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Population status of great crested newts (*Triturus cristatus*) at sites subjected to development mitigation

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Increasing development of natural habitats frequently causes conflict with the conservation of protected species. Consequently, interventions that attempt to mitigate the impact of development are becoming increasingly commonplace. We used four approaches to assess the effectiveness of development mitigation on a species subject to widespread development pressures in Europe – the great crested newt (*Triturus cristatus*). Firstly, a systematic evidence review revealed eleven published studies of great crested newt populations at development sites. None provided conclusive evidence that the mitigation carried out was effective in maintaining populations. Secondly, less than half of 406 mitigation licence project files examined contained reports of results. Of those that did, only 16 provided post-development population assessments. These included one extinct population, and 10 'small' populations. Thirdly, standardised population assessments were carried out at 18 sites in England, at least six years after the initial mitigation was completed. Although newt populations persisted at most of these sites, there was evidence of an overall decline, with extinctions occurring at four sites. Fourthly, although the annual cost of mitigation for great crested newts in England is estimated at between £20-43 million, information on the status of populations and habitats makes it difficult to assess whether this is cost-effective for either conservation or development. The quality and quantity of available data make it difficult to assign reasons for population changes at mitigation sites, but the study highlighted four general issues concerning mitigation practice: (1) presence of non-viable populations pre-mitigation; (2) inadequate mitigation interventions and site management; (3) cumulative impacts of further developments; and (4) emergence of new threats post-mitigation. Nevertheless, it is possible that some mitigation activities may have unforeseen and undocumented benefits, such as providing green spaces and biodiversity enhancement in urban areas.

Key words: amphibian, conservation, habitat management, impact assessment, salamander

INTRODUCTION

Although the designation of protected areas away from areas of human population is a fundamental component of conservation, for many threatened species this is not possible. This is particularly the case for widespread but declining species that inhabit areas of high human population density. In such cases, conflict with development often arises. Although human-wildlife conflict is often associated with risks to human health or life in developing countries (Messmer, 2000; Woodroffe et al., 2005), there are numerous scenarios that can impact on incomes and livelihoods in the developed world (Heydon et al., 2011). These include protected species that have populations that lie in areas proposed for development. Reconciling the ensuing conflict can prove complex, but interventions may be required to mitigate or offset the development impact. Such interventions may require reducing the scale of the development, improving, creating or restoring habitat, or translocating animals to alternative sites (Kyek et al., 2007). Although such interventions are becoming increasingly commonplace around the globe, they operate largely outside standard conservation guidelines (IUCN/SSC 2013), may be driven by development agendas rather than ecological need (Gardner & Howarth, 2009), and are often inadequately evaluated (Platenberg & Griffiths, 1999; Glista et al., 2009; Stone et al., 2013; Germano et al., 2015). Indeed, non-compliance with regulatory requirements may actually be quite commonplace (Brown et al., 2013), and restoration projects may struggle to meet designated goals (Maron et al., 2012). By combining a review of the evidence with standardised field surveys, in this paper we attempt to analyse the situation for one high-profile species that comes into conflict with development – the great crested newt (*Triturus cristatus*).

The great crested newt is highly protected under EU legislation. In the UK, this legislation is predominantly enacted under the Conservation of Habitats and Species Regulations 2010. The legislation confers protection against deliberately or recklessly disturbing, capturing, injuring, killing, transporting or to sell or offer animals

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for sale, as well as the disturbance or destruction of habitats or resting places. However, some actions that would normally result in an offence under the legislation can be made lawful under derogations of the legislation, providing certain conditions are met (Heydon et al., 2011). When great crested newt habitat is threatened by development, there is a legal requirement to carry out interventions to mitigate the impact of the development on the population. Applications for licences to carry out such mitigation are assessed by the government regulatory agencies, and are granted only if the agencies consider that appropriate measures are in place to safeguard the species and its habitat. Because of the widespread distribution of the great crested newt in England and Wales, it frequently comes into conflict with development. This has resulted in a rapid growth in mitigation projects, with over 600 derogation licences issued in England alone by 2009 (Lewis, 2012).

