

## Ecological Education: K–12

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*With rapidly changing technology we are seeing a number of innovative ways emerging that can engage young people and help them understand some of the complexities of ecology. In the following example submitted by Riley Pratt and colleagues at the University of California, Irvine, we see how fruitful collaboration between ecologists and computer scientists can be within the field of ecological education.*

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### The EcoRaft Project: An Interdisciplinary Approach to Teaching Lessons in Ecological Restoration

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#### Introduction

A major challenge for ecological scientists is to effectively communicate knowledge to a lay audience. Successfully reaching nonscientists is important for numerous reasons, from informing policy makers on issues of conservation, to educating students and future scientists. Perhaps the most challenging group to reach is children, as they often lack specialized scientific vocabulary needed to make sense of scientific discussions. In addition, their limited life experience makes it difficult for them to understand the larger implications of scientific discoveries. For example, the discovery that habitat fragmentation tends to reduce biodiversity has broad implications on all our lives, and thus is meaningful to even nonscientist adults (Wilson 1988:81). Traditional, passive lecture-based methods

of science education do not engage young audiences well. In a society where youth clamor over quick, visual, interactive sources of information (e.g., the Internet and video games), it is not surprising that complex ecological processes operating over long time scales (e.g., restoration) seem dull to young people.

One way to overcome these challenges is to attach the scientific principles we want young people to engage with, to a format that already draws their attention. An interdisciplinary group of computer scientists and ecologists at the University of California, Irvine used this approach to construct EcoRaft, a novel teaching tool designed to educate 8–12 year olds about ecology and restoration.

Specifically, the goals of EcoRaft are communication of the following themes in restoration:

- biological communities may be easier to destroy than to rebuild;
- restoration requires an understanding of the local

ecology;

- conservation of native species and their habitats is important to restoration;
- restoration is a collaborative effort;
- humans can have both negative and positive impacts on ecosystems.

This paper describes the EcoRaft Project, assesses its goals, and reports results from preliminary evaluations of the project.

### What is EcoRaft?

EcoRaft is an interactive, animated, computer-based ecosystem. The virtual world of EcoRaft is composed of three flat-panel monitors separated in physical space (Fig. 1). Monitors are arranged in the shape of a triangle, with a monitor at each corner and the screens facing toward the center. The area inside the triangle is large enough for up to 15 children to stand and walk comfortably.

The monitors represent different "islands" or patches of tropical forest in various states of

ecosystem health. Two of the islands are outfitted with "deforest buttons," which when pushed transform the island from its existing ecological state to a desolate landscape. The button symbolizes potentially destructive forces, such as deforestation followed by over-grazing. The third island is an aesthetically pleasing, diverse "National Park" and acts as a biological preserve and repository for native plant seeds and animals that can provide propagules to aid the restoration of the two disturbed islands. The restoration process is initiated by transferring seeds of early-, intermediate-, and late-successional plant species, as well as four ecologically distinct species of hummingbirds, from one island to another. Although a completely degraded island may require a seed from the National Park to initiate its restoration, the newly emerged plant can in turn produce seeds that can be introduced to any of the other islands. This transfer is accomplished via tablet PCs—mobile devices that serve as "virtual collecting boxes" or "virtual rafts"—which people can use to move species between any of the islands (Fig. 2). Onscreen text bubbles help the children achieve the restoration process by providing background information on the different species and

