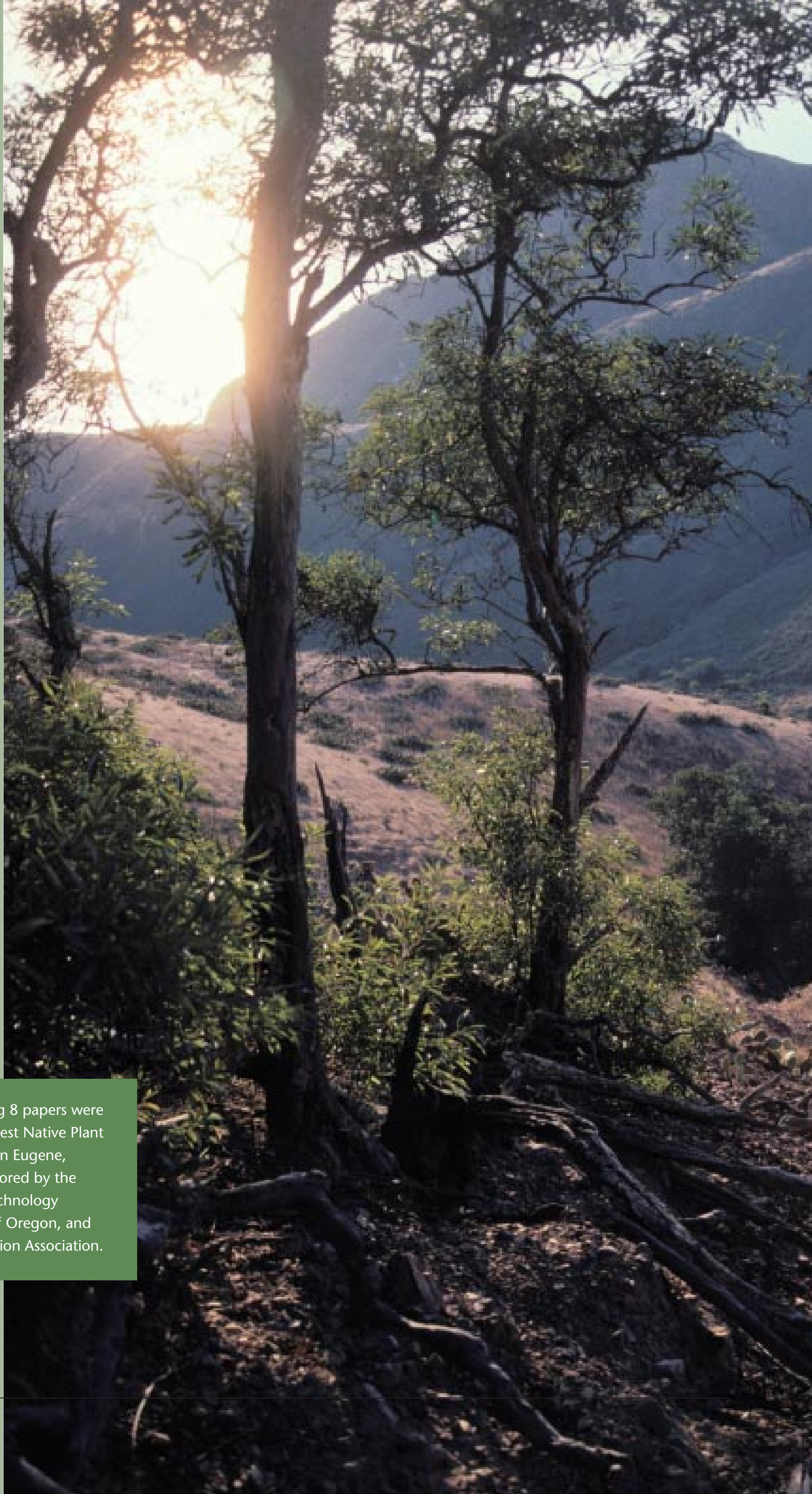

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RESTORATION OF NATIVE PLANTS ON

