captured, sex, age group, snout-vent length and weight were recorded. The newts were considered adults if they had obvious sex characters, i.e. dorsal crest and white/grey/silver striped tail for males or a swollen cloaca for females (Langton et al. 2001), otherwise as a juvenile. A portable scale with a 0.1-gram precision and a minimum weighing capacity of 0.4 g was used for weighing the newts. Each captured newts' abdomen was also photographed, and capture date recorded.

2.4. Data analysis

The photographs of the captured newts were compared, and recaptures recorded. To estimate the breeding population sizes (N), seven estimates were calculated at each receptor site using the Chapman model for closed populations (cf. Sterenborg & Koffman 2019). The population was assumed to be closed since most of the newts should have remained within the study area (the pond) given the short time frame of the capture period, and since the time interval between each estimates' capture dates were very short; only three days. Migration, emigration, deaths and births were therefore considered to be non-significant between the two capture dates of each estimate. The N estimates and Ci were calculated using the package recapr (version 0.4.3) in R 4.1.0 (R Core Development Team 2021). Bootstrapping was applied to fit the data to normal distribution and determine confidence intervals for the population means. The highest population size estimate including Ci, were then compared to the number of translocated adults for each receptor site. For the population of which a breeding population size estimate had been calculated before translocation (Djurgården), this was also compared to the highest estimate including Ci, after translocation.

The proportion of the breeding population post-translocation that consists of individuals that were translocated as adults was calculated using abdomen photographs for recognizing recaptured individuals. Since abdomen photographs only existed for the Djurgården population (see 2.1.), this was considered as the main study site of the project. Abdomen photographs taken at the translocation event (2019 or 2020) were compared with photographs from the capture-mark-recapture study 2021. The body condition pre- and post-translocation for each recaptured individual were also calculated and compared using the Scaled mass index (SMI; Peig & Green 2009) formula

$$\widehat{M_i} = M_i \left[\frac{L_0}{L_i}\right]^{b_{SMA}}$$

where *Mi* is the observed weight and *Li* the observed length (snout-vent) of the individual. L_0 is the mean length of the population and b_{SMA} the slope divided by Pearsons's correlation coefficient from an OLS regression of the logged weight and length data for the population (Peig & Green 2009). A tailed t-test was done to see if the difference between pre- and post-translocation was significant. The population estimates used in the SMI calculations (population mean as well as the logged weight and length data) was calculated separately for males and females. The average male body condition for each receptor site population was calculated using the SMI formula. All calculations were done in Excel (Microsoft Office Excel 2007).

3. Results

During the study period of 2021, there were a total of 198 great crested newt captures, including 53 great crested newt captures (31 males, 15 females and 7 juveniles) at Brunnslättsdammen, 78 (32 males, 35 females and 11 juveniles) at Bukettvägen and 67 (27 males, 34 females and 6 juveniles) at Farsta slottsväg (Table 1). Of these, 17% (n=30) of the total number of adults (n=174) were recaptures, including two adult individuals recaptured at Brunnslättsdammen, 12 at Bukettvägen and 16 at Farsta slottsväg (Table 1). Consequently, 44 adult individuals (30 males, 14 females) were caught at Brunnslättsdammen, 55 (23 males, 32 females) at Bukettvägen and 45 (20 males, 25 females) at Farsta slottsväg. The number of adult newts captured at each capture occasion varied from three to 11 at Brunnslättsdammen, one to 15 at Bukettvägen and two to 19 at Farsta slottsväg. The sex ratio of adult male and female individuals was close to 50 % whereas the sex ratio of recaptures was 57 % males and 43 % females. Smooth newts (Table 1), aquatic insects Dytiscidae and Corixidae, freshwater snails Gastropoda and one three-spined stickleback *Gasterosteus aculeatus* (at Farsta slottsväg) were also found in the traps during the study.

Table 1. Total number of captures; male, female and juvenile great crested newts during a capture-mark-recapture study at three different receptor sites - Brunnslättsdammen (Br; Djurgården), Bukettvägen (BV; Värmdö) and Farsta slottsväg (FS; Värmdö). Number of recaptured great crested newts as well as numbers of smooth newt captured at each site are also shown in the two last columns.

Site	**Tot. nr. of captures**	**M**	**F**	**Juv.**	**Recapt.**	**Smooth newt captures**
Br	53	31	15	7	2	120
BV	78	32	35	11	12	114
FS	67	27	34	6	16	170
Sum	198	90	84	24	30	404

The population size estimates differed in time and space. Based on the capture-mark-recapture analysis, the seven N estimates from Brunnslättsdammen varied from 15 to 65 adult newts, at Bukettvägen from 5 to 168 adult newts and at Farsta slottsväg from 17 to 71 adult newts (Figure 1). For the calculations with no recaptures recorded, Ci was however not possible to estimate.

