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NOTE

TRANSLOCATION AND REPRODUCTIVE BENEFITS TO A HIGHLY ENDEMIC AND ENDANGERED SPECIES, THE BANBURY SPRINGS LIMPET, *IDAHOLANX FRESTI* (MOLLUSCA: GASTROPODA)

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ABSTRACT

We have monitored four isolated populations of the endangered freshwater Banbury Springs limpet for eight or more years. One of these populations consistently exhibited low numbers and very limited recruitment. In an effort to increase its size and reproductive vigor, we translocated 19 limpets from a large, robust population to the smaller, declining one (focal population). This translocation effort was carried out along with a small-scale habitat management effort. Post-translocation monitoring has seen the focal population increase by up to 900%, with an increase in reproduction from 6% to 33–55% annually. Limpet densities in the focal population also have increased from 5.5 m^{-2} to 43 m^{-2} post-translocation, reaching densities seen in more stable populations. The augmentation of additional individuals, in addition to ongoing habitat management efforts, likely played an important role in the observed increases. The observed recruitment also suggests some level of increased genetic vigor following the translocation, but we lack the data to fully support a genetic rescue effect. Although translocation and augmentation of isolated and declining populations should be approached cautiously, our results support a growing body of literature that suggests the shortcomings associated with these techniques may have been overstated in the earlier literature. If done properly, their use can provide important conservation gains for small and isolated populations of sensitive species.

KEY WORDS: limpet, translocation, augmentation, Mollusca, freshwater, genetic rescue

INTRODUCTION

As isolated populations become smaller, they are at increased risk of extirpation due to demographic stochasticity (Lande 1988; Holsinger 2000) as well as increased inbreeding and the expression of genetic load (Frankham 1998; Keller and Waller 2002; Rowe and Beebee 2003). For vulnerable and endangered species, translocating individuals from larger, more robust populations into declining ones (population augmentation) has been proposed as an effective conservation tool (Taberlet et al. 1997; Amos and Balmford 2001; Tallman et al. 2004; Bodine et al. 2008). The use of translocation, "the human-mediated movement of living organisms from one area, with release in another" (International Union for the Conservation of Nature [IUCN] 2013), is not without risk, and the IUCN and others (Moritz 1999; Dudash and Fenster 2000; Amos and Balmford 2001) have outlined criteria and precautions to avoid or minimize these risks. Given the growing trend of small and fragmented habitats, translocation may provide an effective tool for managers dealing with species that occur in small populations and exhibit reduced genetic vigor (Moritz 1999; Tallman et al. 2004).

The Banbury Springs limpet (*Idaholanx fresti*) is a monotypic species endemic to Idaho and placed in the subfamily Lancinae, which is restricted to the Pacific Northwest, USA (Campbell et al. 2017). The Banbury Springs limpet (or limpet) has a conical shell that can measure up to 7.1 mm in length and 4.3 mm in height (Fig. 1). The species is confined to four aquifer-fed springs along the Snake River in south-central Idaho, where it prefers cobble-dominated habitat, free of fine sediments, in clear spring tributaries that maintain consistent temperatures 13–17° C year round (U.S. Fish and Wildlife Service [USFWS] 2018). They are rarely found on submerged woody debris, nor have they been associated with rooted macrophytes (e.g., *Stuckenia* spp.) as habitat. The species is presumed to feed on saxicolous periphyton, but little else of its life history (longevity, fecundity, or reproduction) is documented. These four populations are located within 10 km of one another, but they are reproductively isolated as *I. fresti* requires good water quality (Bowler and Frest 2018) and

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Figure 1. *Idaholanx fresti* is the only representative of a monotypic genus and is restricted to four spring creeks in south-central Idaho (photo credit Robert Jaeger).