Catalina Island

CALIFORNIA

| W Douglas Serrill

ABSTRACT

Catalina Island's diverse flora and fauna, as well as its protected status, provide many opportunities and challenges for integrating nursery operations with the restoration efforts of the Catalina Island Conservancy. This paper reviews strategies for dealing with nonnative flora and fauna and the importance of coordinating research and monitoring efforts with nursery operations. Three case studies involving a grass production field, oak ecosystem research, and trials to improve restoration techniques are presented. Lessons learned from research trials cover a variety of topics including herbivory, water availability, weed competition, and the impact of container size on survivorship. These lessons stress the importance of site-specific solutions to achieve best management practices in nursery operations.

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KEY WORDS

native plant nursery, outplanting, grass production field, island scrub oak, seed storage

NOMENCLATURE

USDA NRCS (2005)

Catalina ironwood (*Lyonothamnus floribundus* Gray ssp. *floribundus* [Rosaceae]) growing on Catalina Island, California. Photo by Misty Gay

Catalina Island is located 42 km (26 mi) off the coast of Long Beach, California (Figure 1). The island consists of 197 km^2 (76 mi^2), or 19 475 ha (48 124 ac), of land. It is 34.5 km (21.5 mi) at its longest point and 12 km (7.5 mi) at its widest point. The elevation ranges from sea level to over 610 m (2000 ft), and the topography consists of a series of steep and rugged canyons mostly in a northeast to southwest orientation (Figure 2). The daily average temperature ranges from 4.5 to 27 °C (40 to 80 °F), rarely going below freezing. The island receives on average 127 to 406 mm (5 to 16 in) of rain each winter.

Catalina Island has a diverse flora with 422 native species, including 5 endemics. Eighty-six percent of the island is dominated by 3 plant communities: coastal sage scrub, island chaparral, and grassland (Junak and others 1995; D Knapp 2005). Several rare plant communities exist on the island including mulefat scrub (0.5 ha [1.2 ac]), maritime cactus scrub (1.1 ha [2.7 ac]), coastal marsh (1.3 ha [3.2 ac]), and coastal bluff scrub (31.4 ha [77.6 ac]) (Junak and others 1995; Philbrick and Haller 1995). Further, several plant communities occur on Cata-

Figure 1. Location of Catalina Island, California.

Photo by Denise Knapp

Figure 2. Black Jack Peak is typical of Catalina Island landscape.

lina Island that are considered to be rare on the mainland, including southern beach and dune, island woodland, and southern riparian (Junak and others 1995; Knapp 2002b). Approximately 20% of the native flora (n = 87) are listed as endangered, threatened, or of special concern by the federal government, state, or Natural Heritage Programs (NatureServe 2005).

Most of the island (88%) is managed by the Catalina Island Conservancy, a nonprofit organization founded in 1972, whose mission is responsible stewardship of its lands through a balance of conservation, education, and recreation. The remaining portion of the island is privately owned and includes the city of Avalon with a resident population of 4000. Catalina Island is a tourist destination serving 1 million visitors annually. Public access to conservancy lands is actively managed.

THREATS FROM NONNATIVE ANIMALS

Over the past century, cattle (*Bos taurus* L. [Bovidae]), sheep (*Ovis aries* L. [Bovidae]), feral pigs (*Sus scrofa* L. [Suidae]), feral goats (*Capra hircus* L. [Bovidae]), bison (*Bison bison* L. [Bovidae]), and mule deer (*Odocoileus hemionus* Raf. [Cervidae]) were introduced to the island for sport hunting and ranching. The impact of grazing, browsing, rooting, and trampling on island ecosystems not evolutionarily adapted to such pressures has been profound. Additional impacts include nonnative seed dispersal through fur, hoof, and feces as well as nutrient addition. The combination of these factors can contribute to establishment of nonnative plant species and have a negative impact on native plants.

