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Journal
Biodiversity and Conservation, 29(13)

ISSN
0960-3115

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Publication Date
2020-11-01

DOI
10.1007/s10531-020-02045-y

Peer reviewed

Biodiversity and Conservation
https://doi.org/10.1007/s10531-020-02045-y

ORIGINAL PAPER

Lessons from the reintroduction of listed plant species in California

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Received: 17 March 2020 / Revised: 2 July 2020 / Accepted: 2 September 2020

Abstract

Reintroduction is an increasingly common practice to conserve and recover threatened and endangered plant species, so understanding how practitioners view their work and identifying persistent resource mismatches are key to the long-term viability of these listed species. We interviewed practitioners involved in reintroduction projects for 14 species in the state of California to understand (1) how they defined recovery; (2) their assessment of the likelihood of recovery; (3) what advice they would share with other practitioners to improve reintroduction efforts; and (4) what resources could make future projects more successful. Practitioners' definitions of recovery aligned with ecological theory and emphasized the importance of self-sustaining populations and large populations, as well as the presence of multiple populations. However, most practitioners felt that recovery was unlikely or did not think the species they worked with should or would be de-listed without the guarantee of perpetual future interventions. Practitioners thought that studying basic biology and natural history, using experiments to determine the best techniques, and repeatedly planting populations were important to project success. However, practitioners also felt they were missing critical resources, including long-term funding for implementation and maintenance, successful and positive relationships between members of the practitioner-agency-scientist-landowner nexus, and assurances/safe harbor agreements for experimental populations. Overall, rare plant reintroductions are complicated by persistent mismatches in timing and goals, but some individuals have been able to successfully navigate these challenges. Longer duration funding mechanisms for monitoring and maintenance and better data handling, storage, and dissemination would benefit future projects.

Keywords Endangered species · Perceptions · Recovery · Natural history · Monitoring · Experimental introduction

Communicated by Daniel Sanchez Mata.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10531-020-02045-y) contains supplementary material, which is available to authorized users.

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Background and introduction

The Endangered Species Act ('the Act') is one of the strongest pieces of conservation legislation ever to be passed in the United States (Gray 2007; Rohlf 2014). Though the Act has generally been well-supported by the public (Bruskotter et al. 2018), it has been subject to significant scholarly and political criticism both for doing too little to protect species and for overstepping the legal rights of individuals (Bean 2009; Rohlf 2014). The Act, designed in response to concerning declines in the US's biodiversity, was meant to identify species at risk of extinction, halt and reverse their declines, and 'recover' them so that they could be removed from the list. The emphasis, however, has long been on identifying species at risk and managing them in ways to prevent extinction, with fewer resources going towards recovery (Doremus and Pagel 2001; Evans et al. 2012). Indeed, state and federal species protection policies tend to focus on the conditions under which rare and endangered species become protected (e.g. listing) and much less on the viability and recovery of those populations many decades later. Even the much-used habitat conservation plans (HCPs), under Section 10 of the Act, do little to ensure adaptive management for more than a few years after incidental take permits have been granted.

Relatively few species were down- or delisted in the 15 years immediately following the ESA's passage in 1973, resulting in a 1988 amendment requiring the administering agencies (the US Fish and Wildlife Service and US Marine Fisheries Service) to write or update species recovery plans with specific, actionable requirements for delisting. Recovery plans were required to have clear goals, descriptions of necessary management actions, and estimates for the costs and timeline for these criteria to be met. To date, these recovery plans and their implementation have a mixed track record, though they often provide important guidance and support for the conservation of listed species (Gerber and Hatch 2002; Foin et al. 2006; Doak et al. 2015).

For listed plant species with recovery plans, a commonly prescribed recovery action is population introduction (i.e. planting at sites where a species was not historically found) or reintroduction (i.e. planting at a site within its known historical range). For simplicity, we typically use the term "reintroduction" throughout the rest of the paper, though we acknowledge the complex spectrum of activities that exist along the introduction-translocation spectrum that occur in this type of work (Seddon et al. 2007, 2010). As more species require human conservation intervention, reintroductions have become increasingly common over the last 30 years, resulting in the advancement of reintroduction science (Seddon et al. 2007; Hölzel et al. 2012). Though species reintroduction should never take precedence over in situ conservation (Maschinski and Haskins 2012), these actions are critical for the protection and persistence of many rare and listed plant species. Over the past few decades, useful guidelines regarding proper practices have been published, producing a literature documenting the best methods and practices for the planning, implementation and monitoring of rare species reintroductions (Kaye 2008; Maschinski and Albrecht 2017).