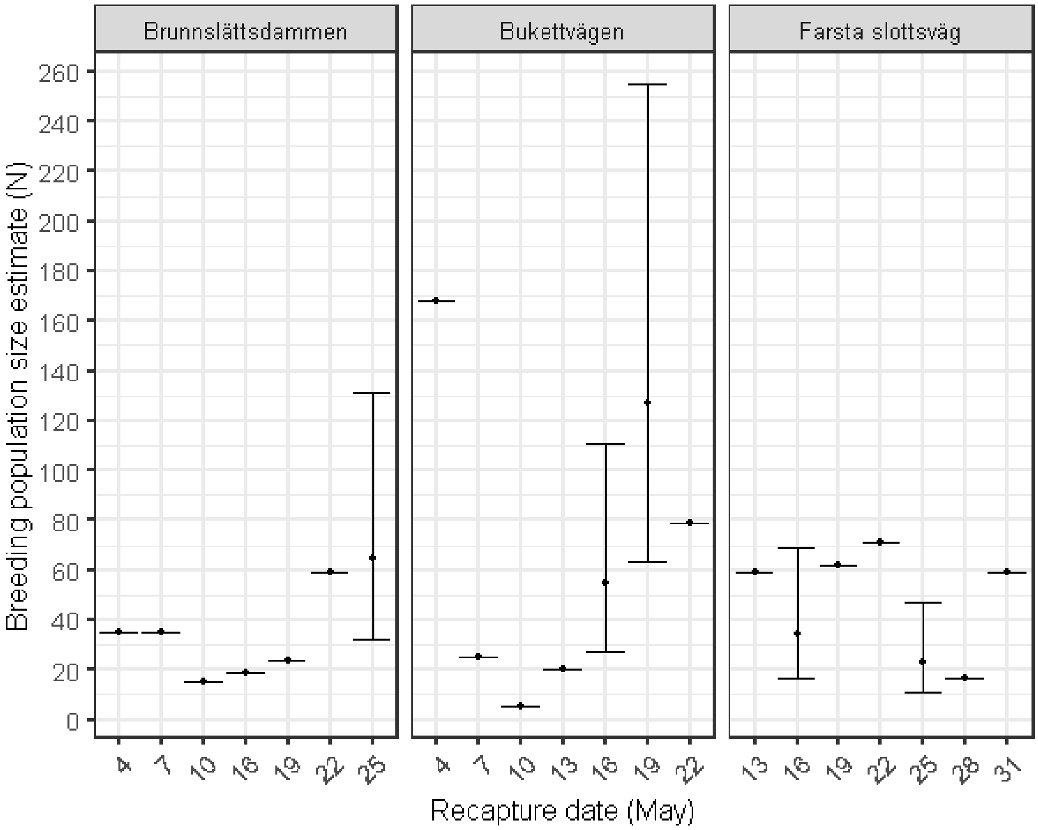

Figure 1. Breeding population size estimates (N) for three translocated populations of great crested newt at the three new sites; Brunnslättsdammen (Djurgården), Bukettvägen (Värmdö) and Farsta slottsväg (Värmdö). There are seven estimates for each receptor site population with capture occasions in three days intervals between the 4th and 31st of May 2021 (except between two occasions at Brunnslättsdammen, when there were six days between). Only for capture occasions including recaptured individuals, a 95% confidence interval (Ci) could be calculated.

For one N estimate at Brunnslättsdammen, recaptures were more than zero and Ci could be calculated; 65 [32-131]. At Bukettvägen two estimates included recaptures, resulting in N; 55 [27-111] and 127 [63-255]. Also at Farsta slottsväg two N included recaptures, resulting in two N with Ci; 34 [16.5-69] and 23 [11-47] (Figure 2).