Ranching operations were discontinued prior to the formation of the Catalina Island Conservancy. Sheep were removed in the 1890s and cattle were taken off the island in the 1950s. The conservancy's first restoration efforts, beginning in 1990, involved dealing with nonnative feral animals. A partnership with the Institute for Wildlife Studies for feral animal removal was initiated in 1996. Today, efforts have resulted in near eradication of feral goat and pig populations, with the removal of 24 000 to 28 000 animals (Ryan 2004).

Bison were brought over in the 1920s as part of a film shoot for the movie *The Vanishing American* and subsequently left on the island. They have been actively managed by the conservancy through bison roundups, regular censuses, health checks, blood tests, and herd reductions by which the population was historically maintained below 400. A bison impact study, completed in 2003, determined the carrying capacity on the island to be approximately 150 bison (Sweitzer and others 2003). The conservancy has responded by reducing the size of the herd to that level through shipments to American Indian reservations in the Dakotas.

Mule deer, our dominant browser, were first introduced by the California

Department of Fish and Game between 1930 and 1932 (Manuwal 2005). That department continues to regulate the mule deer population, which is controlled under the Private Lands Management program by means of fall and winter deer hunting. A 2-y mule deer impact study began in early 2005.

The nursery has responded to the challenges of nonnative animals through the use of deer fencing, wire caging, tree tubes, experimentation with deer repellants, and hiding native seedlings in and among nurse plants such as coyote brush (*Baccharis pilularis* DC. [Asteraceae]). Further strategies include using native plants unpalatable to deer, using protection of native cactus patches to our advantage during outplanting and sowing, and outplanting natives only when other plants favorable for browse are most healthy and abundant (that is, during the wet winter season).

THREATS FROM NONNATIVE PLANTS

The impacts of nonnative invasive plants include biodiversity reduction, habitat loss, local extinctions through competition, and the alteration of natural ecological processes (Soule 1990; D'Antonio and Vitousek 1992; Wilson 2002). Nonnative plants came to Catalina Island through a number of ways. Several species, such as French broom (*Genista monspessulana* (L.) L. Johnson [Fabaceae]), arrived as ornamentals in Avalon. Harding grass (*Phalaris aquatica* L. [Poaceae]) was planted in various locations for erosion control, and various pine species (*Pinus* L. [Pinaceae]) were planted as part of an early 1920s reforestation effort. Wild oats (*Avena fatua* L. [Poaceae]) were cultivated for hay production during ranching operations, and a variety of other nonnative species are assumed to have arrived accidentally, possibly by way of shoes, tires, bird droppings, waves, or wind.

Prior to formation of the conservancy, the primary method of managing nonnative flora was through periodic use of herbicides. Although the eradication and control of introduced animals have released native plant species from grazing and rooting pressures, invasive plant species have been released from those same pressures, which is likely to increase the threat they pose to the native flora.

To address the impacts of nonnative flora on an island-wide level, the Catalina Habitat Improvement Restoration Program (CHIRP) was developed under the direction of our new Invasive Plant Program Manager. This initiative sought to systematically address the 240 nonnative plant species on Catalina Island. Seventy-six species were identified as invasive and mapped by hiking and driving every drainage and ridgeline. Populations were defined as any size, from one individual to 4 ha (10 ac) with minimum gaps of 30.5 m (100 ft) separating a population. Populations (n = 37 208, median size = 58.1 m^2 [625 ft^2]) were recorded with GPS (Trimble Navigation Limited, Sunnyvale, California) and placed into size classifications with estimates placed on cover/density using the Daubenmire method (USFWS 2003; J Knapp 2005). Populations were then ranked by invasiveness and prioritized for control (Knapp 2004). Spatial information was then classified, based on the island's 54 watersheds, into 76 weed management units and is being used to create a long-range management plan.