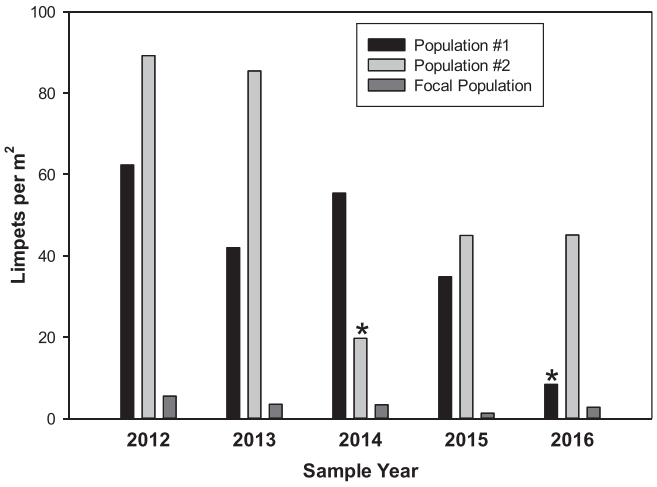

Figure 2. Estimated population densities of Banbury Springs limpets at three populations, prior to the translocation event. The focal population was consistently low throughout the study period, while the other two typically maintained larger numbers of snails found at higher densities. The two asterisks (*) denote years in which disturbance events (water diversions) caused significant declines in both numbers and densities of limpets within the denoted populations.

cannot tolerate the poor water quality found in the Snake River into which these springs feed. A recent phylogenetic review (Campbell et al. 2017) confirmed the species' distinctness from other lancines but lacked the resolution to discern differences between the four populations.

Biologists from the USFWS began annual monitoring of three of the four populations, including the population addressed in this study (focal population) of limpets, in 2012 (USFWS 2018). Frest and Johannes (1992) first documented the focal population in 1991, estimating its total numbers to range from 600 to 1,200 individuals, with densities ranging from 16 m^{-2} to 48 m^{-2}. When regular, systematic monitoring began in 2012, the number of recorded individuals was low (32 individuals, 5.5 m^{-2}), and it declined steadily with subsequent annual monitoring (Fig. 2). While other limpet populations also have encountered periodic declines due to disturbance events, they have rebounded toward predisturbance levels and typically have included a larger percentage of subadults (i.e., juveniles), exhibiting more robust recruitment. By comparison, the focal population exhibited low recruitment, with monitoring never recording more than 10% of individuals encountered being classified as subadults (Fig. 3). In addition, the area occupied by the focal population had declined from approximately 12–14 m^2 in 1991 (Frest and Johannes 1992) to no more than 2 m^2 in 2016. In comparison, limpet-occupied habitat in the other monitored populations largely remained unchanged (USFWS 2018).

In addition to the suppressed population levels at the focal population, we observed increased abundance of aquatic macrophytes (e.g., *Stuckenia pectinate*) during the spring and summer months. These macrophyte beds produce and capture fine sediments and stimulate further expansion of macrophyte growth (Mebane et al. 2014), burying and covering the limpets' preferred habitat of clean cobble substrate. Excessive macrophyte growth is regarded as a major threat to the focal population, which appeared to face possible extirpation. In 2015, the USFWS and conservation partners agreed to translocate *I. fresti* from a larger, more robust population to augment the declining focal population. Following the translocation event, periodic macrophyte

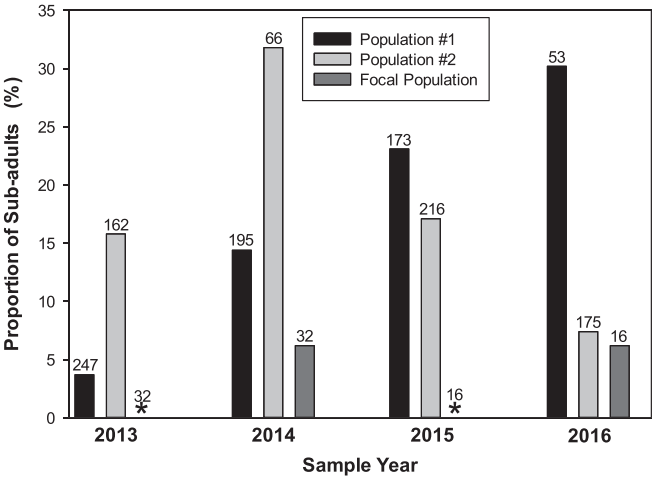

Figure 3. The proportion (%) of subadults detected in each of the three monitored populations prior to the translocation event. The asterisks (*) denote samples that lacked subadults (focal population only) and the numbers above each column show the total number of limpets recorded at each population in each of the sample years. Note that at populations 1 and 2, subadult detections made up a sizable proportion of the population even during years when low numbers of limpets were recorded.