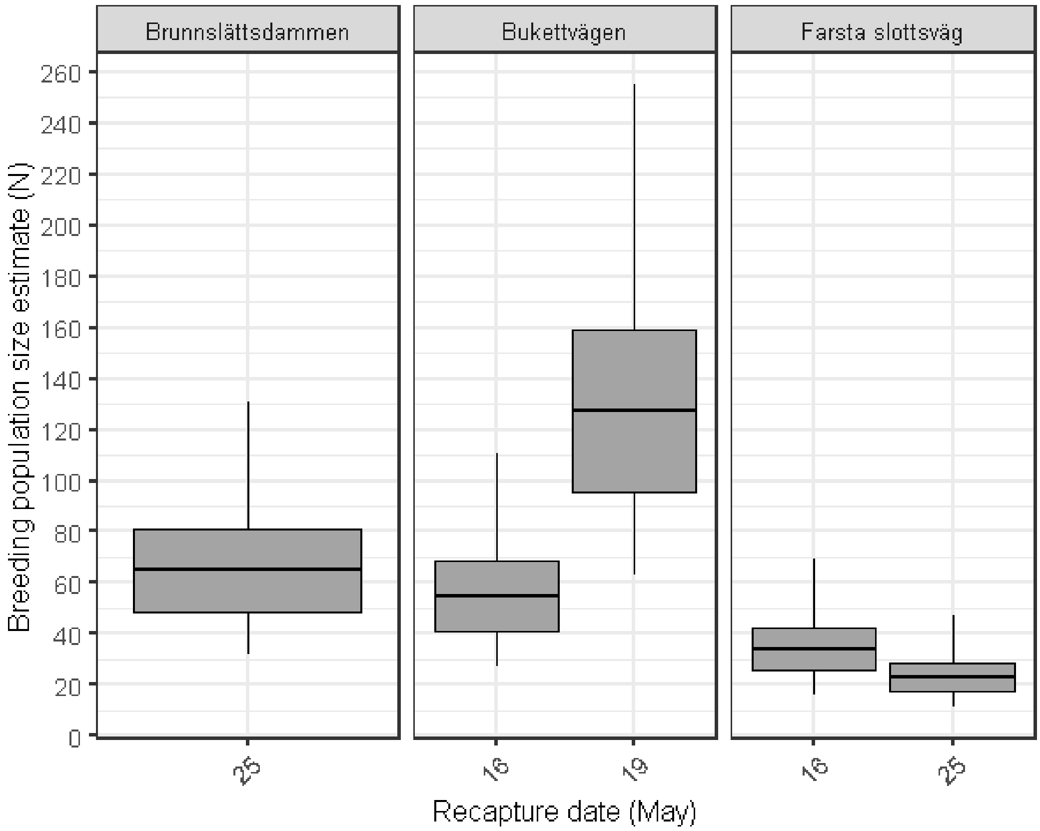

Figure 2. Breeding population size estimates (N) when recaptures were more than zero, making 95 % confidence intervals (Ci) possible to estimate. For the three great crested newt populations; Brunnslättsdammen (Djurgården), Bukettvägen (Värmdö) and Farsta slottsväg (Värmdö), this generated a different number of estimates. In Brunnslättsdammen one breeding population size estimate with Ci was possible to calculate; 65 [32-131], at Bukettvägen two; 55 [27-111] and 127 [63-255]. At Farsta slottsväg there were also two estimates where Ci could be calculated; 34 [16.5-69] and 23 [11-47].

For the Djurgården population, the highest breeding population size estimate post-translocation of 65 [32-131], is lower than the breeding population size estimate pre-translocation of 584 [189-1141]) (Figure 3). It is also lower than the number of translocated adults - which was 654. For the Bukettvägen population, the highest breeding population size estimate post-translocation of 127 [63-255] adults, is similar to the number of adults translocated – which was 125. For the Farsta slottsväg population the highest breeding population size estimate post-translocation of 34 [16.5-69] is slightly less than the number of adults translocated - which was 78.

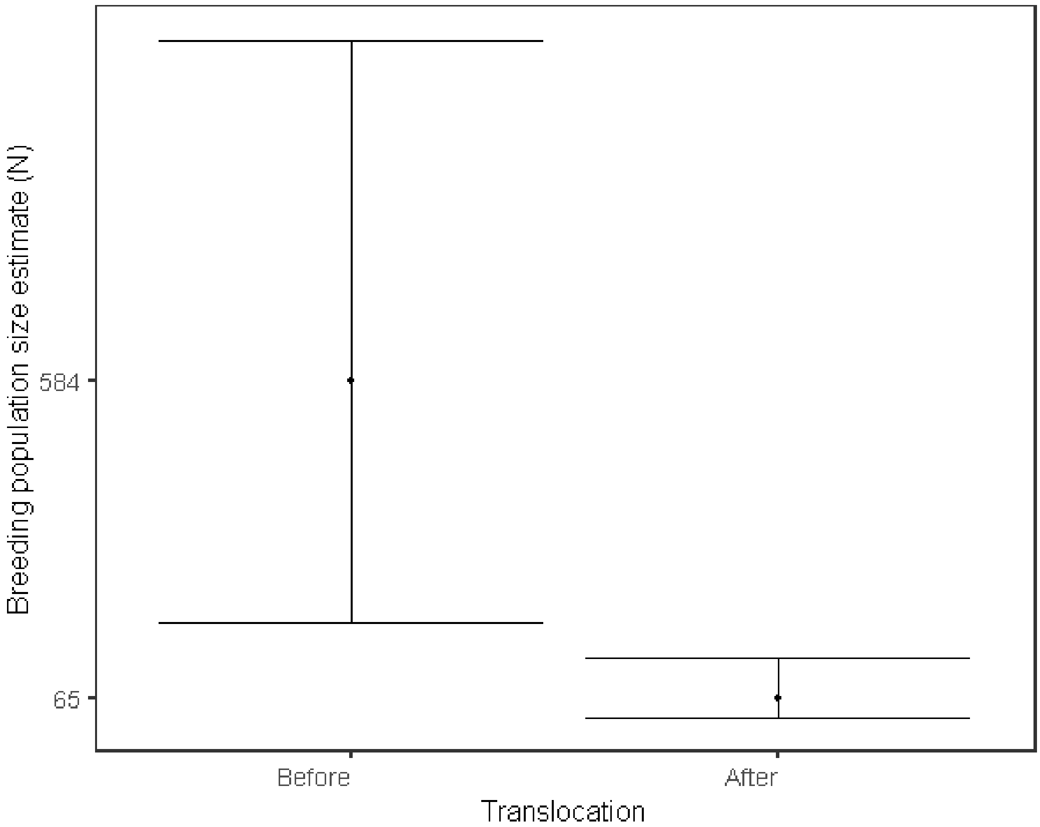

Figure 3. Comparing breeding population size estimates (N) including 95% confidence intervals [Ci], before and after translocation of a great crested newt population on Djurgården in Stockholm, Sweden. N including Ci after translocation; 65 [32-131], is lower than N including Ci before translocation; 584 [189-1141].

In Brunnslättsdammen, the comparison between abdomen photographs taken at the capture and translocation event and the photographs taken at the capture-mark-recapture study 2021 resulted in 16 newts being identified as recaptured. Three of these adult individuals were translocated 2019 and 13 in 2020. Consequently, 31% of captured individual adults 2021 had been translocated as adults one or two years earlier. Of the 16 recaptured adults, 11 had weight and length data from both first and second capture. A SMI score, before and after translocation could therefore be calculated for these 11 individuals (Figure 5; six females and five males). The comparisons of their SMI score pre- and post-translocation showed an increased body condition 2021 (Figure 4; *Mean*=9.4, *SD*=1.5, *SE*=0.5) as compared with their time of capture prior translocation in 2019 or 2020 (Figure 4; *Mean*=7.3, *SD*=1.3, *SE*=0.4), $t(10)=-5.5$, $p<0.001$). All recaptured individuals had increased their body condition at their new site (Figure 5).