Over the past three decades the legislation has been strengthened, and awareness and compliance raised (Hill & Arnold, 2012). Despite the widespread occurrence of development mitigation, there is remarkably little analysis of its effectiveness in achieving its goals. In this paper we address this problem using four approaches. Firstly, we carry out a systematic evidence review of the effectiveness of mitigation; secondly, we analyse data contained within licence returns for evidence of population persistence; thirdly, we carry out field assessments of great crested newt populations that have been subject to mitigation over the past two decades; and fourthly, we estimate the costs of carrying out mitigation and compare these to the cost of more conventional interventions.

METHODS

Systematic Evidence Review

The systematic evidence review was undertaken following guidelines produced by the Centre for Evidence Based Conservation (CEBC) (2010) to address the primary question 'Are current mitigation actions effective in the conservation of great crested newts?' A draft review protocol was sent out to a wide circle of practitioners, government agencies, species specialists and other interested parties. Comments and feedback were drafted into the final protocol document. The finalised review protocol was published online via the CEBC website and provides the rationale and methods used for the study (Lewis, 2009; Online Appendix 1).

Ten electronic databases were searched for information using standard search strings related to great crested newt mitigation (Lewis, 2009). Publication searches were undertaken on conservation and statutory organisation websites (e.g. Natural England; Countryside Council for Wales – now Natural Resources Wales; Department for Environment, Food and Rural Affairs (Defra); Joint Nature Conservation Committee) as well as websites and publications produced by non-governmental organisations such as the Wildlife Trusts and herpetofauna groups (Herpetological Conservation Trust – now Amphibian and Reptile Conservation; Froglife; British Herpetological Society; Amphibian and Reptile Groups-UK). Further information was gathered from existing contacts within the field of herpetofauna conservation, ecological consultants and through professional organisations such as the Chartered Institute of Ecology and Environmental Management (CIEEM). Meta-search engines such as Google Scholar, Alltheweb and Dogpile were also used. The first 100-word document or PDF hits from each data source were examined for appropriate data.

Studies were initially filtered by title and any obvious irrelevant articles were removed from the list of captured articles. Subsequently, the abstracts of the remaining studies were examined with regards to possible relevance to the systematic review question. All remaining articles were assessed for relevance by a second, independent reviewer; agreement on inclusion between the reviewers was deemed to be in "Fair agreement" (Cohen's Kappa test: K=0.21 [Viera & Garrett, 2005]). Studies were accepted for viewing at full text if it appeared that they might contain information pertinent to the review question, or if the abstract was ambiguous and did not allow inferences to be drawn about the content of the article (i.e. if there was insufficient information to determine that the study was inappropriate for the systematic review).

Studies accepted into the review at full text were considered for relevance by two additional independent reviewers. Any disagreement on inclusion was then discussed and resolved by the two reviewers.

Licence returns

Permission was granted by Natural England and the Welsh Assembly Government to access the derogation licence folders and licence return data that are submitted at the end of licensed mitigation projects. Due to logistical constraints only a sample (8%) of licences obtained from Natural England was examined including licences dating from 2002 (i.e. one year post-publication of the great crested newt mitigation guidelines) through to 2010. Beyond this time, projects were still underway and licence return information was not readily available. All derogation licence folders for great crested newt mitigation projects carried out in Wales, dating from 2001 to 2010 were examined.

Information extracted from the licence files comprised date of issue and expiry; newt population status pre-development; whether or not extensions to the original licence were granted; and post-development population monitoring data submitted within a licence return.

Field surveys of populations subjected to development mitigation

Standardised population assessments of great crested newts were carried out at 18 sites where development mitigation had previously taken place. Six of these sites had undergone mitigation actions between 1992 and 1999 ('1990s sites'), prior to the publication of detailed guidance (English Nature, 2001). These sites were surveyed over four years (2005, 2006, 2009 and 2010), at least six years after the original mitigation actions had been completed. The remaining 12 sites underwent mitigation actions in 2004, and the practitioners therefore had access to the new guidance published in 2001 ('2004 sites'). The 2004 sites were surveyed over a two-year period (2012-13), at least eight years after the original mitigation actions had been completed.

