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How difficult is it to reintroduce a dragonfly? Fifteen years monitoring *Leucorrhinia dubia* at the receiving site

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ABSTRACT

Conservation translocations (including reintroductions) are potentially powerful tools for wildlife conservation, and their use has increased worldwide. However, most studies have focused on vertebrates, with the long-term impact and ecological progress of translocations being neglected. Moreover, such projects rarely target insects. The present study reports the long-term persistence of a population of *Leucorrhinia dubia* (Odonata: Libellulidae) reintroduced to artificially created bog pools in the Czech Republic. Eighty (pen)ultimate instar *L. dubia* larvae were translocated in 2001, and the dragonfly assemblage at the reintroduction site was monitored for 15 years following larvae release. In 2015–2017, the capture-mark-recapture method, the Jolly-Seber model, and exuviae collection were used to evaluate the demography of the translocated population. Microsatellite analysis was performed to assess the genetic variability of source and reintroduced populations. Over the monitored period, population size increased (80 larvae released vs. 108–115 exuviae and 75 adults at the end of the study) and *L. dubia* became a dominant species, whereas the composition and abundance of the local dragonfly assemblage were not substantially changed. These results indicate that reintroductions are effective measures for dragonfly conservation, as translocating a relatively small number of individuals led to the establishment of a self-sustaining population. Using (pen)ultimate instar larvae was optimal for dragonfly translocation, but the availability of a high-quality habitat and the active collaboration with nature conservation authorities were vital for the successful outcome. Genetic analysis suggested that the translocated population might serve as a source of genetic variation for the original population, if depleted.

1. Introduction

Dragonflies are a useful indicator for nature management and conservation and an increasing effort has been recently made to acquire more information concerning their ecology, life histories, and conservation. Since the second half of the 20th century, many dragonfly species have shown a dramatic decline in their distribution and abundance caused by habitat destruction, eutrophication, acidification, and pollution of aquatic habitats in general (Kalkman et al., 2008). The loss and fragmentation of habitats and (sub)populations have been recognized as the main threats to biodiversity (Drag and Cizek, 2015; Primack et al., 2000). Therefore, conservation efforts should mainly focus on the most valuable and threatened habitats or species, and successful conservation requires both passive and active measures (Sahlén et al., 2004).

Conservation translocation, which is the human-mediated movement of living organisms from one area to another with the primary objective of benefiting species conservation (IUCN/SSC, 2013), is a method of active conservation. Such translocation usually reduces the risk of extinction for a focal (endangered) species by creating more self-sustaining populations (Hochkirch et al., 2007), and/or restoring natural ecosystem structure and functions or processes (IUCN/SSC, 2013). Conservation translocations (synonym *relocation*) consist of: (i) population restoration, comprising reinforcement/re-enforcement (synonyms *supplementation*, *restocking*, *augmentation*) and reintroduction (synonym *re-establishment*) within a species' indigenous range; and (ii) conservation introduction (synonym *benign introduction*), comprising assisted colonization (synonym *assisted migration*, *managed relocation*) and ecological replacement, outside the indigenous range, but in an appropriate habitat. Species translocations particularly aim to: 1)

Abbreviations: CMR, capture-mark-recapture; IUCN, International Union for Conservation of Nature; PLA, Protected Landscape Area; AICc, corrected Akaike information criterion; HWE, Hardy-Weinberg equilibrium; CI, confidence interval; MVPs, minimum viable population sizes; PVA, population viability analyses

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enhance the population viability of conspecifics, for instance by increasing population size (*reinforcement*), 2) re-establish a viable population of the focal species at any scale (*reintroduction*), 3) avoid extinction of populations of the endangered species (assisted *colonization*), and 4) re-establish an ecological structure and function lost through extinction (ecological *replacement*) (IUCN/SSC, 2013; Seddon et al., 2012). A special case is the so-called *mitigation translocation* involving the removal of organisms from a habitat lost through land use change and their release in an alternative 'wild' site (IUCN/SSC, 2013).

Ecological translocations, including reintroductions, in practical conservation activities are increasingly important worldwide (Godefroid et al., 2011; Taylor et al., 2017). Despite ongoing debates about their effectiveness, risks, and costs, translocation reintroductions have become a popular, widely used, potentially powerful, and high-profile conservation tool, and have been increasing almost exponentially every year (Harding et al., 2015; Seddon et al., 2012; Taylor et al., 2017). Although translocation strategies may be useful for a wide range of taxa, the vast majority of reintroduction projects have so far focused on large vertebrates, such as birds and mammals (e.g. Ewen et al., 2012; Stewart et al., 2017; Hochkirch et al., 2007). Although amphibians and fishes have also been frequently used in reintroduction case studies (Griffiths and Pavajeau, 2008; Harding et al., 2015; Muths et al., 2014; Soorae, 2011), reptiles, and especially invertebrates have been rarely used (Devang-Song et al., 2016; Seddon et al., 2007; Soorae, 2011, 2013, 2016), even though this does not fully apply to butterflies (e.g., Andersen et al., 2014; Thomas et al., 2011; Webb, 2010). However, many invertebrates have unique life-history attributes, such as small body size, low cost, and small spatial requirements, that make them more favorable and more promising candidates for such programs when compared to large vertebrates (Harding et al., 2015; Hochkirch et al., 2007).

