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NINE ENDANGERED TAXA, ONE RECOVERING ECOSYSTEM: IDENTIFYING COMMON GROUND FOR RECOVERY ON SANTA CRUZ ISLAND, CALIFORNIA

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ABSTRACT

It is not uncommon to have several rare and listed taxa occupying habitats in one landscape or management area where conservation amounts to defense against the possibility of further loss. It is uncommon and extremely exciting, however, to have several listed taxa occupying one island that is managed cooperatively for conservation and recovery. On Santa Cruz Island, the largest of the northern California island group in the Santa Barbara Channel, we have a golden opportunity to marry ecological knowledge and institutional "good will" in a field test of holistic rare plant conservation. Here, the last feral livestock have been removed, active weed control is underway, and management is focused on understanding and demonstrating system response to conservation management. Yet funding limitations still exist and we need to plan the most fiscally conservative and marketable approach to rare plant restoration. We still experience the tension between desirable quick results and the ecological pace of system recovery. Therefore, our research has focused on identifying fundamental constraints on species recovery at individual, demographic, habitat, and ecosystem levels, and then developing suites of actions that might be taken across taxa and landscapes. At the same time, we seek a performance middle ground that balances an institutional need for quick demonstration of hands-on positive results with a contrasting approach that allows ecosystem recovery to facilitate species recovery in the long term. We find that constraints vary across breeding systems, life-histories, and island locations. We take a hybrid approach in which we identify several actions that we can take now to enhance population size or habitat occupancy for some taxa by active restoration, while allowing others to recover at the pace of ecosystem change. We make our recommendations on the basis of data we have collected over the last decade, so that management is firmly grounded in ecological observation.

Key words: adaptive management, Channel Islands, constraint, rare plants, recovery.

COMMON GROUND

The California Channel Islands span an ecological gradient off the coast of southern California where cold waters from the north mix with warmer waters from the south. Each of the Channel Islands, which were never connected to the mainland, developed unique floras as colonizing plants adapted to their new island homes. This part of California is one of only five Mediterranean climate regions in the world, characterized by hot, dry summers and cool, wet winters. Thus the islands support an assemblage of plants and animals found nowhere else, either regionally or globally. Santa Cruz Island is the largest of the northern California Channel Islands. Eight taxa are endemic to Santa Cruz Island; an additional 29 taxa also occur on one or more of the other 7 islands, but not the mainland (Junak et al. 1995). Nine of these endemic taxa are federally listed as endangered or threatened (Table 1). They include a range of life-histories, from tiny annuals that complete their life in one year to slow-growing shrubs that may live for decades. Although they differ vastly in stature and longevity, they and the other island plants have all had to contend with the same environmental challenges brought on by more than a century of ranching land use, including grazing by sheep and cattle, and impacts from feral pigs.

Santa Cruz Island is currently owned by the National Park Service and The Nature Conservancy; both organizations share the goal of conserving and restoring endemic taxa within the island ecosystem. The last feral livestock have been removed, active weed control is underway, and management is focused on conservation. Yet funding limitations still exist, recovery funding must be raised, and we need to plan a fiscally conservative and marketable approach to rare plant restoration. In our research, we seek to identify mechanisms that constrain population growth across suites of species so that we can design a cost-effective recovery program that

Table 1. Federally listed plant taxa of Santa Cruz Island, CA.

Listed Taxon	Life history	SCI sites
Malacothrix indecora Greene Santa Cruz Island chickory	annual herb	3
Malacothrix squalida Greene Island malacothrix	annual herb	2
Thysanocarpus conchuliferus Greene Island lace-pod	annual herb	8
Arabis (Boechera) hoffmannii (Munz) Rollins Hoffmann's rock cress	perennial herb	5
Dudleya nesiotica (Moran) Moran Santa Cruz Island live-forever	succulent herb	1
Galium buxifolium Greene Sea-cliff bedstraw	sub-shrub	8
Helianthemum greenei B.L.Rob. Island rushrose	sub-shrub	36
Berberis pinnata Lagasca subsp. *insularis* Munz Island barberry	shrub	5
Malacothamnus fasciculatus (Torr. & A.Gray) Greene var. *nesioticus* (B.L.Rob.) Kearney Santa Cruz Island bush mallow	shrub	4

benefits the most species possible, while addressing the management needs of each landowner for short- and long-term recovery success. Here we are seeking common ground among both the species and the management agencies to develop a mutually sustainable, long-term rare plant recovery program.