The sites were selected on the basis of information provided by Natural England. Within the constraints imposed by available data, accessibility and landowner permissions, the sample of sites was intended to be representative of a range of project scales (i.e. from small to large sites and impacts) and provide a good geographical spread across England (Lewis et al., 2007; Lewis et al., 2014).

At most sites a combination of bottle trapping and torchlight counts was used to assess the newt populations. Where the water was particularly clear and not obscured by vegetation, only torchlight counts were used. Where the water was turbid or choked with vegetation, only bottle traps were used (Griffiths et al., 1996). Standard field survey protocols for population assessment were followed with 3-6 torching/trapping nights conducted at each water body at each site (Gent & Gibson, 2003). The surveys were all carried out at peak season (i.e. from March-May) and repeated surveys at each site were separated by a few days or weeks whenever possible. As far as possible, surveys were carried out during optimal weather condition i.e. no/little wind or rain, and at temperatures above 5° C.

Between 5-61 sampling points were established at 2 m intervals around accessible areas of shoreline, the exact number of sampling points depending on the pond size (Griffiths, et al., 1996). For the torchlight counts, each 2 m section of the sampling area was scanned using a 'Clulite' 500,000-candle power torch about 1 hr after dusk. Two- litre plastic bottles were used to construct the bottle traps (Griffiths, 1985; Gent & Gibson, 2003). One trap was placed at each sampling point. Traps were set after the torch counts were completed and checked between 0700-0930 hours the following day depending on the site, resulting in a trapping period of about 10 hrs.

Two population scoring systems are currently used to assess great crested newt populations. The 'peak count' system reports the maximum number of newts counted by any method over several survey visits to a site within a year (English Nature, 2001). If several ponds occur on the site the counts are summed across the ponds and the peak count for the site is then used to classify the population as 'small' (≤10), 'medium' (11-100), or 'large' (>100). An alternative method is based on population densities at individual ponds, calculated as the mean number of newts counted by either torch or trap per 2 m section of shoreline. Confidence intervals have been used to classify the scores obtained from either method based on a sample of natural ponds, as 'poor', 'below average', 'average', 'good' or 'excellent' (Griffiths et al., 1996). Both scoring systems were applied to the survey data collected from the mitigation sites. Neither of these scoring systems account for spatial or temporal variation in detectability of the target species, which can affect estimates of population status (Schmidt, 2003; Sewell et al., 2010; Griffiths et al., 2015). However, as the objective of the study was to evaluate mitigation using protocols currently adopted by professional practice in the UK, the comparisons described below would not be possible using statistical models that account for variation in detectability.

Comparisons with sites not subjected to mitigation

Counts and densities of great crested newts at the mitigation sites were compared to those obtained at a sample of ponds not subjected to mitigation surveyed in England and Wales in 1994-1995 (Griffiths et al., 1996). The control ponds were surveyed using the same trapping protocol as described above, but were all surveyed on a single visit between March and May, rather than repeatedly surveyed as in the present study. For the 'count' analyses, trapping data for a single site visit was therefore randomly selected from the 3-6 surveys made at each pond in the present study – this eliminates the possible bias inherent in using the peak count from repeated surveys. For the comparison of densities, the average densities from the repeated trapping surveys were used, as these do not suffer from the same potential bias. As newt counts from the sample of mitigation sites were skewed towards zero, Mann Whitney U tests were used to compare the median count and median density between the mitigation and control sites.

Costs

A web-based search was carried out to collate the costs of mitigation cases that are published online. The following search strings were used: (Great crested newt* OR GCN OR *Triturus cristatus*) AND (mitigation or development or cost). Only projects that were carried out or reported between 2001– 2012 were accepted for review on the basis that they would have been subject to current, published guidelines (English Nature, 2001) and provide the most contemporary examples. The first 1000 returns (of circa. 90,000) were reviewed.