removal was conducted at the release site to ensure sufficient habitat for the focal population. This paper provides an overview of the population augmentation effort for this federally endangered freshwater limpet; in combination with habitat management, translocation shows promise in reversing or slowing the decline of a small and isolated population.

METHODS

Monitoring

The three populations covered in this study have been monitored annually since 2012. Populations are monitored by randomly selecting the local basalt cobbles within the occupied habitat area, recording the number of individuals on each cobble, and estimating the available surface area of each cobble (Carlsson et al. 1977; McCreadie and Colbo 1991). We recorded limpets as adult (>5.0 mm in length) or subadult (≤5.0 mm) and attempted to sample a consistent number of cobbles within each population (e.g., 170–202 annually at the focal population), though the area surveyed varied based on the size of sampled cobbles. The fourth population, used as the donor population for the translocation, is not included in our analysis since the monitoring methods differed from those described above. Based on monitoring of the donor population, we estimated its size as over 1,000 individuals and regarded it as the largest population from which a limited number of limpets could be removed safely.

Translocation

On May 4, 2016, biologists from Idaho Power Company, Idaho Department of Fish and Game, and USFWS collected 19 individual Banbury Springs limpets from the large donor population approximately 8 km upriver (Snake River) from the focal population. The occupied basalt cobbles were collected from depths of 15–20 cm in riffle-glide habitats and ranged in dimension from 8 cm^{-3} to 13 cm^{-3} each. Collected limpets ranged from 3 mm to 8 mm in length with emphasis on using larger individuals (14 were ≥5 mm). Given the sensitivity of lancine gastropods, the actual translocation event was carried out as rapidly as possible (<1 h) to minimize stress to individual limpets. Cobbles containing multiple individual limpets were collected from the donor population and nontarget gastropods and other invertebrates were removed using forceps and hard-bristled toothbrushes. Cobbles and limpets were marked with nontoxic underwater markers (Sakura® Solid Marker, Sakura Corporation, Osaka, Japan), and transferred to 19-L buckets filled with local spring water. Brushing cobbles was a precaution to avoid translocation of possible invasive species between locations, although the nonnative New Zealand mudsnail (*Pomatopyrgus antipodarum*) is well established at all colonies and no other invasive species have been documented at any of the populations. In order to minimize impacts to translocated limpets, they were left on their cobbles during marking and cleaning (conducted underwater) prior to moving them to the translocation buckets. Limpets were exposed to the air less than 1 min during the entire translocation process. The buckets containing cobbles and limpets were transferred by hand to jet boats waiting on the Snake River, where they were placed in coolers and aerated. After jet-boat transport down the Snake River, the translocation buckets were transferred to biologists at the focal (recipient) population, who quickly placed the cobbles within occupied habitat (run/glide, 20–30-cm depth). The entire translocation event took place within 30 min and limpets were not exposed to any temperature shift during transport and translocation (i.e., maintained at 15.2°C).

After translocation, the recipient team of biologists observed the translocated limpets for 30 min to determine if there was any immediate mortality associated with the translocation event. The focal population was observed the following day, the following week, and monthly through August in an effort to track translocated individual limpets and assess survivorship.

Macrophyte Removal

During subsequent visits to the focal population after translocation, we observed the encroachment of rooted macrophytes, which reduced the availability of suitable habitat for the limpets. To help ensure long-term success of the translocation, we began a periodic small-scale effort to carefully remove macrophytes by hand to ensure preferred cobble habitat would not become overgrown and sediment-embedded (Fig. 4). Prior experimental studies conducted by the USFWS and others, where plots were cleared of macrophytes and fine sediments, documented *I. fresti*'s ability to recolonize these habitats in as little as 5 mo (G. Burak, personal observation). We continued to remove macrophytes during periodic monitoring visits throughout the summer months through 2019, ensuring a relatively macrophyte-free area of 3–4 m^2 within the occupied area.