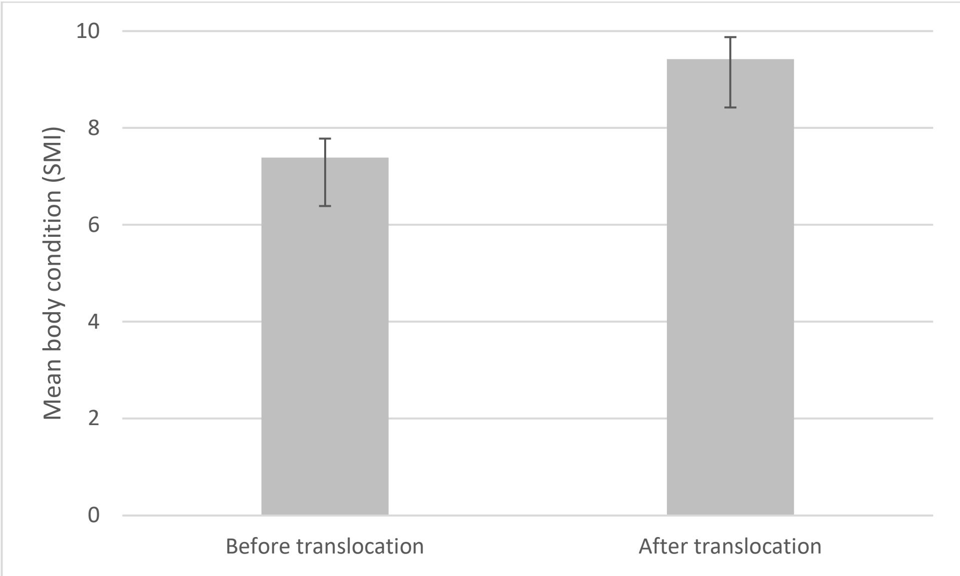

Figure 4. Average body condition using the Scaled mass index (SMI± SE) for 11 adult great crested newts (six females and five males) at Djurgården, before and after they had been translocated to a new location (Brunnslättsdammen). The translocation event was either in 2019 or 2020, and the recapture event were all in 2021. The SMI-scores were calculated using weight and length data collected for each individual before (at the translocation event) and either one or two years after.

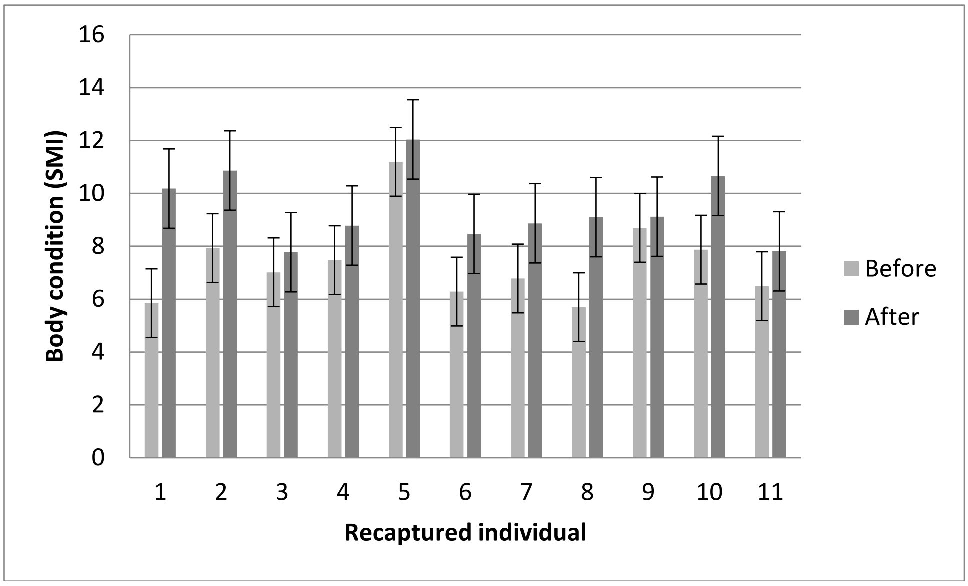

Figure 5. Comparing body condition using the Scaled mass index (SMI; ± SD) for 11 adult great crested newts (six females and five males) at Djurgården before and after they had been translocated to a new location (Brunnslättsdammen). The translocation event was either in 2019 or 2020, and the recapture events were in 2021. The SMI-scores were calculated using weight and length data collected for each individual prior to or post-translocation. All individuals increased their body condition at Brunnslättsdammen.

The average body condition of the 24 males captured 2021 in Brunnslättsdammen was 9.26 ± 0.5 (SE), of the 23 males captured at Bukettvägen it was 11.95 ± 0.4 and for the 19 males captured at Farsta slottsväg it was 11.77 ± 0.5 (Figure 6).