A sample of 28 ecological consultancies were contacted by telephone and asked if they were able to provide data on great crested newt mitigation costs. If they responded positively, they were sent a brief questionnaire on which they were asked to detail costs of staff and administration, survey, mitigation implementation (including expenses, equipment and plant hire), and monitoring.

Two conservation NGOs were contacted for comparative information on the costs of conservation projects that were not related to development mitigation. Amphibian and Reptile Conservation (ARC) provided access to files containing information on grants awarded for great crested newt conservation projects undertaken in England, Wales and Scotland. The awards were designed to help achieve targets set out in the UK great crested newt Species Action Plan (SAP), which includes survey work and the creation/restoration of ponds and terrestrial habitat. Data consisted of a financial breakdown of projects from total costs, number of ponds created/restored, habitat creation/ management, planning costs, machine hire and materials to staff and volunteer costs, travel costs and training. Pond Conservation (now the Freshwater Habitats Trust)

Table 1. Population size classes at '1990s' mitigation sites according to the *Great crested newt mitigation guidelines* (English Nature, 2001). 'Small' population ≤10; 'Medium' population 11-100; 'Large' population >100. Site totals were obtained for maximum adult counts for all ponds on the same visit using either torch surveys or bottle-trapping.

Site and year of initial mitigation	Population size class based on peak count 2005	Population size class based on peak count 2006	Population size class based on peak count 2009	Population size class based on peak count 2010	Population change over survey period
Site A 1998	Medium	Medium	Not detected	Not surveyed	Extinct
Site C 1999	Small	Small	Small	Small	Stable
Site F 1993	Medium	Medium	Medium	Medium	Stable
Site G 1999	Medium	Medium	Medium	Not surveyed	Stable
Site J 1992	Large	Medium	Medium	Medium	Decline
Site K 1992	Medium	Medium	Medium	Medium	Stable

provided access to files containing information on projects and associated costs under the Million Ponds project scheme (http://freshwaterhabitats.org.uk). This is a national partnership initiative to protect freshwater wildlife by creating networks of clean water bodies across the UK. Whilst the projects did not specifically target great crested newts, only those projects that identified great crested newts within their Biodiversity Action Plan (BAP) as a target species were examined for this study. All projects were carried out over a two-year period and provide information on site locations, pond associated BAP species, other species which benefit, number of ponds created, surface area and estimated project costs among other criteria.

Ethics statement

The research was approved by the School of Anthropology and Conservation Research Ethics Committee. Fieldwork on great crested newts was carried out under licence from English Nature/Natural England, and adhered to best practice protocols laid down by these organisations in terms of both conservation and animal welfare.

RESULTS

Systematic Evidence Review

Searching was completed in January 2011. Only 13 studies remained in the systematic review after the abstract filter stage. All responses from web-based search engines were removed from the study due to lack of information relating to the original question. Many searches revealed websites associated with ecological consultancies and crested newt information pages. Two further studies were removed as they were considered irrelevant by the two independent reviewers, leaving 11 studies for examination at full text. These studies revealed that although great crested newts were found to be present at sites post-mitigation, it was unclear if the persistence of the populations was related to the mitigation actions undertaken. The studies reviewed could not unequivocally show evidence of self-sustaining great crested newt populations or effective connectivity of the populations to the wider countryside. It was therefore not possible to answer the primary question 'Are current

Table 2. Comparison of population counts and population densities at mitigation sites with those obtained at a sample of control (i.e. unmitigated) ponds (from Griffiths et al., 1996). *P*-values indicate the significance of Mann Whitney U-tests. The sites are divided into '1990s sites' and '2004 sites' depending on when the initial mitigation was conducted.