To date, several reviews of reintroduction efforts have focused on quantitative measures of project success and population size to identify best practices and techniques (Dalrymple et al. 2011; Godefroid et al. 2011; Guerrant 2012; Albrecht et al. 2019). Overall, these studies have found mixed evidence for the value of plant reintroduction as a conservation tool, with differing criteria of success and plant life history impacting the value of reintroduction as a technique (Guerrant 2013; Albrecht et al. 2019). In combination with other conservation strategies, such as seed-banking, genetic material preservation, or ex situ conservation in gardens and arboreta, reintroduction to historical habitat is one of a palette of techniques that can be used to protect biodiversity. Given the expansion of human enterprise globally, and the many threats faced by plants, it is unlikely that reintroductions will become less necessary or likely in the future. Therefore, it is valuable to understand what factors are perceived to be limiting or enhancing their success.

This study aims to complement past work studying ecological processes governing reintroduction success by examining the perceptions and attitudes of the practitioners involved in plant reintroduction projects in the state of California. We focused on practitioners' definitions of recovery, their assessment regarding the likelihood of recovery, what advice they have for future practitioners of rare plant reintroductions, and finally, their thoughts on the resources they felt were lacking, but are critical to project success.

Methods

We focused on reintroductions that have occurred in California, USA., since California has stronger protections for listed plant species and has conducted more introductions and reintroductions than other states in the US. This focus limits our ability to draw conclusions at larger national and international scales, where there is variation in policies protecting and governing the recovery of rare plant species. However, we contend that the challenges facing rare plant conservation efforts are likely to similar but potentially more problematic outside of California, as these regions may dedicate even fewer resources to rare plant protection and restoration. In California, introduction and/or reintroduction are required or suggested actions for the down- or de-listing of 87 of the 120 listed species with recovery plans in the state of California (72.5%; out of 183 listed plant species total). According to recovery plans and the US Fish and Wildfire Service's Environmental Conservation Online System, introduction or reintroduction plantings have occurred or are underway for between 25 and 38 species, providing a reasonably-sized pool of potential projects and interviewees.

One of us (J.C.L.) conducted semi-structured interviews with individuals who were involved with reintroductions in a variety of ways: as on-the-ground practitioners, scientific advisors, landowners, and/or officials at permitting and funding agencies. We assured respondents of anonymity, and therefore identify them only as respondents, or by their relationship to a project ("landowner", "scientific advisor"). Potential interviewees were identified through analysis of published documents and 'snowball sampling', in which we asked respondents to identify other potential respondents they felt we should speak with (Goodman 1961). In total, we contacted 32 potential interviewees, of whom 28 responded and 20 consented to being interviewed. These 20 individuals represent projects for 14 species that have undergone reintroduction efforts in California. Some interviewees worked with multiple species or on multiple projects for the same species. We think our respondents are representative of individuals working on rare plant recovery throughout the state, given that respondent's recommendations for further individuals that we might interview often named those we had already interviewed, or individuals who had declined to be interviewed. Most of the projects were introductions or reintroductions carried out as a part of a recovery plan, though some respondents had also worked with species on mitigation-related introduction and/or reintroduction efforts. For practitioners who provided information about how long they had worked in the field of rare plant reintroductions (16/20), the mean was 15.5 years (range 2–42 years) and the median was 11 years.

Interviews were conducted mostly by phone and a few via email between January and September 2019. Phone interviews lasted 30–120 min. J.C.L. took notes on interviews during and directly after interviews. Interviews were structured around the following four sets of questions:

1. Project background: What is your understanding of the species biology/history and project history? How were you involved in the (re)introduction efforts?
2. Defining recovery: How would you define success/recovery for this species or project? Do you (or did you) think the species is likely to recover? How would you describe project outlooks or outcomes? Have your goals for the species or project changed since starting the work?
3. Advice for practice: What key information or knowledge did you learn from this project that you would pass on to future practitioners?
4. Missing resources: What would you change about the project to make it more successful, or what resource do you feel the project could have benefited from most?