The James H Ackerman Native Plant Nursery is coordinating with CHIRP to integrate nonnative plant removal with native plant restoration efforts in 3 ways. First, the nursery is collecting seeds within weed management units to preserve local genotypes. Second, it is maintaining a diverse seedbank to supply source materials to offset localized losses in biodiversity. Third, it is growing large quantities of those native species that establish well after disturbance to be outplanted in dense groups to help prevent nonnative recruitment in areas where invasive plants have been controlled. Additionally, native plants

JAMES H ACKERMAN NATIVE PLANT NURSERY

In 1989, the nursery was formed by the Catalina Island Conservancy to provide native seeds and propagules for the conservancy's conservation and restoration efforts. The nursery is responsible for all horticultural tasks ranging from seed collection to outplanting. It is part of the Conservation and Education Department, one of 11 departments within the organization. Since its formation, the nursery has gathered germination and propagation data on 124 of the 422 island natives. The operation was expanded in 1998 with the addition of a new facility to add seed processing and storage facilities and increase available space for plant propagation to meet increasing needs of restoration activities on the island. Volunteers remain at the heart of the work accomplished at the nursery, committing thousands of hours (5795 in 2004) to help nursery staff grow 8000 to 12 000 plants annually (increased to 22 000 in 2005).

Currently, the 2 staff at the nursery face a variety of complex challenges as the Conservation and Education Department transitions from initial research to revegetation and restoration activities. Challenges include collaborating with the department to develop strategies to address adverse impacts of nonnative animals and plants, and propagating and growing for a variety of restoration needs (that is, revegetation, rare plant population augmentation) while striving to be environmentally sustainable.

Image by Denise Knapp

Figure 3. General vegetation distribution on Catalina Island.

Photo by Michael Herrera

Figure 4. Grass production fields are used to increase seed supplies of native grasses needed for restoration on Catalina Island.

are made available for landscaping to island residents to integrate native plants into the urban landscape. These are all viewed as long-term projects requiring present-day action to ensure results that may not be seen for decades.

CONSERVATION EFFORTS FOR RARE PLANTS

Catalina Island is home to several rare and uncommon native plant species, including the federally endangered Catalina Island mahogany (*Cercocarpus traskiae* Eastwood [Rosaceae]), Catalina ironwood (*Lyonothamnus floribundus* Gray ssp. *floribundus* [Rosaceae]), island oak (*Quercus tomentella* Engelm. [Fagaceae]), and cliff spurge (*Euphorbia misera* Benth. [Euphorbiaceae]). To ensure effective conservation of these and other species, the conservancy has collected thorough baseline data over the past 7 y through inventory and monitoring programs, including floristic surveys of sensitive areas, vegetation transects correlated with wildlife monitoring, and rare-plant mapping and monitoring. Additionally, an island-wide vegetation map (Figure 3) was created by the conservancy's plant ecologist using a mosaic of aerial photographs that were scanned, digitally ortho-rectified (ER Mapper, San Diego, California), and placed into Arcview 3.2 (ERSI, Redlands, California) (D Knapp 2005). Sixteen different plant communities were delineated through these aerial photographs in combination with groundtruthing as needed.

The nursery uses this baseline data and vegetation mapping information to develop priorities for a conservation seedbank and to conduct further studies on germination, plant growth, and specialized habitat requirements. The nursery also plays a role in conservation actions such as growing and planting cliff spurge for population augmentation, installing protective fencing around the Catalina Island mahogany to prevent browsing, and collecting and growing island oak seedlings in support of a characterization study of island oak stands. Thus, the nursery is a key part of the conservancy's efforts to preserve these rare plants.

CASE STUDY: ESTABLISHING AND USING A GRASS PRODUCTION FIELD

Of California's grasslands, 96% have been destroyed by human activities and settlement during the past 300 y (Ornduff and others 2003). On Catalina Island, approximately 3778 ha (9336 ac) are classified as grassland, most of which are dominated by nonnative annual grasses and subject to grazing pressures from the introduced animals. As CHIRP efforts advance into large-scale grassland restoration, the ability to establish a cultivation source for large quantities of native grass seeds is required.