		Counts			Density		
	n	Median	Interquartile range	*p* value	Median	Interquartile range	*p* value
Control Ponds	25	7.00	10.00		0.35	0.75	
1990s sites							
2005	29	0.00	3.00	<0.01	0.05	0.28	<0.05
2006	12	2.50	8.25	0.156	0.22	0.54	0.475
2009	12	2.50	3.75	<0.05	0.14	0.26	0.347
2010	8	2.50	8.50	0.911	0.14	0.32	0.262
2004 sites							
2012	23	1.00	3.00	<0.01	0.07	0.20	<0.05
2013	22	0.00	2.00	<0.01	0.05	0.14	<0.01

Table 3. Population density ratings of ponds at '1990s' mitigation sites. The scores obtained, based on average density (no. of newts per 2 m), were compared to the table devised by Griffiths et al. (1996) for scoring great crested newt populations.

Site and pond number	Rating 2005	Rating 2006	Rating 2009	Rating 2010
Site A – pond 1	Average	Good	Not detected	Not surveyed
Site C - pond 1	Average	Average	Average	Average
Site C – pond 2	Average	Below Average	Average	Average
Site F – pond 1	Average	Average	Average	Average
Site G – pond 1	Average	Average	Average	Not surveyed
Site G – pond 2	Average	Average	Average	Not surveyed
Site G – pond 3	n/a	n/a	n/a	Not surveyed
Site G – pond 4	Average	Average	Average	Not surveyed
Site J – pond 1	Average	Average	Average	Average
Site J – pond 2	Average	Excellent	Average	Average
Site J – pond 3	Average	Average	Average	Above Average
Site K – pond 1	Average	Good	Average	Above average
Site K – pond 2	Average	Average	Average	Average

mitigation actions effective in the conservation of great crested newts?' on the basis of the evidence extracted. As there was no clear answer to the original question, potential biases that might explain the findings were not explored further. The studies are summarised in Online Appendix 2.

Licence information

Interrogation of the files provided by both Natural England and the Welsh Assembly produced a total of 309 and 151 project files respectively. When a project is completed, licensees are obliged to lodge a licence return form stating that all work has been carried out in accordance with the original method statement and include post-development monitoring data to assess the population status. Of the 309 Natural England derogation files surveyed, only 127 contained licence return documents. Similarly, of the 151 Welsh Assembly derogation files surveyed only 46 contained licence return documents. Of these licence returns, 29% (*n*=51) did not contain any monitoring data. A further 53% (*n*=91) also did not contain monitoring information, but this was based on the premise that the development was of low impact and no monitoring was prescribed within the method statement. Seven percent (*n*=12) of licences suggested that some monitoring was undertaken, but

Table 4. Population size classes of '2004' mitigation sites according to the *Great crested newt mitigation guidelines* (English Nature, 2001). 'Small' population $\leq$10; 'Medium' population 11-100; 'Large' population >100. Site totals were obtained for maximum adult counts for all ponds on the same visit using either torch surveys or bottle-trapping. Pre-development data are taken from methods statements supplied during the licence application.

Site	Population size class based on peak count Pre-development	Population size class based on peak count 2012	Population size class based on peak count 2013	Population trend
Site A	Medium	Small	Small	Decrease
Site B	Medium	Small	Small	Decrease
Site C	Small	Not detected	Not detected	Extinct
Site D	Small	Not detected	Not detected	Extinct
Site E	Small	Medium	Small	Increase/Stable
Site F	Small	Small	Small	Stable
Site G	Large	Small	Small	Decrease
Site H	Large	Medium	Medium	Decrease
Site I	Small	Small	Small	Stable
Site J	Small	Not detected	Not detected	Extinct
Site K	Large	Medium	Large	Decrease/Stable
Site L	Large	Medium	Large	Decrease/Stable

Table 5. Population density ratings of ponds at '2004' mitigation sites. The scores obtained, based on average density (no. of newts per 2 m), were compared to the table devised by Griffiths et al. (1996) for scoring great crested newt populations.