To synthesize results, we categorized responses after conducting the interviews, using email text and phone interview notes. Categories were developed based on the responses given. After coding, we calculated the frequency at which topics were noted. We present all responses that were mentioned more than once.

Results and discussion

Defining recovery

Fourteen of the 20 participants provided definitions of species recovery, and 6 respondents provided definitions for project success (Table S1). Interviewee definitions of species recovery aligned with the recommended de- and down-listing criteria presented in USFWS recovery plans and were ecologically sound. We identified five components of species recovery from our interviews.

The most-cited criteria for recovery (86%) was evidence of a self-sustaining population, meaning they reproduced over time, showed "evidence of new plants," and eventually created "an F3 generation," meaning that the introduced plants' offspring successfully produce reproductive offspring. Additional criteria commonly mentioned by respondents were having multiple populations (57%), large populations (50%), land being protected in perpetuity (29%), and spatially distributed populations (14%). The large population sizes and multiple populations criteria for success are supported by ecological theory, as large and multiple populations of rare plants are better buffered against stochastic environmental and demographic events (Menges 2000; Traill et al. 2010). Respondents sometimes provided exact values for what they felt constituted a 'large population' (from 50 to 10,000 individuals), but these values varied depending on the species life history. Several respondents felt that having consistently large populations were not valuable recovery criteria, as some species, such as some native annual wildflowers, have notoriously variable population sizes (Eviner 2014) and would need to be compared "over a period of 'average' weather conditions" to obtain an accurate estimate of recovery success, or because they felt that the required population sizes described in recovery plans or other documents were selected arbitrarily.

Outlooks for down- or de-listing

Respondents expressed mixed attitudes towards the likelihood of species delisting, and three preferred not to respond to the question (Table S2). The largest proportion (7) of respondents who answered felt that the species they worked with were unlikely to recover to the point of delisting in the near future. Only 2 out of the 17 respondents who answered the question felt that recovery to the point of delisting was likely in the foreseeable future, though they couched their opinions in warnings about how long it might take to occur: respondents made clear that delisting "wouldn't be happening anytime soon," or that at least "ten years of efforts might lead to a sustainable population of the species". Roughly a third of respondents (6) felt that the species could recover, but only with the guarantee of perpetual intervention from humans, precluding the possibility of delisting. As one respondent explained, their "biggest concern [was] the self-sustaining definition", as the need to manage invasive species in perpetuity meant they "[didn't] know if the plant will ever be down-listed or delisted". Another respondent indicated that they could not reconcile "always need[ing] to manage the occurrence" with the concept of a self-sustaining population.

This conflict between delisting and the need for perpetual management has been discussed in the literature extensively in the past, under the term "conservation-reliant species" (Scott et al. 2005, 2010). These conservation-reliant species are defined as those for which threats cannot be eliminated, but only managed—potentially in perpetuity. For many of the respondents, threat management in perpetuity or stewardship of the species was viewed as the desired outcome, rather than a negative outcome that mitigated success. In other words, respondents indicated that conducting a reintroduction and 'walking away' after 3–5 years was rarely the goal of the project.

Finally, two respondents felt that down- and de-listing should not occur, regardless of whether projects resulted in self-sustaining populations and met recovery criteria. Two explanations given for this perspective were concerns over climate change and the value of listed species as 'umbrella species' to protect habitat. As one respondent stated, it would be unwise to delist a species that had reached recovery goals, given that "climate change looms large on the horizon." This uncertainly about how a changing climate will impact currently protected species is supported by model findings that climate change is more likely to negatively affect endangered than common plant species (Bartholomeus et al. 2011). Another respondent felt down- or de-listing species would eliminate the protections for entire habitats and potentially affect swaths of valuable natural spaces that protect substantially more than a single rare species within it. The concept of an umbrella species which protects co-occurring species has been argued to be a potentially important conservation tool for protecting considerably more than a single species, but most work examining the value of umbrella species in conservation planning and outcomes has focused on animal species (Roberge and Angelstam 2004; Branton and Richardson 2010). Required critical habitat designation does not always occur for listed species, but listed species can provide protection for a variety of high conservation priority habitats in California (Pavlik 2003).