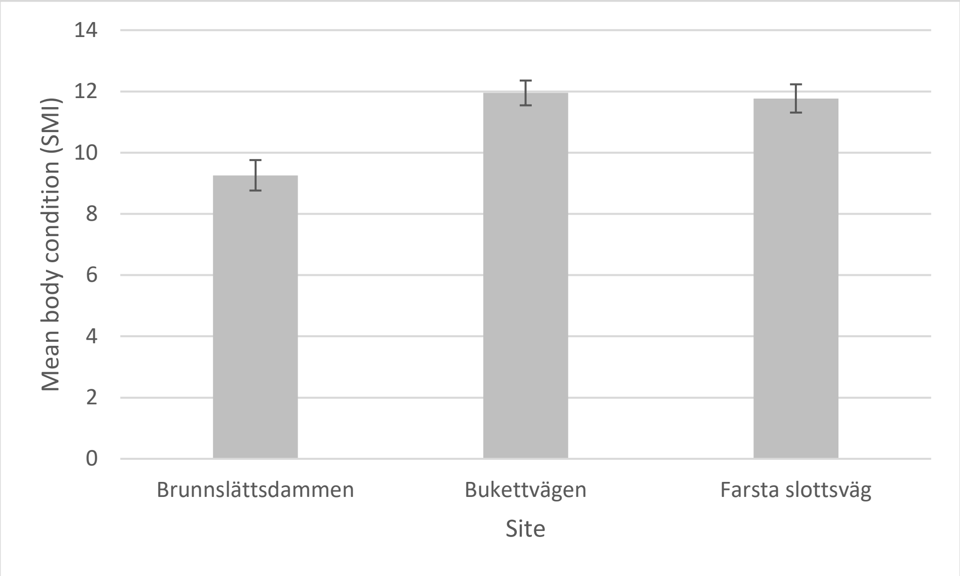

Figure 6. Average body condition using the Scaled mass index (SMI±SE) for adult males during breeding season 2021 at three great crested newt ponds; Brunnslättsdammen (Djurgården), Bukettvägen (Värmdö) and Farsta slottsväg (Värmdö). At Brunnsättsdammen 24 males were captured 2021 with an average SMI of 9.26 ± 0.5 (SE), at Bukettvägen 23 were captured and had an average SMI of 11.95 ± 0.4. At Farsta slottsväg 19 males were captured and had an average SMI of 11.77 ± 0.5.

Discussion

The breeding population size estimate for the Djurgården population (Brunnslättsdammen) is significantly lower post-translocation than both the estimate calculated before translocation in the original pond, as well as the number of newts translocated. The results indicate a local population decline of approximately 90 % post-translocation. The most probable reason for this is that individuals have moved back (homing) to their original localities or adjacent ponds, despite four months to one and a half years trapped with drift fences. This can be compared with the estimates of the two other receptor ponds that still have drift fences, where the highest breeding population sizes post-translocation are more similar to the number of newts that were translocated. Homing and migration from the release site, are the two most common reasons for failure in amphibian and reptile translocations (Germano & Bishop 2009). In a project evaluated by Oldham & Humphries (2000), more than half of translocated newts escaped or attempted to escape from their release site, of which 39 % were found back at their original pond. Also, a translocation project in Sweden was initially considered ineffective since a large proportion of great crested newts disappeared from the release site (Gustafson et al. 2016). Even though drift fences were hindering most newts from homing during their first one and a half year at Brunnslättsdammen, it is possible that newts have migrated from the area when drift fences were dismounted. The relatively low population size in Brunnslättsdammen may also be caused by stochastic effects. Studies of great crested newt population dynamic show that breeding population size can have large annual fluctuations (e.g. Arntzen & Teunis 1993) with increases or decreases from one year to another with around 50 % (Hagström 1979; Miaud et al. 1993). These very drastic changes in population size however, often derive from increased size of or newly introduced fish populations in the pond (Bell 1979; Hagström 1979; Cooke et al. 1980; Dolmen 1982; Beebee 1985; Arntzen & Teunis 1993; Baker 1999). This should not be the case in Brunnslättsdammen since no fish were caught in the traps during the study. Also, climatic factors as unusually long periods of heavy rainfall during either hibernation (Shoemaker et al. 1992; Zakaria 2017) or breeding season (Cayuela et al. 2020), as well as mild winter temperature (Griffiths et al. 2010) have been found to correlate with declines in great crested newt populations. Since the three monitored sites all are in the same approximate geographical region, climatic factors should however not differ considerably.

According to Cayuela et al. (2020) population fluctuations of great crested newts are more dependent of site-specific characteristics than regional climatic factors.

My results show that 11 translocated individuals from Loudden to Brunnslättsdammen increased their body condition post translocation. One reason for this may be a release from high levels of potential pollution of petroleum in their original pond. High degree of urban areas and heavy metals have previously been shown to reduce body condition in amphibians (Li et al. 2016; Guo et al. 2018). Another explanation for the increase in body condition post-translocation could be that the decrease in population size has led to lower intra- (and inter-) specific competition for resources (Hoare et al. 2006; Guerra & Aráoz 2015; Zakaria 2017), and consequently a higher energy store of individual newts (Hoey & McCormick 2004). Unglaub et al. (2018) found body condition of great crested newts not to be predicted by the quality of their habitat, but instead to be negatively correlated with the size of their population. Average body condition is also higher at the ponds that maintained more stable breeding population sizes, as compared with the one that experienced a decline, and indicates a lower fitness of the newts at Brunnslättsdammen (Bancila et al. 2010; Sivan et al. 2014), as compared with the Värmdö sites. This difference may be caused by an ongoing recovery from the potential pollution prior the translocation to Brunnslättsdammen.

Within the scope of this study it is impossible to say whether the decrease in population size or differences in body condition (that also can vary between years (Wheeler et al. 2003; Bancila et al. 2010; Jarvis 2015; Jarvis 2016)), are effects of the translocation or not. This study has shown that at least one of the three newly constructed sites, still contains translocated great crested newts one-two years after translocations, and the other two most probably do (since still encircled with newt proof drift fences). Two populations seem to have maintained similar breeding population sizes as were translocated, while the third has experienced a decline. Since amphibian populations are known to vary in population size between years (e.g. Arntzen & Teunis 1993; Pechmann et al. 1991), continued monitoring, including capture-mark-recapture methods for estimating population size, should be carried out during the next coming years so that the sustainability of the populations can be evaluated.