In 2002, nursery staff members prepared and fenced a 1.1-ha (2.75-ac) area referred to as the grass production field in order to grow 12 native perennial bunchgrasses over a 6- to 7-y period. Seeds of 8 native grass species were cleaned (Table 1) and 500 plants of each species were installed in the first year (Figure 4). When completed, each plot will consist of 2000 individual plants propagated from diverse documented collections and placed in rows of 50. To ensure genetic diversity, as many locations as possible are utilized in the grass seed collection. Staff and knowledgeable volunteers scout collection locations and record the data using a GPS unit to produce maps of these locations. Although cross-pollination may occur between grasses originating from separate locations, the concern is balanced with the need to collect sufficient amounts of seeds by a limited number of staff and volunteers.

Collected seeds are brought to the nursery for processing. Each collection is assigned an accession number and

TABLE 1

Properties of native grass species (Poaceae) installed in grass production field on Catalina Island.

Species	Cleaning technique	Number of collections tested	Average [z] germination of all collections (%)	Days to germinate (average)
beard grass *Bothriochloa barbinodis*	Use Oregon Seed Blower [y] to remove chaff and nonviable seeds	9	43	21
California brome *Bromus carinatus*	Use brush deawner [x]; check for nonviable seeds	20	71	12
blue wildrye *Elymus glaucus*	Use brush deawner; check for nonviable seeds	6	78	19
chaparral melic *Melica impefecta*	Sieve #14 / #8 screen (Newark [w]); use Oregon Seed Blower to remove chaff and nonviable seeds	11	52	24
nodding needlegrass *Nassella cernua*	Use brush deawner; use Oregon Seed Blower to remove chaff and nonviable seeds	21	64	21
foothill needlegrass *Nassella lepida*	Use brush deawner; use Oregon Seed Blower to remove chaff and nonviable seeds	19	51	39
purple needlegrass *Nassella pulchra*	Use brush deawner; use Oregon Seed Blower to remove chaff and nonviable seeds	12	52	47
one sided bluegrass *Poa secunda*	Sieve "W" pan (Grainman [v]); use Oregon Seed Blower to remove chaff and nonviable seeds	3	38	35

[z] For germination tests, cleaned seeds were sown in Petri dishes on top of agar gel.
[y] Oregon Seed Blower, model, 115 volt, Hoffman Manufacturing, Albany, Oregon
[x] Brush deawner, LAH-0210, Westrup Inc, Plano, Texas
[w] Newark Sieves, Newark, New Jersey
[v] Grainman, Sieves, Miami, Florida

Photo by Matthew Sutton

Figure 5. A healthy acorn of *Quercus pacifica*. Collecting green, healthy acorns improves germination and overall project success.

recorded in our seed database. Initial records include collection date and location (including the watershed), noted environmental conditions, and collectors. Records are updated as new data are gathered regarding seed processing (that is, cleaning and weighing), treatment, and germination.

Seeds are initially air-dried on trays in a covered Quonset under ambient conditions for at least 1 mo. Processing may include awn or pappus removal with a debearder machine (Westrup Inc, Plano, Texas) and separation of chaff and nonviable seeds with an Oregon Seed Blower (Hoffman Manufacturing, Albany, Oregon) and (or) sifting with various sieves (Newark Wire Cloth Company, Newark, New Jersey; Grainman®, Miami, Florida).

Cleaned seeds are weighed and inventoried, with 4 subsets of 100 seeds each used for seed germination tests that assess both initial and stored viability, as well as germination-enhancing techniques. Seeds that are not immediately sown or used for field seeding are desiccated with silica gel in a sealed aquarium tank to 40% relative humidity and placed in Mason jars that are sealed prior to entering cold storage. Processed seeds are stored at 4.5 °C (40 °F) and 40% relative humidity. In use since 1999, our cold storage unit currently contains more than 1000 accessions totaling approximately 27 million seeds from 165 different native species.