RESEARCH APPROACH

Our research has focused on the listed plant taxa for nearly a decade, with the objective of identifying mechanisms constraining population growth and expansion at multiple levels of ecological organization. The taxa were listed because populations are few in number, small in size, isolated, and declining (U.S. Fish and Wildlife Service 1997). We want to move them in the direction of becoming more numerous, larger, connected, and stable or growing (Fig. 1). We expect that there are constraints that prevent or retard recovery at population, habitat, landscape and ecosystem scales. Thus, we used a multi-level approach to our research, ranging from herbarium searches and field surveys through habitat characterization and demographic monitoring to studies of reproductive biology and seed ecology. We tailored our work for each species individually, based on our findings as the work progressed, but our objective throughout has been to identify common patterns or trends among the species that we can use to develop a cost-effective suite of recovery tools for use on the island. We are in the unusual position of having two cooperative landowners focused on island recovery. However, they need to demonstrate

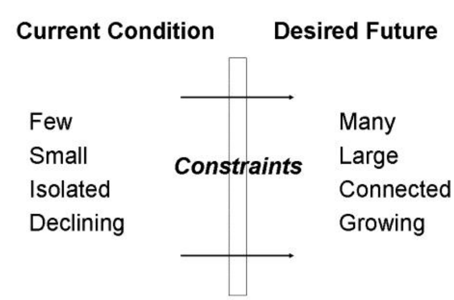

Fig. 1. Moving endangered species from current degraded conditions to desired future conditions requires consideration of recovery constraints.

recovery progress to sustain funding for a long-term conservation program. Therefore, we began outplanting experiments for two taxa, *Arabis (Boechera) hoffmannii* (Hoffmann's rock cress) and *Malacothamnus fasciculatus* var. *nesioticus* (Santa Cruz Island bush mallow), each with good potential for successful establishment, based on our observations of life-history, population structure, and planting trials. We also contribute to long-term seed banks and off-site living collections as back-up material for long-term recovery, and we monitor native and restored populations to better understand demographic trends and restoration results. Ultimately, recovery will only be successful if we can identify appropriate tools and apply them consistently in a long-term and sustained program.

PATTERNS AND TRENDS

In general, we found that the majority of populations (80%) known from earlier in the 1900s were still there (McEachern et al. 2010), a testament to persistence in the face of severe ecosystem alteration. However, these populations occurred in isolated refugia—sites inaccessible to ungulates during ranching. The habitats were dominated by native plants, but typically had open canopies and an understory of non-native plants. Soil erosion was common. Rooting and trailing were evident, both as signs of recent pig activity and as remnant scars left from the sheep and cattle grazing era, spanning the mid 1800s to the late 1900s. Censuses and demographic studies confirmed comments in the federal listing package (U.S. Fish and Wildlife Service 1997): populations remained generally few in number and small in size (Table 1), and populations were not expanding beyond the peripheries of their native-dominated habitat patches. Demographic patterns were variable among the taxa, with some recruiting and showing a range of stage-classes within habitat patches, while other taxa failed to produce many seeds or recruit new individuals into the reproductive population. Floral biology studies indicated that the species ranged from good to poor in their rates of seed set, and viability likewise ranged across a spectrum of high to low.

Annuals

There are three listed annuals of Santa Cruz Island. *Malacothrix squalida* (island malacothrix) and *Malacothrix indecora* (Santa Cruz Island chickory) inhabit nearly barren knolls and terraces very close to the coastal bluff edge—their habitats are small and eroding. *Thysanocarpus conchuliferus* (island lace-pod) is found on massive rock outcrops growing in ledges and cracks where soil crusts and mosses provide a slight seed bed. All three species have small populations that are geographically isolated and not establishing new individuals outside of their small habitat patches; those habitat edges are generally dominated by annual grasses. In addition, they have extremely variable seed production from year-to-year, high among-year variability in plant numbers, and low seed viability.

Perennials

Arabis (Boechera) hoffmannii (Hoffman's rock-cress) is a short-lived, herbaceous perennial known from only four sites on the island. Its habitat ranges from cliff faces to oak understory and open chaparral, but in each case it is on north-facing slopes in or near a belt of fog that persists for most of the day during the summer months (Fisher et al. 2007). Like the listed annuals, it is not establishing in the annual grassland that surrounds the habitat refugium. However, this species has high rates of seed production and germination, good recruitment within sites, and each population has individuals present across a range of ages, indicating high and consistent past recruitment. *Dudleya nesiotica* (Santa Cruz Island live-forever) is a diminutive, succulent perennial known from one area of the island (near Fraser Point), where it is present in the thousands. This species suffered from pig rooting and herbivory in the past (Wilken, pers. obs.). Numbers would be expected to increase now that pigs have been removed. However, this species, too, does not establish in dense annual and perennial grasses (Wilken, pers. obs., Nancy Vivrette, unpubl.), and so it may not expand beyond its current footprint until grass cover is reduced.