Practitioner advice

Interviewees provided many pieces of key advice that they would pass onto those conducting future reintroduction projects (Table 1). The two most common were for

Table 1 Key advice provided by interviewees regarding the reintroduction of rare plant species

Advice	Number of mentions (n = 20)
Study natural history and biology	10 (50%)
Use experiments	9 (45%)
Visit field sites of all extant populations	5 (25%)
Test the edges of the range/niche	5 (25%)
Develop social connections	5 (25%)
Develop high quality data collection and management skills	3 (15%)
Plant repeatedly	3 (15%)
Prepare for long-term investments	2 (10%)

Some practitioners provided multiple pieces of advice

practitioners to study organisms in the field (natural history) and to use experiments as a part of the reintroduction process (Fig. 1).

Using resources to understand basic biology and natural history

Practitioners who highlighted the need for thorough research prior to starting a project (Table 1) lamented the lack of basic information about species ecology: pollination, propagation techniques, seed viability over time, the effects of competitors, and responses to disturbance regimes. While it seems obvious to say that a good understanding of basic biology is necessary for projects to be successful, basic biological and ecological information is missing, scattered, or inaccessible for many rare species, and practitioners find it difficult to gather and access.

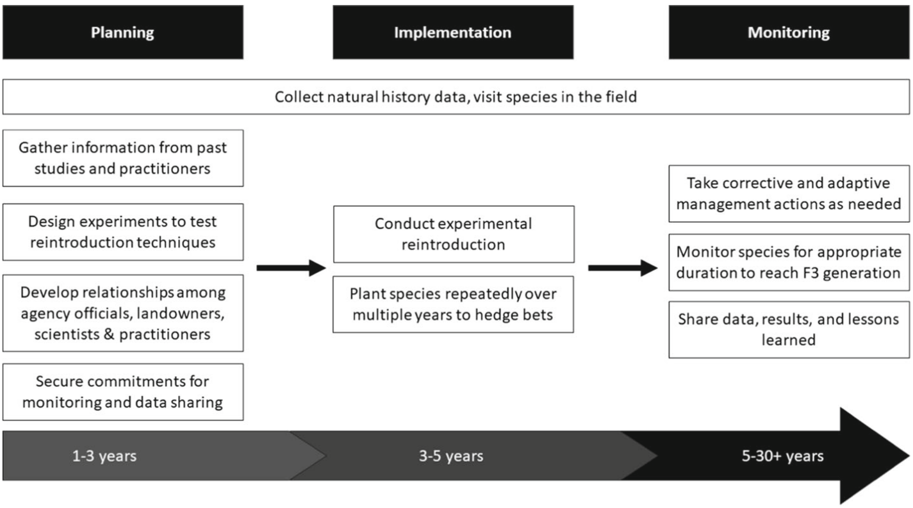

Fig. 1 A schematic summarizing the most common advice and lessons learned to improve reintroduction project outcomes and when these activities should occur, illustrating the need for longer-term funding and monitoring commitments than are typical

Practitioners repeatedly highlighted the importance of conducting natural history studies prior to beginning a project, but also noted the difficulty in balancing limited budgets with the time needed to fill critical information gaps. Some basic biology inventories for rare species (Massey and Whitson 1980; The Center for Plant Conservation 2019) can be partially filled out with valuable information gathered from historical and modern sources (such as USFWS recovery plans, traditional cultural knowledge from indigenous groups and local communities, and peer-reviewed publications when available). Nonetheless, the most consistent recommendation was to spend large quantities of time in the field studying the natural history of a species, especially in different seasons. As one agency scientist with experience permitting rare plant reintroduction projects explained, reintroduction projects based on thorough on-the-ground research are less likely to fail. For another respondent, “spend[ing] enough time with a species to watch the conditions under which it grows” led to crucial insights about the species that improved project outcomes, and yet another described how natural history was important to their process: “I developed a series of research questions based on my years of observation in the field, and then collaborated with different research institutions to conduct the studies. It’s all about learning to ask the right questions. And the right questions come from spending time observing the species in its natural habitat (or a suitable surrogate reference species or population).”

These comments underscore the calls of others for the holistic study of rare plant taxa to better guide management, conservation, and reintroduction strategies (Silva et al. 2015), and the concerning concurrent decline in support for natural history research, or the observational study or organisms in their habitat, over the past several decades (Tewksbury et al. 2014). Thirty percent of respondents identified information about species ecology as a missing resource that could improve project outcomes, and without support and investment to study the basic biology of listed species, practitioners will be limited in their ability to generate appropriate and successful reintroduction plans.