Seeds for the grass production field are sown under ambient conditions into Deepot 40 containers (656 ml [40 in^3], Stuewe and Sons, Corvallis, Oregon) using a potting mix of 4:1:1 perlite, compost, and peat moss, supplemented with a 3- to 4-mo control release fertilizer ($14N:14P_2O_5:14K_2O$ [540 ml/m^3 (14 fl oz/yd^3] Osmocote, Scotts Company, Marysville, Ohio), and a micronutrient formulation fertilizer (110 ml/m^3 [3 fl oz/yd^3] (Apex, Simplot Company, South Lismore NSW, Australia) incorporated into the mix. Germination rates for each species vary by a variety of ecological factors (Table 1), but most germinate after 4 wk and are ready for planting after 6 to 7 mo. Seedlings are grown under 30% shadecloth and watered thoroughly with overhead irrigation every 2 to 3 d as needed.

Planting into the grass production field is done with a 2-person auger (Hydraulic Earth Drill, Little Beaver® , Livingston, Texas) using a 7.6-cm (3-in) bit to a depth of 25.4 cm (10 in). The rows to be planted are prepared by removing vegetation manually and installing polypropylene weedcloth (PAK Unlimited, Cornelia, Georgia) fastened with ground staples. The weedcloth is slit and folded-under prior to the holes being augered. Each row of native grass planted in the grass production field is labeled with its accession number so that its seed source information can be tracked. Plants are spaced on 30.5-cm (12-in) centers within and between rows; every fifth row is a nonplanted walkway. Planting into the augered holes is done by hand with no fertilizers or soil amendments added. One 10-l (2.5-gal) water jug is placed directly above each plant's root zone immediately following outplanting with the valve opened slightly to provide a slow drip for initial irrigation. Subsequent irrigation in the field is accomplished by means of tape drip lines (RoDrip®, Roberts Irrigation Products Inc, San Marcos, California) laid over the weedcloth and is only utilized in dry periods to prevent mortality. Natural precipitation accounts for most water uptake by the native grasses. The field is kept weed-free through manual weed control and the judicious use of herbicides.

Seeds from grasses grown at the grass production field are hand collected annually, processed, and stored in intermediate cold storage for use in island-wide restoration efforts.

CASE STUDY: REGENERATING OAK ECOSYSTEMS

Island scrub oak (*Quercus pacifica* Nixon & C.H. Muller [Fagaceae]) is the dominant of 5 species of oak that occur on the island. Historically thought to be more abundant than at present, several factors may be limiting its ability to regenerate: herbivory by deer, rooting by pigs, insect predation, competition from nonnative weeds, soil health and structure, and moisture availability (Knapp 2002a; Herrera 2005). In 2003, a workshop was hosted by the conservancy to assess necessary areas of investigation and to help identify priorities for oak ecosystem research. Participants from across the US provided valuable direction and emphasized the need for further understanding in several different areas.

One outcome of the workshop was establishment of an oak regeneration trial. This trial is designed to evaluate 3 potential limitations to oak regeneration (herbivory, nonnative species competition, and canopy influences [such as fog drip and light exposure]) in 3 different soil types (healthy oak stands, dieback areas [possibly infected with Armillaria fungi], and eroded sites). Nursery staff participated in this trial by collecting acorns and storing them at the nursery (n = 36 000).

To assure high germination for the trial, acorn collection followed strict guidelines: only green acorns without blemishes and still on the tree were gathered; those exhibiting signs of fungus or insect predation were rejected (Figure 5). Collection sites (n = 68) across the island were recorded using handheld GPS units. Acorns were labeled, brought to the nursery, inventoried, and processed by administering a float test; floating acorns were considered immature or nonviable and discarded.