Sub-shrubs

Galium buxifolium (sea-cliff bedstraw) and *Helianthemum greenei* (island rushrose) are two brittle suffrutescent shrubs that are especially vulnerable to trampling. The *Galium* inhabits shaded native scrub of ocean bluff faces in scattered locations on the north shore of the island. It was described as more widespread on marine terraces prior to sheep introduction that started in the mid-1800s (Hochberg et al. 1980), but the terraces above the bluffs are now occupied by annual grasslands lacking native species cover and shade. *Galium* has moderate to low seed germination and slow growth in the field. The *Helianthemum*, on the other hand, inhabits openings in the pine and chaparral woodland understory, open ridges, and disturbed, eroded areas. It appeared in large numbers following a controlled burn in a pine stand on the north side of the island (Junak et al. 1995), and we found it in numerous open sites throughout the island. Population numbers and number of occurrences are hard to gauge for this species though as the adult plant only lives for approximately 5–10 years. After that it is present in an area in the seed bank. Like the *Dudleya* however, it may respond well to pig removal.

Shrubs

Two of the rarest plants of the island are the clonal shrubs *Berberis pinnata* subsp. *insularis* (island barberry) and *Malacothamnus fasciculatus* var. *nesioticus* (Santa Cruz Island bush mallow). Neither taxon produces much seed in the wild, but seed production is increased by augmentative hand-pollination. The *Berberis* is a long-lived, slow-growing plant with generally low fecundity, inhabiting sites near seeps in shaded northerly canyons. Attempts in the nursery to establish new plants from stem and root cuttings of the *Berberis* failed, but new experiments with tissue culture appear successful (pers. comm., Valerie Pence, Cincinnati Zoo and Botanical Garden, 2009). *Malacothamnus*, on the other hand, is a shorter-lived, fast-growing shrub inhabiting coastal scrub and chaparral on slopes, ridges, and in canyons. It has responded well to propagation by stem cuttings, and three of the four native clones are observed to be expanding at the verges of the old, established plants (Wilken and McEachern 2011).

CONSTRAINTS

It is apparent that the listed taxa share common constraints even though they span a wide range in life-history types. Constraints to growth and expansion operating at the population level (Fig. 2) include few plants, poor seed production, low seed viability and low recruitment rates. These represent factors intrinsic to each taxon, perhaps related to such characteristics as lack of genetic variability, or to such factors as inherently low survivorship and low fecundity. At the habitat level we see grass competition, open canopies, and the lack of adequate seed beds for seed retention and germination. In the extreme, we find that the native community that supported the rare taxa is so degraded that it no longer forms adequate habitat, or it is simply missing, as in the case of the coastal bluff scrub that once supported *Galium* on terraces above the cliff faces. At this level, the habitat has ceased to offer good opportunities for species recovery. Landscape scale mapping of past and current listed plant localities shows isolation of populations from one another and from potential habitats, habitat fragmentation, and habitat loss. Finally, recovery can be retarded at the ecosystem level by pollinator limitation, herbivory and trampling, and soil erosion and compaction.

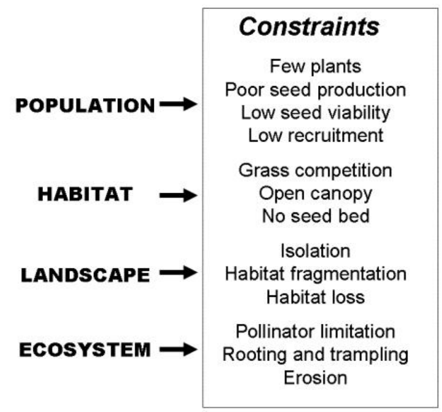

Fig. 2. Recovery constraints can exist at several levels of ecological organization.

Identifying mechanisms limiting recovery allows us to directly address these weak links or vulnerabilities with management actions. Identifying mechanisms operating at different scales prevents us from designing recovery treatments that may fail because other aspects of the system are still dysfunctional. By telescoping among levels of ecological organization, we can take a holistic approach to restoration of functions both within and across species for the most effective use of our conservation effort.

