Title

Making Restoration More Efficient: Testing the Contributions of Planting Diversity and Introduced Plant Legacy Effects to Recovering Coastal Ecosystems

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Project Information

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Title Making restoration more efficient: Testing the contributions of planting diversity and introduced plant legacy effects to recovering coastal ecosystems.

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Project Hypothesis

Hypothesis: Plant invaders with an architecture that is novel to the invaded system, will dramatically alter the abiotic and biotic environment through changes to physical properties, primary production food sources and/or living space.

Hypothesis: the addition of organic litter and higher planting diversity, characteristics of a mature system, would lead to faster ecosystem development of soils, plant communities and invertebrate communities after the removal of plant invaders than no litter addition and a monoculture.

Project Goals and Objectives

Goal 1. Determine the biotic and abiotic effects of a couple of common invasive, introduced plant species in coastal transition ecosystems to better understand approaches needed for removal and ecosystem (re)development
Objective a: test the effects of the invasion of Canary Island palm on a riparian invertebrate community.
Objective b: test the effects of *Chrysanthemum coronarium*, crown daisy, on a coastal scrub invertebrate community

Goal 2. Determine scientifically based but simple and inexpensive methods to facilitate post-removal ecosystem recovery.
Objectives. Determine the relative roles of planting diversity and plant litter on: (a) coastal soil properties (decomposition rates, soil organic matter, salinity, texture, soil nitrogen content), (b) plant communities (native and invasive) and (3) invertebrate communities.

Briefly describe project methodology

We used a combination of field surveys (goal 1) and field experimental manipulations (goal 2) to achieve our goals. To assess effects of introduced, invasive species we used natural variability of the presence and abundance of the introduced and native species to assess effects of invasions on invertebrate communities. Each of two studies was conducted over one growing season with a focus on the Canary Island date palm and chrysanthemum. To test the effectiveness of altering planting diversity and litter additions on ecosystem development, we established a large-scale field experiment spanning two elevations (high salt marsh transition and coastal sage scrub). Treatments included four planting diversity levels (0,1,3,6) and two litter addition levels (added, not added). Reference plots were used to assess the development status of the treatments. Sampling of physical properties, soils, plant community and invertebrate community variables took place each spring from 2009-2011.

Describe progress and accomplishments toward meeting goals and objectives.

Canary Island date palm was published while the other, focusing on chrysanthemum, is accepted pending revisions. A third paper (goal 2) is nearly ready for submission to a restoration journal.

Testing the Effects of an Introduced Palm on a Riparian Invertebrate Community in Southern California

Despite the iconic association of palms with semi-arid regions, most are introduced and can invade natural areas. Along the San Diego River (San Diego, California, USA), the introduced Canary Island date palm (*Phoenix canariensis*) forms dense patches among native riparian shrubs like arroyo willow (*Salix lasiolepis*). The structural differences between the palm and native shrubs are visually obvious, but little is known about palm's effects on the ecosystem. We tested for the effects of the palm on a riparian invertebrate community in June 2011 by comparing the faunal and environmental variables associated with palm and willow canopies, trunks and ground beneath each species. The palm invertebrate community had lower abundance and diversity, fewer taxa feeding on the host (e.g., specialized hemipterans), and more taxa likely using only the plant's physical structure (e.g., web-builders, oak moths, willow hemipterans). There were no observed effects on the ground-dwelling fauna. Faunal differences were due to the physical and trophic changes associated with palm presence, namely increased canopy density, unpalatable leaves, trunk rugosity, and litter accumulations. Palm presence and resulting community shifts may have further ecosystem-level effects through alteration of physical properties, food, and structural resources. These results were consistent with a recent study of invasive palm effects on desert spring arthropods, illustrating that effects may be relatively generalizable. Since spread of the palm is largely localized, but effects are dramatic where it does occur, we recommend combining our results with several further investigations in order to prioritize management decisions.