After the float test, acorns were placed on a 1:1 peat and sand mix in rectangular storage trays (Superior Products, St Paul, Minnesota) and placed in the cold storage unit. Peat was chosen for its water-holding capacity and slight acidity to help retain moisture and reduce fungal development, while sand provided drainage to further reduce mold. Short-term storage at 4.5 °C (40 °F) in the nursery's cold storage unit ranged from 2 to 3 mo, with weekly monitoring for fungal growth and desiccation. Peat was remoistened as needed and any acorns with signs of fungal development were treated in a brief (< 5 min) 5% bleach solution soak. Our qualitative observations were that this storage method worked well, protecting the acorns from significant moisture loss or fungal infestation and maintaining their viability into the outplanting season.

The trial consists of 5 replicate plots in each of the soil types: healthy, dieback, and eroded. To assess herbivory, half of the planted sites at each plot are inside fenced areas. Nonnative species competition is evaluated using weeded and nonweeded replicates, half inside the fenced areas, and half outside. Canopy influences are measured by collecting fog drip in collection stations under the canopy and soil probes identify moisture levels. In addition, soil samples will be analyzed at a laboratory for physical and chemical properties of the 3 soil types. Monitoring of acorn germination and seedling growth will occur every 3 mo the first year, every 6 mo the second year, and once annually for several years thereafter. In November 2004, AmeriCorps volunteers completed acorn planting in 4400 holes (8 acorns/hole based on germination results of 14% for island scrub oak from a 2001 trial).

CASE STUDY: RESTORATION TECHNIQUES IN MIDDLE CANYON

Old ranching lands in Catalina Island's Middle Canyon, known as the Hayfields, were taken out of forage production in 1998 (34.3 ha [85 ac]). The conservancy conducted a variety of trials to establish appropriate planting techniques to improve survivability of seedlings for future restoration activities on these lands (Stratton 2004). Trials were conducted for 6 y to assess the degree to which the fields could be restored with minimal inputs (least cost, least disturbance). Through an evaluation of 4 trials, we have determined several practical factors for plant survival, such as the need to protect seedlings from browsing and trampling, the need for deep root development, and the water needs for several different species after outplanting.

In 1999, a 2-y trial was conducted to test the effectiveness of mulching with wood chips to reduce nonnative plant competition. Eight plots with 58 plants per plot were planted using 4 different species: golden bush (*Isocoma menziesii* var. *menziesii* Hook & Arn. Nesom [Asteraceae]), lemonadeberry (*Rhus integrifolia* (Nutt.) Benth. & Hook. f. ex Brewer & S. Wats. [Anacardiaceae]), California fuschia (*Epilobium canum* (Greene) Raven [Onagraceae]), and coastal sagebrush (*Artemisia californica* Less. [Asteraceae]). Half of the seedlings were mulched with wood chips. None of the species were protected from herbivory or trampling, and they were severely impacted by deer and bison. Of the 4 species, lemonadeberry had the highest survivorship (69%, $P < 0.001$). Three of the 4 species were noted to be the same height or shorter 2 y after outplanting, highlighting the importance of protecting native plant seedlings from animal damage during their initial growth and establishment phase.

In January 1999, a 3-y trial was initiated using planted island scrub oak seedlings (n = 168) grown in containers at the nursery to examine the effects of 3 watering treatments applied monthly (a non-watered control, DriWater gel packs [DriWater Inc, Santa Rosa, California], or deep pipe waterings to the root zone) and 2 soil treatments applied once at outplanting (a nontreated control or incorporation of leaf duff and soil collected from the understory of healthy oak stands). Twelve plots of 14 seedlings each were outplanted with 4 plots randomly assigned to each of the 3 watering treatments. Soil amendments were added to every other seedling in each plot. Tree tubes were used to reduce the effects of herbivory. After 2.5 y, survivorship was not significantly affected by watering treatments; the control seedlings had the highest survivorship (93%). Native soil amendments resulted in higher survivorship (94% as compared with 85% without soil amendments, $P = 0.03$) (Stratton 2002). Based on these results, we no longer provide supplemental irrigation to newly outplanted oak seedlings, but we do add native soil amendments.