3.1. Implications for conservation

This study supports that the drift fences in combination with translocation of great crested newts do not seem to affect their population status or body condition negatively and should therefore work as a plausible method. The encircling of the new site with newt proof drift fences before the arrival of the translocated population seems to hinder initial homing and should therefore be included when translocating populations. Additionally, this study shows that translocated individuals even can increase their body condition. There is however, a risk that the translocated population will decline or move from the new locality when drift fences are removed and additional studies investigating factors affecting long-term population changes and body condition of newts after translocation are urgently needed. For how long newts will attempt to migrate back to their original locality after translocation and its relationship with the optimal duration for drift fences to be mounted, should also be considered to be studied in future research.

References

Angelini, C., Bielby, J. & Costa, C. (2020). A bibliometric-mapping approach to identifying patterns and trends in amphibian decline research. *Acta Herpetologica*. 15(2). 95-104. DOI: 10.13128/a_h-8478

Arntzen, J.W. & Teunis, S.F.M. (1993). A six year study on the population dynamics of the crested newt (*Triturus cristatus*) following the colonization of a newly created pond. *The herpetological journal*. 3(3). 99-110.

Baker, J.M.R. (1999). Abundence and survival rates of great crested newts (*Triturus cristatus*) at a pond in central England: monitoring individuals. *Herpetological journal*. 9. 1-8.

Bancila, R.I., Hartel, T., Plaia, R., Smets, J. & Cogalniceanu, D. (2010). Comparing three body condition indices in amphibians: a case study of yellow-bellied toad Bombina variegata. *Amphibia-reptilia.* 31(4). 558-562. DOI: 10.1163/017353710X518405

Beebee, T.J.C. (1985). Discriminant analysis of amphibian habitat determinants in south-east England. *Amphibia-reptilia*. 6(1). 35-43. DOI: 10.1163/156853885X00164

Beebee, T.J.C. (1997). Changes in dewpond numbers and amphibian diversity over 20 years on chalk downland in Sussex, England. *Biological conservation*. 81(3). 215-219. DOI: 10.1016/S0006-3207(97)00002-5

Beebee, T.J.C. & Griffiths, R.A. (2005). The amphibian decline crisis: A watershed for conservation biology? *Biological conservation.* 125(3). 271-285. DOI: 10.1016/j.biocon.2005.04.009

Bell, G. (1979). Populations of crested newts, *Triturus cristatus*, in Oxfordshire, England. *Copeia*. 3(2). 350-353. DOI: 10.2307/1443426

Blaustein, A.R. & Kiesecker, J.M. (2002). Complexity in conservation: lessons from the global decline of amphibian populations. *Ecology letters*. 5(4). 597-608. DOI: 10.1046/j.1461-0248.2002.00352.x

Brönmark, C. & Hansson, L.A. (2005). *The biology of lakes and ponds*. 2nd edn, Oxford: Oxford University Press.

Cayuela, H., Griffiths, R.A., Zakaria, N., Arntzen, J.W., Priol, P., Léna, J-P., Besnard, A., Joly, P. & Hewison, M. (2020). Drivers of amphibian population dynamics and asynchrony at local and regional scales. *Journal of animal ecology*. 89(6). 1350-1364. DOI: 10.1111/1365-2656.13208

Cooke, A.S., Scorgie. H.R.A. & Brown. M.C. (1980). An assessment of changes in populations of the warty newt (*Triturus cristatus*) and smooth newt (T. vulgaris) in twenty ponds in Wood walton fen National Nature Reserve 1974-1979. *British herpetological society bulletin.* 6. 45-47.

Denoël, M. & Ficetola, G.F. (2008). Conservation of newt guilds in an agricultural landscape of Belgium: The importance of aquatic and terrestrial habitats. *Aqutic conservation*. 18(5). 714-728. DOI: 10.1002/aqc.853

Dolmen, D. (1982). Zoogeography of *Triturus vulgaris (L.)* and *T. cristatus* (Laurenti) (Amphibia) in Norway, with notes on their vulnerability. *Fauna Norvegica*. Ser. A: 3. 12-25.

Downie, J.R., Larcombe, V. & Stead, J. (2019). Amphibian conservation in Scotland: A review of threats and opportunities. *Aquatic conservation*. 29(4). 647-654. DOI: 10.1002/aqc.3083

Drechsler, A., Steinfartz, S., Bock, D. & Ortmann, D. (2010). Ortmann's funnel trap – a highly efficient tool for monitoring amphibian species. *Herpetology notes*. 3(10). 13-21. URL: https://pub.uni-bielefeld.de/record/2665101

Edgar, P.W., Griffiths, R.A. & Foster J.P. (2005). Evaluation of translocation as a tool for mitigating development threats to great crested newts (*Triturus cristatus*) in England, 1990–2001. *Biological conservation*. 122(1). 45-52. DOI: 10.1016/j.biocon.2004.05.022

Ficetola, G.F. (2015). Habitat conservation research for amphibians: methodological improvements and thematic shifts. *Biodiversity and conservation.* 24(6). 1293-1310. DOI: 10.1007/s10531-015-0869-9

Gent, A.H. & Gibson, R.A. (2003). *Herpetofauna Workers' Manual*. (ISBN 1 86107 450 6). Peterborough: Joint Nature Conservation Committee (JNCC).