Site and Pond No.	Rating 2012	Rating 2013
Site A – Pond 1	Average	Average
Site B – Pond 1	Average	Average
Site C – Pond 1	Not detected	Not detected
Site C – Pond 2	Not detected	Not detected
Site D – Pond 1	Not detected	Not detected
Site D – Pond 2	Not detected	Not detected
Site E – Pond 1	Average	Below Average
Site G – Pond 1	Below Average	Below Average
Site G – Pond 2	Below Average	Below Average
Site G – Pond 3	Below Average	(Torchlight survey only)
Site H – Pond 1	(Torchlight survey only)	Below Average
Site H – Pond 2	Average	Below Average
Site H – Pond 4	Below Average	Average
Site H – Pond 5	Average	Average
Site H – Pond 6	Average	Average
Site I – Pond 1	Average	Average
Site I – Pond 2	Below Average	Below Average
Site J – Pond 1	Not detected (pond dry)	Not detected (pond dry)
Site K – Pond 1	Average	Below Average
Site K – Pond 2	Below Average	Average
Site K – Pond 3	Average	Average
Site L – Pond 1	Average	Average
Site L – Pond 2	Below Average	(Torchlight survey only)
Site L – Pond 3	Above Average	Excellent
Site L – Pond 4	Average	Below Average

no data were provided within the files. Of the remaining files, 9% (*n*=16) actually provided post-development population monitoring data and 2% still had ongoing work at the time of this study. Of these 16 projects, one population was apparently extinct, 10 were classified as 'small', three were 'medium' and one was 'large'.

Sites subjected to development mitigation in the 1990s

Great crested newts were found to be present in 12 ponds at the six sites surveyed between 2005-2010. However, at one site newts were only recorded in two out of the four years (i.e. 2005-2006), presumably as a result of fish introduction leading to extinction in the later years. Using the English Nature (2001) classification system, one site contained a 'small' population, four sites contained 'medium' populations (although one of these was extinct by 2009), and one was 'large' (2005) or 'medium' (2006-2009) (Table 1). As pre-development data were not available for these sites, it is not possible to determine how population status changed after the mitigation actions were completed. However, there was a trend for current counts to be lower than those observed at control sites also surveyed in the 1990s, and this was significant in two out of the four years (2005 and 2009: Table 2).

Using the population density method of assessment (Griffiths et al., 1996), the majority of surveys revealed 'average' populations to be present at all ponds, but with some fluctuation between years at five ponds (Table 3). However, as with the counts, there was a tendency for population densities to be lower than those observed at control ponds, and this was significant for 2005 (Table 2).

Sites subjected to development mitigation in 2004

Great crested newts were found to be present in 25 ponds at nine out of the 12 surveyed sites in 2012-2013. Newts were not found at six ponds on four sites, and were presumed to be extinct at three of these sites. Using the English Nature (2001) classification system, five sites contained 'small' populations, one site was 'small' (2013) or 'medium' (2012), one was 'medium', and two were 'medium' (2012) to 'large' (2013). Compared to the pre-development population assessments carried out at these sites, seven populations had declined (in three cases to apparent extinction), four populations showed fluctuations, and one population showed a possible increase (Table 4). Overall, there was a downward trend in population status (Sign tests: 2012, p=0.021; 2013 p=0.016). Moreover, the counts were significantly lower than those observed in control ponds in both years of the survey (Table 2).

Using the population density method of assessment, six ponds were classified as 'below average', seven were 'average' and six fluctuated between 'below average' and 'average'. One pond fluctuated between 'above average' and 'excellent' (Table 5). The population densities were significantly lower than those observed in control ponds in both years of the survey (Table 2).