Using reintroductions as experiments

Numerous authors have called for reintroduction projects to be conducted as scientific experiments with explicit hypotheses to improve our understanding of ecological and evolutionary processes (Sarrazin and Barbault 1996; Guerrant and Kaye 2007; Maschinski and Haskins 2012), and the practitioners we interviewed largely agreed, with nearly half (45%) of respondents listing experimental practice among their advice. Interviewees valued experimentation in reintroductions to provide information about basic species biology and to identify the best techniques for reintroduction. One of the benefits of using experiments as part of population reintroduction is that even if the project itself is not successful, something about the species can be learned regardless, which Pavlik (1996) describes as the differences between *project* success and *biological* success. One practitioner referred to their series of experiments as developing a “prescription of how you grow them and how you plant them.” Multiple practitioners told stories of using experiments to compare techniques, describing their experiments as a “series of learning events” to try to “nail down” which treatment was most successful.

Several interviewees also advocated for using experiments to test the limits of known species niches. One respondent summarized the concept succinctly as “don’t assume that the extant population characteristics are what the species wants.” Another interviewee noted that many listed species are only found in a small number of extant populations but may have been found historically at sites that are “now under shopping malls.” Thus, species could be tolerant of a wider range of biotic and abiotic conditions than is reflected by their extant populations. Greenhouse and field experiments can test these boundaries, potentially providing insight about alternative reintroduction sites. One respondent, lamenting the quality of the distribution and abiotic tolerance information in the recovery plan for their species, declared that future efforts should not “take on faith the received wisdom of what plants need.”

Planting repeatedly to hedge bets

Planting in multiple years can help practitioners hedge their bets, as published evidence supports the use of repeated plantings to overcome stochastic events like sudden drought, and to improve the chances of catching a good year for plants to establish (Wilson 2015; Stuble et al. 2017). For several interviewees, initial planting efforts during a drought year failed, but the same techniques in later years appeared more successful. One respondent described this technique as “founder cost averaging” (analogous to the financial concept of ‘dollar cost averaging’) in which repeated plantings would be more likely to lead to long term success: “don’t do it all at one time, do it one year at a time in hopes of catching that one up-year.”

Missing resources

Two resources were identified as likely to improve project outcomes by over half of interviewees: long-term funding and provisions for active management or monitoring (Table 2; Fig. 1).

Fixing mismatches in the scales of funding and timing: monitoring and active management

The most cited resources desired by interviewees were commitments for long-term funding (55%) and long-term monitoring and active management (55%). This is unsurprising, given that most restoration projects are only monitored for short periods (Suding 2011). Moreover, meta-analyses of plant reintroductions have found that monitoring rarely extends more than three years beyond project implementation, and self-sustaining populations are rarely achieved after initial efforts (Godefroid et al. 2011; Guerrant 2013). This

Table 2 Key resources interviewees felt were missing and would have improved rare plant reintroduction outcomes

Desired resource	Number of mentions (n = 20)
More/longer-term funding	11 (55%)
Long-term monitoring/active management	11 (55%)
Better relationships with other groups	7 (35%)
Info on species	6 (30%)
Flexibility/assurance if pop needs to be moved	4 (20%)
More propagules	4 (20%)

Some practitioners identified multiple missing resources short-term funding is a mismatch with practitioner's perceptions that the species they worked with could recover only with perpetual human intervention or management, reflecting a shift from short-term intervention thinking towards long-term stewardship thinking.

Fixing this mismatch will require alternative funding mechanisms, such as bonds and endowments, to ensure proactive long-term management. Bonds and endowments are two methods by which large sums of principle funds are used to fund long-term projects using interest or income on the principle investment. Currently, common grants for rare species recovery (such as traditional Section 6 cooperative endangered species conservation fund Grants) are limited to a short number of years of funding (1–4 years), which, while valuable for some experimental projects, do not align with the time needed to monitor of a reintroduced population (Fig. 1). This mismatch in the scale of funding and of ecological processes is well recognized across restoration ecology (Hodge and Adams 2016; Holl 2020). Multiple respondents described piecing grants together from different sources over the years to keep project monitoring afloat, and one succinctly stated, "we want longer funding cycles." We do not argue for indiscriminate increases in funding, as funds to monitor projects should but put the good use, such as measuring relevant processes and answering specific questions (McDonald-Madden et al. 2010), but rather for funding to be guaranteed over longer periods so that long-term data collection and management can take place as needed.