Germano, J.M. & Bishop, P.J. (2009). Suitability of amphibians and reptiles for translocation. *Conservation Biology.* 23(1). 7-15. DOI: 10.1111/j.1523-1739.2008.01123.x

Germano, J.M., Field, K.J., Griffiths, R.A., Clulow, S., Foster, J., Harding, G., & Swaisgood, R.R. (2015). Mitigation-driven translocations: are we moving in the right direction? *Frontiers in Ecology and the Environment.* 13(2). 100-105. DOI: 10.1890/140137

Griffiths, R.A., Sewell, D. & McCrea, R. (2010). Dynamics of a declining amphibian metapopulation: Survival, dispersal and the impact of climate. *Biological Conservation*. 143(2). 485-491. DOI: 10.1016/j.biocon.2009.11.017

Guerra, C. & Aráoz, E. (2015). Amphibian malformations and body condition across an agricultural landscape of northwest Argentina. *Diseases of aquatic organisms*. 121(2). 105-116. URL: http://explore.bl.uk/primo_library/libweb/action/display.do?tabs=detailsTa b&gathStatTab=true&ct=display&fn=search&doc=ETOCRN608313149&indx=1&recIds=ETOCRN608313149

Guo, R., Zhang, W., Yang, Y., Ding, J., Yang, W. & Zhang, Y. (2018). Variation of fitness and reproductive strategy in male *Bufo raddei* under environmental heavy metal pollution. *Ecotoxicology and environmental safety*. *164*. 253-260. DOI: 10.1016/j.ecoenv.2018.08.035

Gustafson, D., Blicharska, M. & Mikusinski, G. (2016). When development and amphibians meet: a case study of a translocation of great crested newts (*Triturus cristatus*) in Sweden. *Herpetological conservation.* 11. 552-562. URL: http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-312474

Hagström, T. (1979). Population ecology of Triturus cristatus and *T. vulgar* is (Urodela) in SW Sweden. *Holarctic Ecology*. 2(2). 108-114. DOI: 10.1111/j.1600-0587.1979.tb00688.x

Hoare, J.M., Pledger, S., Keall, S.N., Nelson, N.J., Mitchell, N.J. & Daugherty, C.H. (2006). Conservation implications of a long-term decline in body condition of the Brothers island tuatara (*Sphenodon guntheri*). *Animal Conservation.* 9(4). 456- 462. URL: http://explore.bl.uk/primo_library/libweb/action/display.do?tabs=detailsTab&gathStatTab=true&ct=display&fn=search&doc=ETOCRN196435874&indx=1&recIds=ETOCRN196435874

Hoey, A.S. & McCormick, M.I. (2004). Selective predation for low body condition at the larval-juvenile transition of a coral reef fish. *Oecologia*. 139. 23-29. DOI: 10.1007/s00442-004-1489-3

Houser, A. (1960). A collapsible nylon fish trap for pond sampling. *Progressive fish-culturist*. 22(3). 129-133. DOI: 10.1577/1548-8659(1960)22[129:ACNFTF]2.0.CO;2

Hull A. (1997). The pond life project: a model for conservation and sustainability. In: Boothby, J. (ed.). *British pond landscape, proceedings from the UK conference of the Pond life project*. Liverpool: Pond Life Project. 101–109.

IUCN (2021). *IUCN red list of threatened species*. https://www.iucnredlist.org/ [2021-10-21])

Jarvis, L.E. (2015). Factors affecting body condition in a great crested newt *Triturus cristatus* population. *The Herpetological Bulletin*. 134(134). 1-5.

Jarvis, L.E. (2016). Terrestrial ecology of juvenile great crested newts *(Triturus cristatus)* in a woodland area. *Herpetological journal*. 26(4). 287-296.

Laan, R. & Verboom, B. (1990). Effects of pool size and isolation on amphibian communities. *Biological Conservation*. 54(3). 251-262. DOI: 10.1016/0006-3207(90)90055-T

Langton, T.E.S., Beckett, C.L. & Foster, J.P. (2001). *Great Crested Newt Conservation Handbook*. Halesworth: Froglife.

Lewis, B., Griffiths, R.A. & Wilkinson, J.W. (2017). Population status of great crested newts (*Triturus cristatus*) at sites subjected to development mitigation. *Herpetological journal*. 27(2). 133-142. URL: https://kar.kent.ac.uk/id/eprint/55726

Li, B., Zhang, W., Shu, X., Pei, E., Yuan, X., Sun, Y., ... & Wang, Z. (2016). The impacts of urbanization on the distribution and body condition of the rice-paddy frog (*Fejervarya multistriata*) and gold-striped pond frog (*Pelophylax plancyi*) in Shanghai, China. *Asian herpetological research*. 7(3), 200-209. DOI: 10.16373/j.cnki.ahr.150061

Miaud, C., Joly, P. & Castanet, J. (1993). Variation in age structures in a subdivided population of *Triturus cristatus*. *Canadian journal of zoology*. 71(9). 1874-1879. DOI: 10.1139/z93-267

Microsoft Office Excel (2007). Microsoft office 365-se. URL: https://www.microsoft.com/sv-se/

Oldham, R.S. (1994). Habitat assessment and population ecology. In: Gent, A. & Bray, R. (ed.) *Conservation and management of great crested newts: Proceedings of a symposium held on 11 January 1994 at Kew Gardens, Richmond, Surrey.* Peterborough: English Nature.