The effect of invasive *Chrysanthemum coronarium* on a coastal sage scrub invertebrate community in Southern California

The escape of ornamental plants is a main pathway of invasion into many ecosystems. These non-native plants can alter basal resources and abiotic factors leading to effects that ripple throughout an ecosystem. Invertebrates often mediate these effects - responding quickly to abiotic and primary producer changes and, in turn, influencing other species. These invasions are of particular concern in the coastal sage scrub ecosystems of Southern California, where habitat loss and urban encroachment increase invasive species propagule sources and decrease native community resistance. The introduced annual *Chrysanthemum coronarium* (crown daisy) is a common invader with largely undocumented community-level effects. Our study tested the effects of a Chrysanthemum invasion on a coastal scrub invertebrate community using a field study at the Tijuana River Estuary. We found similar or lower abundances and diversity of canopy fauna in the presence of Chrysanthemum. Invertebrate community composition dramatically differed, however, in the presence of Chrysanthemum with higher abundances of detritivorous and pollinating invertebrates (e.g., dipterans, beetles) and lower abundances of herbivores (e.g., hemipterans) than in uninvaded plots. Differences in invertebrate communities were associated with the generally greater plant biomass and shadier conditions afforded by the natives. This study revealed that even a proportionally small amount of Chrysanthemum may shift the invertebrate community through alteration of abiotic properties and plant biomass. We recommend that Chrysanthemum be removed at the first sign of invasion or that measures are taken to prevent spread since effects on the invertebrate community are dramatic and occur quickly.

Native planting diversity and introduced plant litter influence the development of an urban coastal scrub ecosystem

Invasive plants often alter the biotic and abiotic environments that they invade, making conditions more conducive to further invasion and less so for native establishment. Restoration in the presence of invaders, in particular after removal efforts, may therefore lead to alternative and, often, undesirable states. Further inhibiting successful restoration are limited resources—while weed removal efforts gain momentum, the time, person-power and costs associated with post-removal restoration are harder to come by. Needed are scientifically based yet simple and inexpensive methods for encouraging post-removal ecosystem restoration. Using a field experiment, we tested our hypothesis that the addition of organic litter and higher planting diversity, characteristics of a mature system, would lead to faster development of most aspects of the ecosystem (soils, communities of plants and animals) than no litter addition and a monoculture. While we observed this general trend with the addition of plant litter, planting diversity had relatively weak effects. The presence of live native plantings, regardless of diversity level and often in association with litter presence, had associations with faster and/or greater resemblance of experimental plots to the reference site. Resemblance occurred with respect to environmental conditions, decomposition rates, plant abundance and community composition, total abundance of fauna, and faunal diversity, and often within the first year. From these results, we recommend 1) the use of a thick layer of organic litter as a gardening mulch and carbon source for soil microbes, 2) the planting of often dispersal limited native perennials to assuage harsh physical conditions and provide habitat and other functions, and 3) the planting of a diversity of native species. While organic litter had the primary effect on early ecosystem development, it is likely that the effects of plant diversity will increase as the restoration site matures. These simple, inexpensive approaches should increase the rate of development of a broadly functioning ecosystem, which will provide immediate benefits, and jump-start functions that take longer to develop.

PROJECT MODIFICATIONS: Explain briefly any substantial modifications in research plans, including new directions pursued and ancillary research topics developed. Describe major problems encountered and how they were resolved.

Although not originally proposed, we ended up including goal 1 to assess some of the effects these common invaders were having on transition ecosystems in order to better develop approaches for post-removal restoration of ecosystems invaded by these introduced species.

PROJECT OUTCOMES: Briefly describe data, databases, physical collections, intellectual property, models, instruments, equipment, techniques, etc., developed as a result of this project and how they are being shared.

We have datasets and specimens of physical conditions, soils, plants and invertebrates from the experimental site and the reference sites which are available to any of the agencies or researchers working at the Tijuana River Estuary. The reference samples in particular may be used as references for other nearby restoration projects and for assessments of future change within this site. Further, we produced a native and introduced plant photo field guide for use with employees, students and docents/volunteers working and educating in the high marsh transition and coastal sage scrub ecosystems in the Tijuana River Estuary.

IMPACTS OF PROJECT: Briefly describe how this project has contributed to a discipline; to developing human resources; to developing physical, institutional or information resources; technology transfer; and society beyond science and technology. Please notify CASG of impacts that occur after your project ends; CASG may contact you after your project ends to learn about additional impacts that occur over time.

Work resulted in revised management plans for post-removal restoration within the Tijuana River Estuary and San Diego Bay.
Outreach and stewardship. We increased education and stewardship in the community through citizen science events and training of students. We utilized individual and group volunteers throughout each year, with the aim of educating and involving the public while helping us to set-up, maintain and sample our experiment.
Outreach and education of young scientists. Much of this research was conducted by undergraduate and high school students who wish to pursue a career in the sciences. In the past year, training and research experience was provided for undergraduate students (U.C.S.D, University of San Diego, Mesa College, and San Diego State University). Experience and training was also provided for ten high school interns working through the non- profit Ocean Discovery Institute and two other local area high schools (Torrey Pines High, Point Loma High and Lakeside High). Most of the students involved in this project over were from groups under-represented in the sciences thereby increasing interest and opportunity for students that may not have otherwise been engaged.