RESULTS

Prior to the translocation, we carried out annual monitoring of the focal population on April 20, 2016, and found 16 individual limpets on 10 of the 201 cobbles inspected. From 2012 through 2015, the focal population fluctuated between a high of 32 (2012, 2013, and 2014) to a low of 15 in 2015 (G. Burak, personal observation). This monitoring data indicates a population that continued to function and reproduce at very low levels prior to the translocation.

As stated above, the translocation of 19 individual limpets from the donor population to the focal population occurred on May 4, 2016. One week subsequent to population augmentation, we were able to relocate 68% (13 of 19 limpets) of the translocated individuals utilizing colored markings on their shells. It is possible that the unrecovered 32% could represent mortality, poor retention of shell markings, or lack of visual

Figure 4. Pre– and post–macrophyte removal at the focal population. Prior to these management efforts, the majority of limpets had been concentrated in the lower left portion of macrophyte-free cobbles.

detection. All of the relocated individuals appeared healthy and we did not find any sign of mortality of marked limpets.

We continued periodic monitoring of the focal population through the summer of 2016, visiting on three additional occasions. By July 19, we found only two marked limpets with faded marking, one of which moved approximately 30–40 cm from the translocated cobbles. One month later, we found zero marked limpets at the focal population. While there may have been mortality of translocated limpets, the extremely faded markings on the two limpets recovered in July leads us to believe that marking retention was poor and not indicative of actual survivorship.

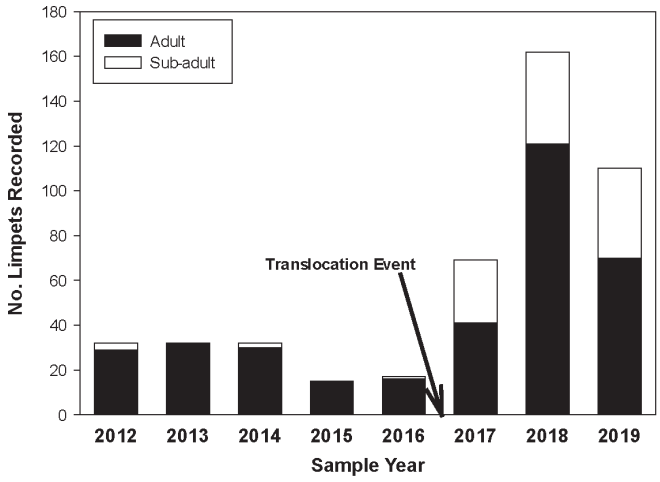

Figure 5. Recorded limpets, adult and subadult, detected at the focal population before and after the translocation event. Density of limpets showed a similar increase, ranging from 1.3–5.5 m^{-2} to 23–43 m^{-2} (before and after the translocation event, respectively).

Prior to the 2016 translocation, results of annual monitoring of the focal population had been flat or in decline over the previous 5 yr (Fig. 5). However, following translocation, the number of detected individuals increased substantially over the following 3 yr (Fig. 5). The number of individuals observed also corresponded to an increase in density at the focal population, with pretranslocation densities ranging from 1.3 limpets m^{-2} to 5.5 limpets m^{-2}, increasing to 22.9 limpets m^{-2}, 42.9 limpets m^{-2}, and 40.0 limpets m^{-2} for 2017 through 2019, respectively. Furthermore, posttranslocation densities at the focal population were comparable to those of the other monitored populations during normal years (years without disturbance events), which typically ranged from 27 limpets m^{-2} to 85 limpets m^{-2}, with an average of 50.2 limpets m^{-2} (G. Burak, personal observation) (Fig. 2).