Oldham, R.S. & Humphries, R.N. (2000). Evaluating the success of great crested newt (*Triturus cristatus*) translocation. *Herpetological journal.* 10(4). 183-190. URL: http://explore.bl.uk/primo_library/libweb/action/display.do?tabs=detailsTab&gathStatTab=true&ct=display&fn=search&doc=ETOCCN038415440&indx=1&recIds=ETOCCN038415440

Pechmann, J.H.K., Scott, D.E., Semlitsch, R.D., Caldwell, J.P., Vitt, L.J. & Whitfield-Gibbons, J. (1991). Declining amphibian populations: the problem of separating human impacts from natural fluctuations. *Science*. 253(5022). 892-895. URL: https://www-jstor-org.ezp.sub.su.se/stable/2878941

Peig, J. & Green, A.J. (2009). New perspectives for estimating body condition from mass/length data: The scaled mass index as an alternative method. *Oikos*. 118(12). 1883-1891. DOI: 10.1111/j.1600-0706.2009.17643.x

Price, S.J., Dorcas, M.E., Gallant, A.L., Klaver, R.W. & Willson, J.D. (2006). Three decades of urbanization: Estimating the impact of land-cover change on stream salamander populations. *Biological conservation*. 133(4). 436-441. DOI: 10.1016/j.biocon.2006.07.005

Primack, R.B. & Sher, A.A. (2018). *An introduction to conservation biology*. New York: Oxford university press.

R Core Development Team (2021). *R for Windows* (4.1.0). [software]. URL: https://www.r-project.org/

Rannarp, R., Lomus, A. & Briggs, L. (2009). Restoring ponds for amphibians: a success story. *Hydrobiologia*. 634(1). 87-95. DOI: 10.1007/s10750-009-9884-8

Sheele, B.C., Pasmans, F., Skerratt, L.F., Berger, L., Wouter Beukema, A.M., Acevedo, A.A., Burrowes, P.A., Carvalho, T., […] & Canessa S. (2019). Amphibian fungal panzootic causes catastrophic and ongoing loss of

biodiversity. *Science*. 363(6434). 1459-1463. DOI: 10.1126/science.aav0379
Shoemaker, V.H., Hillyard, S.D., Jackson, D.C., McClanahan, L.L., Withers, P.C. & Wygoda, M.L. (1992). Exchange of water, ions, and respiratory gases in terrestrial amphibians. In: Feder, M.E. & Burgen, W.W. (Eds.). *Environmental physiology of the amphibians*. Chicago: University of Chicago Press.
Sivan, J., Kam, M., Hadad, S., Degen, A.A. & Rosenstrauch, A. (2014). Body size and seasonal body condition in two small coexisting desert snake species, the Saharan sand viper (*Cerastes vipera*) and the crowned leafnose (*Lytorhynchus diadema*). *Journal of arid environments*. 114. 8-13. DOI: 10.1016/j.jaridenv.2014.10.013
Sterenborg, M. & Koffman, A. (2019). *Inventering population av större vattensalamander i Loudden oljehamn*. Calluna AB.
Sterenborg, M. & Koffman, A. (2020). *Flytt av större vattensalamander från Louddens oljehamn till nyanlagt habitat Brunnslättsdammen*. Calluna AB. URL: https://miljobarometern.stockholm.se/content/docs/tema/natur/Groddjur/Loudden%20Salamander%20inventering%20%20flytt%202019.pdf
Sterenborg, M., Stahre, M., Andersson, P. & Koffman, A. (2021). *Flytt av större vattensalamander från Louddens oljehamn till nyanlagt habitat i Brunnslättsdammen 2020.* Calluna AB. URL: https://miljobarometern.stockholm.se/content/docs/tema/natur/Groddjur/Loudden%20Salamander%20inventering%20%20flytt%202020-02-05.pdf
Stuart, S.N., Chanson, J.S, Cox, N.A., Young, B.E., Rodrigues, A.S.L, Fischman, D.L. & Waller, R.W. (2004). Status and trends of amphibian declines and extinctions worldwide. *Science*. 306(5702), 1783-1786. DOI: 10.1126/science.1103538
Unglaub, B., Steinfartz, S., Kühne, D., Haas, A. & Schmidt, B.R. (2018). The relationships between habitat suitability, population size and body condition in a pond-breeding amphibian. *Basic and applied ecology*. 27. 20-29. DOI: 10.1016/j.baae.2018.01.002
Ward, A.J.W., James, R., Wilson, A.D.M. & Webster, M.M. (2013). Site fidelity and localised homing behaviour in three-spined sticklebacks (*Gasterosteus aculeatus*). *Behaviour*. 150(14). 1689-1708. URL: https://www-jstor-org.ezp.sub.su.se/stable/23525220
Wheeler, B.A., Prosea, E., Mathis, A. & Wilkinson, R.F. (2003). Population declines of a long-lived salamander: a 20+ year study of hellbenders, *Cryptobranchus alleganiensis*. *Biological conservation.* 109(1) 151-156. URL: http://explore.bl.uk/primo_library/libweb/action/display.do?tabs=detailsTab&gathStatTab=true&ct=display&fn=search&doc=ETOCRN119838812&indx=1&recIds=ETOCRN119838812

WWF (2020). *Living Planet Report 2020 - Bending the curve of biodiversity loss.* Almond, R.E.A., Grooten M. & Petersen, T. (Eds). Gland, Switzerland: WWF.

Zakaria, N.B. (2017). *Long-term population ecology of the great crested newt in Kent.* Kent: University of Kent.

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