BENEFITS, COMMERCIALIZATION, AND APPLICATION OF PROJECT RESULTS: Please list any companies, agencies, organizations or individuals who have used your project results, scientific/technical advice, etc., and provide names, emails and phone numbers. Briefly describe how results were used and quantify results and socioeconomic benefits, if possible.

Results can be applied to future post-removal restoration efforts in this region and in other areas. Restoration practitioners in the area may recommend the use of plant litter, large native plants and ground kelp (soil amendment) in their restoration projects, especially post-removal restoration projects, around San Diego.
FWS: Debby Good, Debbie_Good@fws.gov, Phone: 619 575-2704
TRNERR: Jeffrey Crooks- jcrooks@tijuanaestuary.org
PARKS: Chris Peregrin- cpere@parks.ca.gov
Nordby Biological Consulting: Chris Nordby- nordbybio@gmail.com
We have found that the use of introduced-plant litter generated from removal efforts and the use of kelp as a soil amendment (data not presented here) can improve the initial recovery of coastal ecosystem restoration. Removal of introduced-plant litter from a site is expensive, so this action not only jump starts the system but also saves restoration costs. Similarly, the kelp removed from San Diego City beaches has a beneficial use as a soil amendment, which may avoid disposal costs. Additionally, if a restoration activity involves native plantings then assemblages that allow different levels of diversity to accommodate the different functions of the site should be used (e.g., functions such as habitat for invertebrates, limiting re-invasion by plants). Including native plant species that will relatively quickly increase the plant biomass on a site also enhances recovery of the site. All of these recommendations should not increase the budget of a restoration site.

ECONOMIC BENEFITS generated by discovery, exploration and development of new, sustainable coastal, ocean and aquatic resources (i.e., aquaculture, marine natural products, foods, pharmaceuticals).

Issue-based **forecast capabilities** to predict the impacts of a single ecosystem stressor, developed and used for management (i.e., climate change, extreme natural events, pollution, invasive species, and land resource use).

We have found with some certainty that the use of introduced plant litter and live plant biomass/productivity in restoration will limit the establishment of new introduced plants, despite the high likelihood that the litter contains seeds of the fallen plants.

Tools, technologies and **information services** developed (i.e., land cover data, benthic habitat maps, environmental sensitivity index maps, remove sensing, biosensors, AUVs, genetic markers, technical assistance, educational materials, curricula, training).

Publications (list in appropriate category below) Each listing should be a stand-alone bibliographic reference, including all authors' names. For each Publication type, specify title, authors, date and journal details, where appropriate (repeat headers as necessary).

Technical Reports

Title	Authors	Date

Conference Papers, Proceedings, Symposia

Conference	Invasive Plant Council	Location	Tahoe, CA	Date	5-7 Oct 2011
Title	Invasion effects of crown daisy in a coastal scrub ecosystem	Authors	Nguyen, KC, R. Cook, T.S. Talley, P.K. Dayton		
Conference	Western Society of Naturalists	Location	Vancouver, WA	Date	10-13 Nov 2011
Title	The effect of invasive *Chrysanthemum coronarium* on a coastal scrub invertebrate community	Authors	Cook, R. and T.S. Talley		

Peer-reviewed journal articles or book chapters

Journal Public Library of Science (PLoS One) **Issue Num** 7(8) **Page Num** e42460. **Date** 03 August
Title Testing the effects of an introduced palm on a riparian invertebrate community in Southern California **Authors** Theresa Sinicrope Talley, Kim-Chi Nguyen, Anthony Nguyen

Journal Biological Invasions **Issue Num** **Page Num** in **Date** Accepted
Title The effect of invasive *Chrysanthemum coronarium* on a coastal sage scrub invertebrate community in Southern California. **Authors** Roy W Cook, Theresa Sinicrope Talley

Non-peer Reviewed Reprints

Publications, Brochures, Fact Sheets

Books & Monographs

Handbooks, Manuals, Guides

Electronic publications: (non-print formats).