Enhancing data management to move from individual knowledge to institutional knowledge

Several practitioners identified the need for high quality data collection and management skills in order to improve future project outcomes, reflecting past calls for accessible, distributed networks of knowledge (Godefroid and Vanderborght 2011), and the troubles that arise when management methodologies go missing, are trapped in filing cabinets, or never recorded at all (Dickens and Suding 2014). One constraint to high-quality data storage and transmission is the cyclical nature of most organizations, wherein individuals only stay at a single position for a few years. For some organizations, the average tenure of an individual can be quite short (such as masters students at universities and some agency positions), whereas in other cases, individuals may be in a position for decades (such as land owners). Internal turnover can lead to problems if information and data are not stored and shared appropriately. In one case, a respondent was managing several successfully reintroduced populations years after the initial reintroductions had occurred but was missing critical information about what techniques were used and the factors that guided decision-making, as the original efforts had not been recorded in a trackable manner.

With 30% of the respondents describing basic species knowledge as a missing resource and funding for rare plant studies as limited, enhanced database management and results-sharing among different groups are important aspects in overcoming the knowledge deficit. Information about rare plant reintroductions can be difficult or impossible to access unless an individual is working directly with a specific project. Others have called for the creation of accessible online reintroduction information repositories (Godefroid and Vanderborght 2011), and recently, the Center for Plant Conservation developed the "Rare Plant Academy" web page, which includes resources and a forum for practitioners to discuss seed banking, conservation practices, and reintroduction practices (https://academy.saveplants.org/). Though repositories tend to grow slowly at first, they should help fill a gap in rare plant reintroduction information transfer. Similarly, regional workshops and meetings can facilitate knowledge transfer.

Improving academic-practitioner-agency-landowner communications

The problems preventing rare species conservation and recovery are seldom purely biological (Clark and Clark 1997). As one respondent put it, "the ecology is important, but the policy, the people, and everything else is just as important." Despite the rough edges and difficulties that sometimes arise when multiple groups with diverse goals work together, many interviewees recognized that cooperation across organizational and institutional boundaries was critical to achieve project success.

A common stumbling block mentioned by several respondents was obtaining permits to collect rare plant seed, access land, conduct trials, and other tasks, and obtaining those permits depends on relationships with the permit granting agencies. One interviewee explained that while agencies must ensure no harm will come to a listed species, they felt that officials were sometimes so afraid of moving in the wrong direction that they would refuse to take any steps at all to conserve a species, and another described the delays as "permit hand wringing." Respondents overcame these difficulties by developing strong and trusting relationships with permitting agency officials before and during the process of applying for permits. As one interviewee said, "it's important to have good working relationships with the agencies" and that it was important for agency staff to "know you, like you, and respect you" if you hope to conduct successful projects. Most reintroduction best-practices indicate the need to acquire permits well before work is conducted, but few reflect the reality that having a positive, trusting relationship with an agency can make or break a project.

Our interviews also highlighted persistent mismatches between the desires and tenure of research scientists who work with projects and the goals of the project managers. Though they shared the overarching goal of maintaining robust populations of reintroduced rare plants, academic researchers often sought to answer questions that were narrowly focused on the basic ecology of the species, which frequently did not align with specific project goals or inform on-the-ground reintroduction techniques. These responses reflect well-documented gaps in what is published in the conservation and restoration literature, and what is desired by managers (Arlettaz et al. 2010; Dickens and Suding 2014; Matzek et al. 2015). Equally, there is a mismatch in the pace at which scientific journals publish information that could be salient to land managers and when managers may need this information, as peer-review takes a considerable amount of time (Meffe 2001). Interviewees also suggested that even when practitioners and scientists were able to cooperate on a project, project managers sometimes felt burned because academics would move on after several years, either because the results of the initial study were published or because the person who initially worked with the project, such as a graduate student or post-doc, had finished their project or program. This left landowners or agencies without resources to continue monitoring a project, or even missing entire reports about what had occurred. Bridging this knowledge-action boundary for successful reintroductions will require careful and consistent communication, and can be achieved through several mechanisms, such as boundary organizations or working groups (Cook et al. 2013).