In 2001, a trial was conducted to assess the germination of 4 oak species—island scrub oak (n = 768), island oak (n = 144), MacDonald oak (*Quercus* x *macdonaldii* Greene (pro sp.) [*berberidifolia* x *lobata*] [Fagaceae]) (n = 144), and canyon live oak (*Quercus chrysolepis* Liebm. [Fagaceae]) (n = 144)—by testing the possible benefits of pre-augered holes and oak-leaf mulching. It was hypothesized that augering to 75 cm (29.5 in) and then loosely refilling the hole before planting (pre-augering) could aid in tap root development in clay soils, and that the addition of leaf mulch may provide inoculum of oak ectomycorrhizal associates and protection from moisture loss. Tree tubes were again used to reduce herbivory. Applying oak-leaf mulch increased germination of all 4 species but was not statistically significant. Island oak had the highest germination (45%), while island scrub oak had the lowest (14%). Pre-auguring made no statistical difference to any species.

In 2002, a trial was initiated to compare survivorship and growth rates of early and late successional species in both coastal sage scrub and island chaparral communities to gain insight on how species relate to site under various conditions within a plant community (Stratton and Herrera 2004). Early- and late-stage chaparral species were factored with sites on a ridge and in a valley to compare differences in moisture. Coastal sage scrub early- and late-stage species were factored with and without vesicular arbuscular mycorrhizae (VAM) treatments to assess how different stages do with mycorrhizae. Each factor was replicated 4 times in 12 m x 12 m (39 ft x 39 ft) plots. These factorial designs were implemented with both seeds and container seedlings. Throughout the first dry summer after outplanting, half of the planted seedlings received additional water (10 l) monthly to evaluate supplemental watering on survivorship. Additionally, seedlings were outplanted from 4 different container types (#1 Treepot, 2.8 l; Deepot 40, 656 ml; Deepot 16, 262 ml, Stuewe and Sons, Corvallis, Oregon; 4-in pots, 354 ml, McConkey Co, Sumner, Washington) to evaluate the effects of container size on seedling survival. In total, 40 species (n = 2688) were installed in 64 plots (32 seeded and 32 outplanted) on a field previously dominated by Harding grass. Seeding density ranged from 290 to 600 seeds/m^2 (27 to 56 seeds/ft^2), and seedling density ranged from 58 to 113 plants per plot.

Results from this study yielded important lessons. The differences in cover and survivorship between coastal sage scrub mycorrhizal treatments were not significant. Only small, nonsignificant differences between early- and late-stage seral survival were recorded, suggesting that even later stage seral species can be successfully used for restoration. Water availability was the largest factor in sur- vivorship, suggesting the importance of supplemental watering beyond initial irrigation. Plots watered monthly through the summer in 2002 exhibited better overall survivorship than those not watered (59% and 41% without; $P < 0.001$). Only late-stage chaparral species were negatively affected by additional monthly watering (3% survivorship with watering, 6% without). Finally, seedlings grown in Treepots (2.8 l) had a higher survival after 3 y (60%) as compared with seedlings grown in Deepots (656 ml) (45%, $P < 0.01$), suggesting that larger root volumes can increase survivorship after installation.

CONCLUSION

These experimental field trials illustrate the usefulness of using site-specific information to shape nursery practices. For example, to further increase outplanting survivorship, the nursery is experimenting with various potting media, water conservation practices, and container types to achieve ideal growing practices. Less is known about how specific spatial relationships or floral associations affect the outcome of the restoration process on different sites. These require further research and will be the next challenges the nursery faces in integrating off-site with wild population and habitat restoration needs.

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AUTHOR INFORMATION

W Douglas Serrill
Nursery Technician
Catalina Island Conservancy
James H Ackerman
Native Plant Nursery
PO Box 2739
Avalon, CA 90704
nursery@catalinaconservancy.org