Maps, Charts, Atlases

Theses, dissertations

Newsletters, periodicals

Program reports (annual/biennial, strategic plans, implementation plans)

Educational Documents

Topical Websites and Blogs

Miscellaneous documents (not listed above).

MEDIA COVERAGE: Select 'Yes' or 'No'. If yes, describe any radio, TV, web site, newspaper, magazine coverage your project has received. Send original clippings or photocopies to the Sea Grant Communications Office.

Focus of PBS kids' science show, SciGirls, Episode name: Habitat Havoc, filmed: January 2012.
http://pbskids.org/scigirls/video?pid=mU81J37T3eL2wzEhTa3XyzxfzJ_3WLj4

MEDIA NOTES: Brief description of the type media coverage your project has received.

DISSEMINATION OF RESULTS: List any other ways in which results of your project have been disseminated. Indicate targeted audiences, location, date and method.

Invited presenter: San Elijo Lagoon Foundation. Presentation of project and restoration lessons. 17 May 2011.

Report to community. Presentation of research by high school student interns of Ocean Discovery Institute to the community of City Heights. June 2011.

WORKSHOPS AND PRESENTATIONS: A brief description of location, date, time, topic, number of attendees and name of presenter.

Field Trip and Presentation of Education and Research for: The Children & Nature Network's annual Grassroots Gathering conference in San Diego (featuring Richard Louv), Tuesday, Sept 20th 2011

Teacher training workshop: Coastal Ecosystem Ecology: an introduction for teachers. Held at the Chula Vista Nature Center , Sponsored by Ocean Discovery Institute. June 2011.

Field trip and fund raising event for Ocean Discovery Institute. Tijuana estuary. 4/26/2011. Student lead tour of our research site, lesson in native plant identification and significance of work.

COOPERATING ORGANIZATIONS: List those (e.g., county or state agencies, etc.) who provided financial, technical or other assistance to your project since its inception. Describe the nature of their cooperation.

Federal Organizations

USFWS- one of the agencies on site at Tijuana River Estuary. They provide site history information and technical advice (e.g., what plantings they wanted to see, best planting techniques), they granted permission to conduct the project in the reserve, provided the site itself, provided materials needed to set up the experiment such as fencing, fence posts, flagging, provide occasional volunteer labor, and assistance with maintenance when needed (transport of tools, fence repair, watering).

National Estuarine Research Reserve. one of the agencies on site at Tijuana River Estuary. They provide technical advice (e.g., input on treatments), granted permission to conduct the project in the reserve, worked with us to find a site and put us in touch with USFWS, provide extra supplies when needed (e.g., gloves, tools, soil cores), and arrange the organized volunteer events (e.g., like the one that initially planted the site). They will collaborate with us in developing our post-removal management plan handbook.

Regional Organizations

none

State Organizations

California State Parks. One of the agencies on site at Tijuana River Estuary. They granted permission to conduct the project in the reserve and provided site history information.

Nongovernment Organizations

Ocean Discovery Institute, a science education non-profit that provided internship opportunities for students from underrepresented groups in the sciences.

International Organizations

none

Industry Organizations

Academic Organizations

SDSU- an intern supervisor with Ocean Discovery Institute is a full time undergraduate student at San Diego State University.

Sea Grant Organizations

Sea Grant provided an Isaacs Undergraduate Research Assistant Award during the summer 2009 and 2010 to two of our UCSD students, and one Mesa College student.

INTERNATIONAL IMPLICATIONS: Does your project involve any colleagues overseas or have international implications?

We have colleagues at the Centro de Invesigación Cientificas y de Educación Superior de Ensenada (CICESE) in Baja California who provide insights into the interpretation of our nutrient and isotope data, which is helping us to construct a more meaningful food web for our system (Dra. Sharon Herzka); and who work on coastal restoration projects in northern Baja California that will benefit from our findings (Dras. S. Herzka and Silvia Ibarra Obando).

AWARDS: List any special awards or honors that you, or any co-project leaders, have received during the duration of this project.

Roy Cook (UCSD), Erick Ruiz (Mesa College). Isaacs Award. July-Sept 2011

KEYWORDS: List keywords that will be useful in indexing your project.

coastal wetland, coastal sage scrub, community ecology, diversity-function, education, ecosystem restoration

PATENTS: Please list any patents or patent licenses that have resulted from this project, and complete the patent statement form available on the web site: N/A

FOR ALL STUDENTS SUPPORTED BY THIS GRANT,

Volunteer Count = 15

Graduate Student Info: N/A