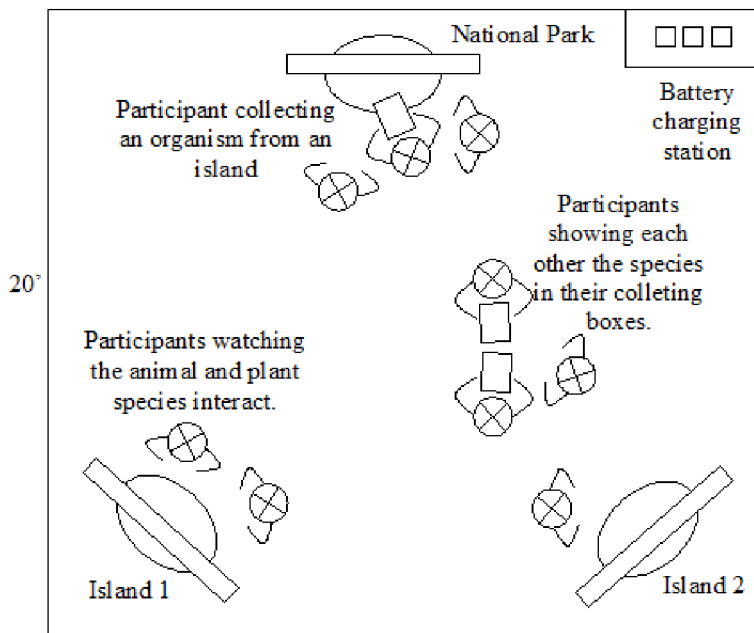


Fig. 1. The layout of the EcoRaft installation. Participants may enter from any side to move from one island to another. The exhibit works adequately with only one participant, but works best with 4 to 8 simultaneous participants.

their unique roles in the ecosystem.

In order to recreate thriving ecosystems on disturbed islands, participants not only have to introduce species, they have to discover which species are appropriate for introduction at each stage in the recovery process. For example, an attempt to transfer a seed of *Heliconia* from the National Park to a completely deforested island will be unsuccessful because of insufficient amounts of shade and nitrogen, which *Heliconia* prefers. Only by first introducing the nitrogen-fixing legume tree *Erythrina* will a seed of *Heliconia* grow. In addition, introducing a hummingbird before introducing a plant with hummingbird flowers results in the wandering and eventual disappearance of the bird. In doing so, participants learn about important ecological concepts like pollination, mutualism, and succession.

The virtual forest of EcoRaft is modeled after tropical wet forest in Costa Rica, where the ecologists involved with the project currently conduct restoration research. As such, all species in EcoRaft and many of the interactions among them have been observed firsthand in the region of the field site. Integrating these ecological data with published information and theory into the virtual ecosystem is a critical aspect of the project. This process consisted of selecting an important ecological concept or behavior, determining the appropriate set of circumstances or behaviors that exist across the range of potential interactions, designing a computer model that depicts these circumstances or behaviors, and incorporating, graphics, animation, sound, and text to illustrate the concept.

For example, the behavior of an individual hummingbird is the product of a suite of ecologically relevant variables that include its unique natural history, the availability of food resources, and the time since it was last fed. (To enhance interaction between user and system, the amount of human activity in front of the display screen also influences hummingbird behavior. This is accomplished by equipping monitors with motion sensors that detect the presence of a nearby observer. Detection causes the hummingbird to approach the screen, creating the illusion that the hummingbird



Fig. 2. Children transferring a hummingbird from the collecting box (i.e., tablet PC) to a virtual island.

is aware and curious about the observer.) Time spent doing various activities such as feeding and perching correspond to time budgets recorded and published in the scientific literature (Stiles 1975). The result is a dynamic, engaging, and biologically realistic simulated environment.

### Challenges and tradeoffs

A major challenge for us was to create a tool that was both visually engaging and biologically accurate. For this reason, we chose species that are commonly used in restoration, and are also aesthetically pleasing. For example, *Erythrina* was chosen, not only because it grows well in full sun and fixes nitrogen, but also because it produces beautiful red flowers that are visited by hummingbirds. Similarly, hummingbirds were chosen because they are important pollinators, and because their quick movements and charismatic behaviors would appeal to young people.

Explaining the ecology in a way that was easy for children to understand was another challenge and required simplified explanations. For example, our explanation for the effect of *Erythrina* on the ecosystem is that the tree increases nitrogen in the soil, and that

the nitrogen in turn helps nearby plants grow. In this case, we don't include the actual mechanism by which *Erythrina* facilitates the growth of *Heliconia*. Although an explanation of the symbiosis between *Erythrina* and nitrogen-fixing bacteria *Rhizobium* would be more precise, we felt it would only confuse and distract children from the broader lessons we wanted to teach.