The translocation of limpets also coincided with an observed increase in the number of subadults detected at the focal population (Fig. 5). The number of recorded subadults went from a high of three individuals in 2012 (10.3% of limpets encountered) to 23 in 2017 (54.8%), 41 in 2018 (33.3%), and 40 in 2019 (36%) (Fig. 5). While we did not attempt to make direct comparisons of changes in the donor population before and after the translocation, our continuing monitoring has shown that population to be as consistent in size and variation as it was historically (G. Burak, personal observation).

DISCUSSION

The history of isolation between the four populations is unknown but could date from prehistoric events such as the Bonneville Flood (14.5 thousand years ago), when Lake

Bonneville drained from Utah through the Snake River of Idaho, or it could predate that event, dating to when Lake Idaho underwent its last contraction (est. 1.7 million years ago). While these events likely played roles in the species' current distribution and isolation, the more recent environmental changes brought on through anthropogenic activities and modifications (agriculture, dams, flood control, irrigation diversion) to the Snake River in south-central Idaho and springs that feed it, have maintained, if not amplified, the observed isolation. We believe recent changes in habitat condition, primarily driven by changes in water quality from the aquifer springs, have led to reduced population size. While we lack the detailed genetic data, the small and declining numbers of limpets at the focal population size, coupled with the very low juvenile recruitment prior to the translocation, have all the hallmarks of a population with low reproductive vigor (Dudash and Fenster 2000) and suggests that genetic factors could be at play in addition to compromised habitat condition.

A number of studies have documented increasing nitrate concentrations over time in this aquifer system and its associated springs (Clark et al. 1998; Schorzman et al. 2009; G. Burak, personal observation), and Mebane et al. (2014) identified total nitrogen as the most important contributor to macrophyte growth in these spring systems. The aquatic macrophytes that seasonally encroach into occupied limpet habitat are native species, but we believe their increasing dominance is due to anthropogenic changes in water chemistry. Seasonal macrophyte encroachment poses the same threat to at least one other limpet population in the study area, and without consistent removal efforts, it will reduce or eliminate suitable habitat available to the species at these locations.

Other population augmentations undertaken to increase genetic diversity in declining populations have provided compelling successes (Hogg et al. 2006; Bossuyt 2007; Finger et al. 2011; Miller et al. 2012; Weeks et al. 2017), and this may have played an important role in the current conservation effort. Nonetheless, the habitat management actions (macrophyte removal) conducted during our visits helped ensure that ample suitable habitat remained available and provided resources necessary to support the observed population growth. Previous habitat manipulations carried out at the donor population site resulted in rapid colonization of limpets from adjacent habitats into areas cleared of macrophytes and fine sediments (G. Burak, personal observation), so we know the species can respond rapidly to habitat availability. However, that earlier colonization event did not result in the rapid population response observed in the current study, with mean densities at the donor population dropping from 24.7 limpets m^{-2} to 14.9–16.0 limpets m^{-2} in the 2 yr following the habitat management event (G. Burak, personal observation). Given this, we feel some of the observed reproductive vigor was driven by some level of genetic rescue as well as increased habitat availability.

While we regret not having better genetic information on the four limpet populations to assess their divergence from one another or their unique genotypic characteristics, these resources were not available to us and we regarded the focal population as too small to support the sacrifice of individual limpets for this purpose. Further, we considered the low observed population numbers and low recruitment of the focal population as a sign of impending collapse, and we implemented the translocation effort as a needed emergency action to help ensure the population did not become extirpated in the immediate future (Moritz 1999).

When designing this translocation effort, our intent was to augment a declining population with conspecifics from a more reproductively vigorous population. The subsequent and ongoing habitat management that began after the translocation event may have been as or more beneficial than the augmentation of conspecifics, but we lack the genetic data to assess this and did not design the study to address these factors independently. The merits and hazards of translocations and population augmentations have been well discussed (Moritz 1999; IUCN 2013), and precaution is warranted before using these actions as management tools. However, there is a growing literature that supports population augmentation as a means to prevent local extinctions and achieve conservation successes (Frankham 2015; Waller 2015; Whiteley et al. 2015; Weeks et al. 2017). While the benefits and risks of translocations and population augmentations require careful consideration, they can be used as important conservation tools in the recovery of vulnerable species and populations.

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