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# Recovery of the endangered false hop sedge: A ten-year study

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## HIGHLIGHTS

- We investigated the success of a recovery plan for an endangered wetland perennial.
- The overall survival rate of transplants was 4% after 10 years.
- Aphid infestation, excessive soil moisture and low light availability caused premature transplant death.
- Transplants were less vigorous than wild individuals, but live just as long as them.
- Transplantation allowed the establishment of one new population and sextuple the population size.

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## ABSTRACT

With a growing number of species at risk of extinction, reintroductions have become an important component of several recovery schemes. In 2005, a recovery program including reintroduction and reinforcement efforts as well as monitoring activities was implemented in Québec for the endangered false hop sedge (*Carex lupuliformis*). Between 2005 and 2010, a total of 600 plants were reintroduced in different habitats (dry and wet) on five distinct sites (swamps). Our objective was to determine which environmental variables (soil moisture, light availability, competition, aphid infestation) influenced the survival and vigour (height, number of shoots, number of fruiting shoots) of the transplanted individuals. We also compared the survival, growth and fecundity of transplanted and wild individuals. Discriminant analyses and ANOVAs indicated that exotic aphid infestation, excessive soil moisture and low light availability were the main causes of premature transplant death. Soil moisture (when not excessive, as shown by the survival analyses), light availability and competition volume positively influenced transplant vigour. Although only 4% of original transplants remain alive after a decade, at least one new population has established and total population has increased six-fold, when wild individuals and transplants still alive in 2015 are included in the calculations. Furthermore, at least 33% of transplants produced seeds at least once. Overall, transplants were less vigorous than wild individuals, but were found to live on average just as long, suggesting that the biological success of our reintroduction program is promising. Further studies of false hop sedge should include an examination of seed viability, to evaluate whether the small, newly-created populations experienced reduced germination.


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## 1. Introduction

Human population growth, associated with increased land-cover change, pollution, habitat degradation, climate change and introduction of invasive species, has resulted in a worldwide biodiversity crisis (McGill et al., 2015). With a growing number of species at risk of extinction, reintroductions have become an important component of recovery schemes for several species (Godefroid and Vanderborght, 2011; Liu et al., 2015). When properly planned, reintroductions can enable recovery of population numbers and size, as well as genetic diversity (e.g., Schaub et al., 2004; Noël et al., 2011; Fant et al., 2013; Daws and Koch, 2015; Zavodna et al., 2015). However, reintroduction is usually a high-risk activity with low or unpredictable biological success (Godefroid et al., 2011; Dalrymple et al., 2012; Drayton and Primack, 2012; Liu et al., 2015). For instance, an analysis of 249 plant species reintroductions worldwide reported average survival rates after one year of 52%, average flowering and fruiting rates after two years of less than of 20%, and no or only sporadic recruitment (Godefroid et al., 2011). This study also found a downward trend over time, as average flowering and fruiting rates decreased by 6% after four years. The failure of reintroduction attempts can often be attributed to an initial lack of knowledge of the ecology and biology of the target species (Aguraiuja, 2011; Abeli and Dixon, 2016).

To better understand the specific requirements of endangered species, many researchers have suggested performing experimental or observational studies parallel to reintroduction trails (e.g., Kaye, 2008; Menges, 2008; Maschinski et al., 2012; Wendelberger and Maschinski, 2016). The importance of sharing the knowledge acquired through such studies has also been emphasized (Kaye, 2008; Godefroid et al., 2011). Recently, reports of successful plant reintroductions have increased (e.g., Maschinski and Duquesnel, 2007; Colas et al., 2008; Daws and Koch, 2015; Burney and Burney, 2016; Holzapfel et al., 2016). For instance, using an experimental approach, Daws and Koch (2015) demonstrated that reducing herbivory and competition significantly increased the survival and fitness of seven understorey species reintroduced in forests restored after bauxite mining. This increase in successful reintroductions may be the result of recent publication of good practice guidelines (e.g., Maschinski and Haskins, 2012), but also in part reflect a publishing bias towards positive results (Godefroid et al., 2011; Liu et al., 2015).

In our study, we investigated the influence of biotic and abiotic factors on the success of reintroduction attempts conducted for false hop sedge (*Carex lupuliformis* Sartwell ex Dewey), an endangered riparian floodplain species in northeastern North America. For the first year of reintroduction and the nine years that followed, we documented the survival and vigour of transplanted and wild individuals, and described transplants microhabitat in terms of soil moisture, light availability and competition. The effect of unexpected aphid infestation was also investigated. We aimed to determine which environmental variables influenced the survival and vigour of the transplanted individuals. We also compared the vital rates (survival, growth and fecundity) of transplanted and wild individuals. Ultimately, we aimed to assess the overall success of our reintroduction trials. We used the establishment of offspring and the similarity between transplant and wild individual vital rates as measures of biological success, as suggested by Menges (2008) and Monks et al. (2012).

## 2. Methods

### 2.1. Study species

False hop sedge is a perennial from the Cyperaceae family that grows mostly under canopy openings in seasonally flooded swamps (Thompson and Paris, 2004; COSEWIC, 2011). Distributed sporadically across eastern North America, it is rare throughout most its range. In Canada, it is found only in the southernmost portions of Québec and Ontario, where it is currently listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2011). The species is rhizomatous and can reproduce both vegetatively and sexually. Flowers are wind-pollinated, and seeds are dispersed by gravity or water. False hop sedge plants can produce seeds within their first year, and are believed to require soil disturbance and light to germinate (Thompson and Paris, 2004). The plant's lifespan is unknown, but is believed to be long (7+ years; COSEWIC, 2011). Although the species is known to form a persistent seed bank in the soil and thus would not be considered an adequate candidate that would benefit from reintroduction (Godefroid et al., 2016), it was believed that without action this species would not naturally colonize isolated suitable habitats or reappear on sites where it used to occur in the study area because most of these have either been destroyed or highly disturbed with no possibility of restoration. Habitat loss and degradation caused by the conversion of riparian wetlands for agricultural and residential use, canopy closure, shore erosion, exotic species invasion and water regime regulations threaten hop sedge populations across Canada (COSEWIC, 2011).

### 2.2. Recovery project

In 2005, a recovery project for false hop sedge was developed in Québec by the Pellerin laboratory in collaboration with the Québec Conservation Data Centre (*Centre de données sur le patrimoine naturel du Québec*). At that time, false hop sedge was considered to be the species with the highest probability of extinction in the province, due to its rapid decline (40% decline between 1998 and 2005; Jolicoeur and Couillard, 2006) as well as the extremely small number of populations (three extant populations located along a 15 km stretch of the Richelieu River) and individuals (31 known individuals; see Appendix A for