The requirements for successful restoration have also been simplified and idealized. For example, our decision not to allow *Heliconia* seeds to grow without the presence of *Erythrina* in EcoRaft obviously does not reflect the natural variation in the species. However, showing consistent cause-and-effect relationships between species and the environment more clearly illustrates their different ecological roles and simplifies a user's choice of species for each step in the restoration process.

We have also simplified the ecology by limiting the number of species that constitute a biodiverse ecosystem. Again, we felt that having ecological niches or functions (e.g., nitrogen fixation) filled by only one species would help users discriminate among species, in comparison to a more biologically diverse system where the functional roles of species may overlap. That aside, the technology itself constrained the sophistication of the virtual ecosystem. The modeling of the appearance of each species and its behaviors required weeks of digital artwork, software engineering, and programming. Furthermore, the programming effort required to implement the interactions among species increased rapidly as we increased the number of species in the system. As a result, the number of species constituting a biodiverse system had to be limited.

## Goals and their assessment

EcoRaft has several goals. One is to communicate that ecosystems are usually easier to destroy than to rebuild. In the game, pressing a button quickly wipes out the diversity and beauty of the biological community. In contrast, recreating these qualities requires

multiple sequential steps. Not only do species have to be introduced in a specific order based on their own natural history, but players have to contend with the encroachment of the weedy species *Brachiaria* and other users hitting the "deforest button."

Secondly, we hope to illustrate the close connection between conservation and restoration. Relatively intact ecosystems, like National Parks, can serve as reservoirs of species necessary to restore degraded areas. Given enough time and protection, restored habitats can in turn become additional sources of propagules for restoration, reducing the burden on conserved areas for maintaining rare and ecologically important species.

Third, EcoRaft seeks to persuade children that cooperation, not competition, is a more effective way to restore an ecosystem. Each tablet PC carries a different species; therefore, the ecosystem can be restored more quickly when many users are collecting and transferring different species at the same time. In addition, delegating one person to guard the "deforest button" reduces the risk of someone else pushing it.

Finally, EcoRaft seeks to demonstrate that humans can have profound impacts, both negative and positive, on the ecosystems. Although our dependence on ecosystems for food and other resources have led to their degradation, our understanding of ecology can be used to positively influence both the direction and pace of restoration (Carpenter et al. 2004).

To evaluate whether these goals were met, we observed over 3000 children and adult users at several public demonstrations. Locations for demonstrations included the Discovery Science Center (DSC) of Orange County, the Emerging Technologies program at the 2005 ACM SIGGRAPH Conference in Los Angeles, California, and a research laboratory on the campus of UCI. In addition, 40 adults and children ages 7–15 were interviewed about their interactions with the system. Answers to prepared, open-ended questions were tape recorded and analyzed (Tomlinson et al., 2006). To see a copy of the questionnaire, please

visit <http://orchid.calit2.uci.edu/EcoRaft/exhibit.html> (coming soon, not online yet).

After the demonstration, the trial users generally agreed that the purpose of the game was to restore a tropical rain forest. They also clearly recognized that the order of species introductions was important to successful restoration. According to one participant, the exhibit was about “*dependencies between environments and creatures that live in them.*” These results suggest that users made the connection between success at restoration and knowledge of the local ecology. However, it was not clear if users made the connection that conserved areas (e.g., National Parks) and their propagules are needed to initiate restoration elsewhere.

Cooperation among participants was strong. Children were often observed interacting with one another, both playing and instructing new users about the principles of the game. In addition to describing procedures, such as where to point the tablet PC's at the monitor to get a seed to transfer, adults and children alike were often observed sharing biological explanations of why species would not establish in the ecosystem. This is an important lesson, because forest restoration often requires the cooperation of many people, including landowners, governments, and scientists. During the interviews, many participants commented on the collaborative aspects of the installation. One interviewee at SIGGRAPH stated that the main concept was “communally helping to grow these ecosystems ... sharing the process of this growth with other people.” Also, one of the children at DSC said she “was working with [her] dad and a couple of kids.” This topic of collaboration emerged from interviews with both children and adults, suggesting that EcoRaft is effective at conveying the necessarily collaborative nature of restoration.