Although captive rearing and species reintroductions could play an important role in rare odonate conservation (Bried and Samways, 2015), there appear to be few of these projects and even less documentation (e.g., Hannon and Hafernik, 2007; Preston et al., 2007). In fact, there is a general dearth in the monitoring of rare insect populations and other hyper-diverse taxa (Bried et al., 2014). Some pilot projects were prepared in Poland, where a small program has been implemented to reintroduce *Nehalennia speciosa* into areas where it formerly occurred (Bernard and Wildermuth, 2005; Sahlén et al., 2004). In California (USA), there was an attempt to reintroduce the forktail damselfly *Ischnura gemina* into the Glen Canyon Urban Park (1996, San Francisco), after the local extinction of this species, aiming at improving the health of the natural area within the park (Hannon and Hafernik, 2007). In 2003, conservation translocations of the native endemic damselfly of Hawaiian Islands, *Megalagrion xanthomelas*, were initiated (Preston et al., 2007), but this project is still in progress. A pilot reintroduction of the southern damselfly *Coenagrion mercuriale* to Venn Ottery Common, Devon, UK, in 2007 allowed recording breeding adults on site in 2009, prior to the main reintroduction action carried out on that same year using a large number of adults (Thompson, 2010). From 2011 to 2015, reintroduction activities were applied to restore and expand the range of the most endangered dragonfly in the Mediterranean, *Urothemis edwardsii*, with only one known relict small population left in Northeast Algeria (Khelifa et al., 2016). An effort has been made to reintroduce *Leucorrhinia dubia* into Foulshaw Moss Nature Reserve, UK. This project began in 2008, with translocations beginning in 2010 and ending in 2014. Monitoring of the site still continues, and so far, authors report a success (BDS, 2016). However, the available set of reports does not provide detailed information on translocation methodology.

Unfortunately, the long-term impact and ecological progress of dragonfly conservation translocations has not yet been elucidated. Generally, the successful reintroduction of living organisms results in a self-sustaining population with the ability to persist and reproduce (Griffiths and Pavajeau, 2008; Guerrant, 2013), which is usually a long-term process (Fischer and Lindenmayer, 2000). The long-term persistence of a new population is thus the key element of the conservation translocation. A lack of long-term post-translocation monitoring and research contribute to the very poor knowledge on the survival of translocated populations and/or on their breeding at translocation sites. It is assumed that most reintroductions will not persist over the long term (Godefroid et al., 2011), because the predictive value of such short-term trends for evaluating long-term status is limited (Albrecht et al., 2011). Thus, continuous or long-term monitoring is crucial to increase knowledge on the translocation of native animals and/or, as the case may be, on how to improve our ability to reintroduce them as a part of species and ecosystem restoration efforts.

Here, we report the results of a long-term translocation project aiming to conserve *Leucorrhinia dubia* (Vander Linden, 1825) in Eastern Moravia (Czech Republic). Although the translocation site is within the species historic range, it has never been recorded there (i.e., the species was reintroduced). Post-release monitoring of the translocated population was performed for 15 years, and translocation outcome was evaluated in multiple ways. For 12 years, reproductive activities of adults (mating, oviposition) were observed annually. From years 13 to 15, population demography was evaluated by combining adult surveys based on capture-mark-recapture (CMR) with exuviae sampling and genetic structure analysis (microsatellites), to characterize the newly established population.

2. Material and methods

2.1. Study species

The white-faced darter *L. dubia* (Libellulidae) is a small dark species found in northern Europe and east to Siberia. Although this species is common in the northern parts of its range, in the last decades its abundance has declined in the southern and western parts, where it is now considered a relict. Anthropogenic changes are persisting menaces for this species, but it is still listed as least concern (Clausnitzer, 2009). *Leucorrhinia dubia* inhabits oligotrophic and usually acidic bogs, ponds, tarns, and lakes; away from the aquatic habitat, it also requires scrub or woodland (important roosting sites). Because larvae are sensitive to fish predation, *L. dubia* prefers fishless habitats, such as small acidic bog pools with considerable semi-submerged rafts of *Sphagnum* spp. at the edges, which are important breeding sites. Adults prefer open-canopy areas. Being a territorial species, males are particularly found near water, whereas females prefer to perch among the surrounding vegetation or on open ground, further away from aquatic habitats. Copulations are relatively short and females oviposit alone, dropping the eggs onto waterlogged *Sphagnum* spp. moss. The species is univoltine, and larval development typically takes two years. In central Europe, individuals usually start to emerge in early May and the flight period mostly lasts from late May to mid-July (Clausnitzer, 2009; Dijkstra and Lewington, 2006; Dolný et al., 2016).

2.2. Study sites

2.2.1. Source site

The Rudné Nature Reserve near Suchá Hora (740–750 m altitude; 49°23′ 28.28″N, 19°47′24.71″E), Oravské Beskydy mountains, NW Slovakia, is a small fragment (1.95 ha) of the formerly raised bog (about 100 ha), later degraded due to drainage by shallow open ditches and subsequent peat extraction by industrial milling (1956–1996). The remaining natural peat bog has an ecotonal character (Fig. 1 C, D). At the beginning of the study, it was at risk of degradation by continuing peat extraction, and therefore, the local population of *L. dubia* was about to perish. The local vegetation mainly consists of *Sphagnum* spp. and Ericaceae, with some low sedges and dispersed short shrubs and trees, mostly birches (Betulaceae), willows (Salicaceae), and conifers (Pinaceae).