Despite these difficulties, several practitioners described successful cooperation with research scientists, and were able to navigate relationships with research institutions by incorporating researcher interests into specific projects that would produce the natural history knowledge and experiments desired by project managers. By identifying who will be responsible for a project's long-term management before it begins, a project is much more likely to move smoothly from implementation to management. Without preparation for long-term care, projects can end up mismanaged or forgotten, so plans should outline early on who will care for a project and the associated data, potentially in perpetuity.

Providing flexibility and assurance for landowners

Four respondents also brought up the concern of creating perpetual land-use restrictions on a property after successfully reintroducing a listed species. They described rejecting opportunities to gain knowledge about appropriate techniques and management strategies due to fears of highly restrictive regulations that might occur if projects were successful in the long term. As one respondent explained, tensions between landowner desires or mandates (such as the need to maintain public access or recreation) could be at odds with the need for 'protection in perpetuity,' and they wanted to avoid "looking back in the future and wondering 'what was I thinking?'".

One policy mechanism to solve this problem could be increasing the use of designated experimental populations under the 1982 Sect. 10(j) amendment of the Endangered Species Act to gain knowledge about techniques and best practices. When a population is designated as experimental, especially as a nonessential population, the regulatory burden associated with take of the species on a property is greatly relaxed. The requirements for experimental designation are that the release has been authorized and that the introduced population is geographically separate from natural populations, so that if 'take' occurs, it is clear which population is the experimental one. To date, this designation has never been used on a plant species at the federal level, though a state-level designation has been applied to some populations as part of reintroduction experiments (Holl and Hayes 2006).

Conclusions

Our findings call attention to shortcomings in the ability of the Endangered Species Act to ensure the long-term success of listed species reintroduction efforts, and the ways in which project success could be improved in the future. Though many of the practitioners we interviewed do not perceive de- or down-listing to be likely in the near future, they are dedicated to the long-term stewardship of the rare species they work with. The Act is a valuable piece of legislation for the conservation of flora and fauna in the United States, but for species that require more than a one-time introduction or reintroduction, or that may depend on human management in perpetuity, the Act itself does relatively little to support the many steps that will be required in the future (Fig. 1).

Our interviews reinforced prior research indicating that there is a disconnect between scientists and managers, but also revealed a high level of agreement between these groups on the use of well-designed experiments in rare plant reintroductions. We are heartened that the value of experimentation is recognized across groups, and urge continued experimentation to increase *project* success, and eventually *biological* success. Increased collaboration on experimental reintroduction projects in the future could go a long way in resolving some of the information gaps that were described in our study, especially if experiments can be designed to improve practitioners understanding of species natural history and specific techniques to improve *project* success.

Finally we feel that holistic mechanisms to support projects through the entire recovery and reintroduction process, from natural history study through post-reintroduction monitoring through continued active management, could greatly benefit future project success. This holistic approach mirrors other calls for a diversity of techniques to be using in conserving rare plant species overall (Havens et al. 2006). Likewise, increased communication of findings among practitioners through both formal and informal networks will continue to be necessary in the future. Future policy development with an eye towards improved long-term funding mechanisms such as endowments and bonds that support stewardship and management, may better protect species than the intervention-style actions currently most supported under the Act. As the science of reintroduction ecology continues to develop, we hope to see the creation of funding and support networks which reduce the pressure on practitioners to string together short-term grants, and provide the stability necessary for long-term data collection, storage, and dissemination.

Acknowledgements We are thankful to all the practitioners who participated in this study. We also thank Peggy Fiedler, Diana Hickson, and Connie Rutherford for their early guidance in the design and topic of this study.

Funding This research was not supported by external funding.

Data availability The datasets generated during and analyzed during the current study are not publicly available to protect the anonymity of respondents in the study, but aggregate and anonymized data are available from the corresponding author on reasonable request.

Code availability Not applicable.

Compliance with ethical standards

Conflict of interest The authors report no conflicts of interest or competing interests.

Ethics approval, consent to participate, and consent for publication This research included human subjects. Subjects were not asked about sensitive or identifying information. All respondents consented to be included in the study, were informed of data management procedures (anonymization and storage) and acknowledged that their responses may be published prior to interviews.

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