Costs

Fifteen out of the 1000 web-based reports examined contained information on costs and met the inclusion criteria. After adjustment for inflation so that the costs were standardised to 2010 rates, the average cost of mitigation per project came to £216,145. Two ecological consultancies responded to a direct request for costs for a total of six projects. After adjustment for inflation to 2010, the average cost per project came to £102,903. In 2010, 215 new great crested newt mitigation licence applications were processed (Natural England, 2011). Because multiple licences may be issued for the same project, and rejected licences may be resubmitted, it is difficult to relate the number of licences in any one year to the number of projects executed. However, assuming that about 95% of the applications were successful (Defra, pers. comm.), multiplying the average costs of mitigation in that year by the estimated number of successful licence applications (n=200) results in annual costs of between £20,580,600 (company estimates) and £43,229,000 (web-based estimates).

Costings for great crested newt conservation projects were obtained for a total 96 projects through grants applied for or grants awarded by the Amphibian and Reptile Conservation Trust and the Million Ponds project. When stated matching funding is included, the total grants awarded from 1999-2009 (adjusted for inflation to 2010) came to £226,274, an average grant of £2596 per project.

DISCUSSION

Despite some two decades of actions designed to mitigate development impacts on great crested newts, there remains insufficient evidence within either published literature or government licence returns to allow general conclusions about the effectiveness of such interventions. Standardised surveys designed to allow comparisons with pre-development data and control ponds suggest that, in some circumstances, great crested newt populations can persist at mitigation sites for 20 years or more. However, overall there was a general decline in population status, with extinctions occurring at four out of the 18 sites surveyed.

There are four possible reasons for such declines. Firstly, the populations may have already been in decline – and possibly non-viable – prior to mitigation. Certainly, half of the populations surveyed in 2012-2013 were classified as 'small' before mitigation took place, but unfortunately the quality and quantity of data available within the licence files make it difficult to assess whether better mitigation interventions would have been able to improve the status of such populations and/or arrest any declines.

Secondly, ongoing development in the vicinity of mitigation sites may result in cumulative impacts. At least four of the sites surveyed underwent further developments and mitigation after the initial round of interventions. Inadequate protection from further development is a flaw in assigning habitats to biodiversity offsets (Bekessy et al., 2010), and the same issue applies to habitats that are enhanced or restored as part of a mitigation package. Moreover, the licence returns for subsequent mitigations were not stored in an easily retrievable format. Consequently, attempting to describe the present-day status of newts at these sites in relation to the mitigation actions undertaken may not have been meaningful because of the incomplete nature of potential predictor variables.

Thirdly, there may have been a failure of the appropriate mitigation interventions. Certainly, at two of the sites where extinctions occurred this appeared to be the case, as newly created ponds were poorly designed and failed to hold water. In addition, several ponds ended up on habitat fragments separated from other potential habitats by significant barriers, such as roads, housing and commercial development. At one site with an extant population, newts were observed trapped in drains that had been installed on the adjacent development. Elsewhere, it is possible that the scale of the mitigation interventions was disproportionately small in relation to the scale of the development. In ecological restoration projects major uncertainties exist in terms of achieving project outcomes (Maron, 2012). Such uncertainties also clearly apply to great crested newt mitigation projects, and assessing the risk of not achieving desired outcomes deserves closer scrutiny.

Fourthly, it is possible that threats unrelated to the mitigation actions emerged after the intervention was completed. Fish introduction occurred in at least three sites post-mitigation, and almost certainly contributed to the extinction of the newt population at one of these. Also, several ponds in the survey suffered from a lack of pond management, with these water bodies undergoing rapid natural succession. In such cases, it is important that appropriate management and monitoring protocols are in place post-mitigation to minimise the risks of such emerging threats. It is quite possible that combinations of all of these factors have contributed to the status of great crested newts at the surveyed sites. Much better collection, management and analysis of survey and habitat data before, during and after interventions is needed if the quality and success rate of mitigation intervention is to improve.

Although the projects where mitigation was carried out in 2004 would have had access to more comprehensive guidelines than those conducted earlier, there was no evidence that later projects were more effective in terms of improving population status. However, this does not necessarily mean that the guidance has been ineffective or not adhered to. Given that some of the populations may have been small to start with and the scale of development pressures are likely to have increased since 2001, it is possible that the population status assessments may have been worse without them. A larger sample of sites, coupled with the collection of more quantitative data on population status and the mitigation actions undertaken, may be needed to demonstrate the impact of the guidelines on mitigation practice.