RECOVERY TOOLS

There are many treatments in the recovery toolbox that can be used on Santa Cruz Island, tailored to address the constraining mechanism at the

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appropriate level (Fig. 3). Not all of the taxa exhibit each of the constraints shown in Fig. 2, but recovery potential is limited for most of the Santa Cruz Island listed taxa by several mechanisms operating simultaneously at these different levels. Recovery tools targeted at the population level, where local populations are unable to increase within sites because of intrinsic factors, include seed banking, growing plants to produce seeds in the nursery (seed increase), hand pollination and tissue culture to get more propagules or individuals for augmentation of numbers within populations. Habitat level recovery tools include invasive control, native plant community restoration, and seed bed development. Development of new populations across the landscape can increase the numbers of occurrences from few to many, reducing the risk of catastrophic species loss, and it can ameliorate landscape-level loss of connectivity among populations. Perhaps the most far-reaching conservation action that has already been taken to jump-start recovery at the ecosystem level is eradication of non-native animals.

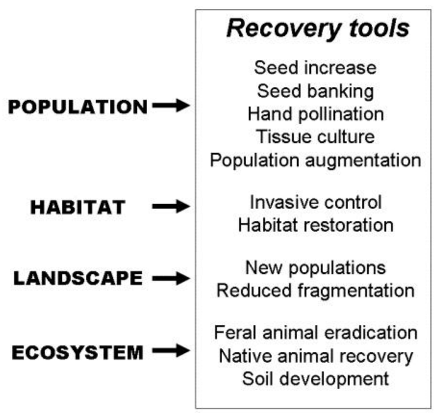

Fig. 3. Recovery tools can be used at multiple levels of ecological organization.

We can rank the listed plants of Santa Cruz Island along an endangerment gradient according to the severity of their multiple constraints, and then develop recovery plans that clearly target those constraints (Fig. 4). Linking the recovery technique to the constraint identified in our studies allows clear communication of the recovery goals and objectives for each taxon, provides a means to group recovery actions to benefit several taxa, develops a structure for monitoring to show effects of the recovery action, and allows us to put the recovery work in the context of the entire system. For example, the least endangered of the taxa appear to be the *Dudleya* and the *Helianthemum*. Both species suffered direct effects of herbivory and trampling, but they produce ample viable seed, with no apparent intrinsic limitations to population growth, other than available habitat. They are expected to benefit from removal of the direct threats presented by feral ranch animals in the past. Monitoring will show whether habitat change accompanying animal removal will allow for population expansion into currently uninhabited sites. At the other end of the endangerment spectrum are the shrubs *Malacothamnus* and *Berberis*. While these taxa will certainly benefit from animal removal, invasive control, and habitat restoration, they will likely also need more labor-intensive and invasive techniques like hand pollination to produce seeds, which can then be grown for planting, coupled with development of plants from tissue culture.

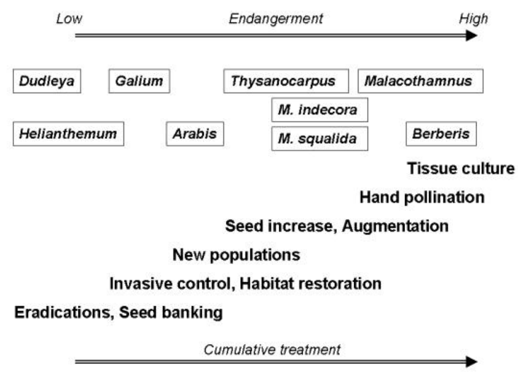

Fig. 4. The listed plants of Santa Cruz Island ranked along gradients of low to high endangerment and cumulative recovery treatments.

In the middle ground is the *Arabis*, a perennial restricted to north-facing foggy slopes with low competition from annual grasses. It has good seed production and high recruitment and population growth within habitats, but is constrained at the habitat and landscape levels by competing annual grasses and habitat fragmentation. This species is a good candidate for outplanting; our preliminary recovery planting experiments have been successful in increasing numbers of populations over the short-term where we are able to identify good habitat patches. Similarly, recent recovery planting experiments have shown that the *Malacothamnus* is well suited for outplanting from nursery-grown stock (Wilken and McEachern 2011). Success with these species provides a foundation within the land management institutions for further commitment to rare plant recovery work.

INSTITUTIONAL COMMITMENT

It is not uncommon to have several rare and listed taxa occupying habitats in one landscape or management area where conservation amounts to defense against the possibility of further loss. It is uncommon and extremely exciting, however, to have several listed taxa occupying one island that is managed cooperatively for conservation and recovery. On Santa Cruz Island, we have a golden opportunity to marry ecological knowledge and institutional "good will" in a field test of holistic rare plant conservation.

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