Another theme we tried to convey, but which was rarely discussed by users, is that people have significant control over the fate of an ecosystem. Because EcoRaft is still in the design stage and has not been made available to a widespread audience, it is pre-

ture to assess fully how well we have met our project goals. We do know that we have been successful at engaging our target age group in this activity and educating them about some of its biological principles. We will continue to measure our success as we have more opportunities to present this educational tool to children and gain their valuable feedback.

### Future directions

Although we are excited about the progress made so far, there are several ways in which we feel EcoRaft can be improved and its impact heightened. First, we need to continue to improve the realism of the ecosystem. While some characteristics of the hummingbirds have been incorporated into the models, they still do not behave like hummingbirds in the wild. Currently, the programming team is integrating defensive behaviors into territorial hummingbird species (Dearborn 1998) and foraging habits of trapline species (Tiebout 1991). The hope is that an observant child will notice the subtle but important behavioral differences among species; that certain hummingbird species defend territories while others do not, and that each species feeds only from the flowers of certain plant species (Wolf et al. 1976).

Currently, failure to take the appropriate steps in the recovery process halts restoration but does not cause further degradation. Instead, future systems will spiral back toward a degraded state when children make poor choices. For example, failure to introduce a hummingbird (i.e., a pollinator) quickly into a newly established plant community will lead to the shrinking of that community and the encroachment of the invasive weed *Brachiaria*. Creating forces of opposition to restoration not only adds realism; it will make the process more challenging and engaging to users.

One frequent criticism of the project by even lay audiences is that the ecosystem is too simple. Time and limited capacity of the technology, however, precluded the addition of more species. As the technology improves and the modelers and animators learn more efficient ways to construct a virtual ecosystem,

we will add species. Including animals like a large cat or monkeys would not only improve EcoRaft's visual appeal, the presence of herbivores and a predator would fill substantial functional voids in the current ecosystem.

Future versions will also incorporate more lessons from the ongoing restoration work in Costa Rica (Carpenter et al. 2004). Currently, three members of our team are investigating the possibility that the early successional tree species *Vochysia guatemalensis* alleviates soil aluminum toxicity for neighboring, later successional species. *Vochysia guatemalensis* has been shown to accumulate high amounts of aluminum in its tissues, perhaps reducing the concentration of toxic forms of this element in the surrounding soil. If we show that *V. guatemalensis* indeed reduces soil aluminum and facilitates the growth and survival of neighboring native plant species, we could then include *V. guatemalensis* as an early successional tree in the EcoRaft plant community. Its inclusion would also represent a novel way to communicate current academic research outside of traditional academic journals.

The project also seeks to develop a series of exhibits for several science centers and museums. Although the current model deals with tropical wet forest in Costa Rica, future exhibits will feature regionally relevant environments and sets of ecological issues. In this manner, participants learn about their local ecosystems and the relevance of conservation to their own lives. This process, however, requires the interdisciplinary collaboration of creative computer scientists and locally knowledgeable ecologists.

Creating awareness of ecological principles among young people is important, as it has a lasting impact on values and habits (Hart 1978) and is a prerequisite to sound decision making (Mappin and Johnson 2005). Hopefully, researchers and policy makers concerned about the environmental education of future generations will see the value of funding and pursuing innovative teaching tools that communicate the messages of ecologists and restoration biologists.

More information about the EcoRaft Project can be found at our web site, <<http://orchid.calit2.uci.edu/EcoRaft>> For information about the technology contact Bill Tomlinson at [wmt@uci.edu](mailto:wmt@uci.edu). For information about the ecology contact Lynn Carpenter at [flcarpen@uci.edu](mailto:flcarpen@uci.edu).

## Acknowledgments

We would like to thank CalIt<sup>2</sup> and the Nicholas Foundation for financial support, and all the members of the EcoRaft group: Grace Chiang, Andrew Gee, Sara Goetz, Bryant Hornick, Stefan Marinov, Calen May-Tobin, Uel McMahan, Robert Moodey, Ed Niecikowski, Erika Ramos, Martin Schmidt, Man Lok Yau, Craig Yoho, and Kristin Young.

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