Although the number of great crested newt mitigation projects was increasing to 2004, there was little evidence available to help plan effective conservation interventions (Griffiths, 2004). This may have represented a missed opportunity to review available data to inform evidence-based practice (Sutherland et al., 2004). Despite these pleas, and subsequent recommendations (Edgar et al., 2005), the situation has only slightly improved. Although pre- and post-development population and habitat assessments are now a legal requirement, problems persist with the storage and dissemination of data. Record systems that are incomplete and difficult to administer seem commonplace within regulatory agencies (Brown et al., 2013; Hill et al., 2013; Griffiths et al., 2015). An analysis of derogation licence information for protected bats from 2003-2005 also found shortfalls in post-development monitoring and data management, resulting in insufficient data to determine whether mitigation is effective (Stone et al., 2013). Likewise, 67% of bat licensees failed to submit post-development reports (Stone et al., 2013), which is similar to the figure of 59% reported here for great crested newts.

There are approximately 2250 ecologists employed in ecological consultancy in the UK (Hill & Arnold, 2012). Consultants are primarily engaged in development and construction projects that have an estimated value of £110-120 million. Our estimated costs of great crested newt mitigation from web-searches of £43 million per annum is probably an over-estimate, as only expensive projects are likely to receive publicity. Nevertheless, even if our lower estimate of £20 million based on a small sample of projects is taken as a more reliable measure, great crested newt mitigation comprises a substantial chunk of business conducted within the sector. An earlier estimate of annual mitigation costs between 1990-2001 came to £1.5 million per year (Edgar et al., 2005). The escalating costs may be partly down to the increased number of licensed projects, but the cost per project also has risen from £15,000-£20,000 per project in 1990-2001 to over £100,000 by 2010. Mitigation projects carried out by professional ecologists clearly involve different types of costs, scales, locations and outcomes compared to conservation interventions carried out by non-government organisations and volunteers. This makes direct comparisons with other types of conservation actions difficult. Nevertheless, it is clear that conventional habitat creation and management projects are being carried out on small grants of a few thousand pounds.

The great crested newt case study demonstrates that even in a developed country with a relatively well-resourced governmental and non-governmental infrastructure for conservation and data management, there remain significant shortfalls in our understanding of the effectiveness of mitigation projects. Inadequate implementation, enforcement and compliance appear to be recurring themes in projects that involve ecological compensation for development (Brown et al., 2013). Equally, compliance with licence conditions may provide a poor indicator of success (Matthews & Endress, 2008), and survey protocols used by professional practice are not yet embracing contemporary tools that account for variation in detectability (Griffiths et al., 2015). If the maintenance of self-sustaining populations is to be an ultimate goal, performance indicators therefore need to be judged against ecological outcomes rather than regulatory outcomes.

We acknowledge that any retrospective analysis such as that performed here provides something of a historical perspective, and that UK statutory agencies are already striving to improve mitigation practice and licensing procedures at a number of levels. This includes wider landscape-level approaches, and assessments of the potential of species distribution modelling to address development-related issues (Bormpoudakis et al., 2015). Equally, there may be unknown and undocumented benefits to some actions such as habitat enhancement and creation, through improved green spaces, enhanced biodiversity and improved public well-being.

The increasingly widely-held belief that the reconciliation of habitats and species protection with development is intractable has led to renewed interest in the concept of offsetting (Hill & Arnold, 2012; Bull et al., 2013). Patchily distributed species – such as amphibians – are attractive models for such schemes as they potentially allow a network of connected wetlands to be maintained within a matrix of development, and predictive modeling may have a role to play in exploring possible impacts of development (Bormpoudakis et al., 2015). However, the present study shows that there remain significant knowledge gaps in how amphibians respond to such interventions. Until such gaps are plugged with evidence, alternative ways of maintaining populations alongside development remain high-risk.

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