Fragmentation and Tropical Forests

Year 1 Initiative Overview & Progress, June 2011

Problem Statement

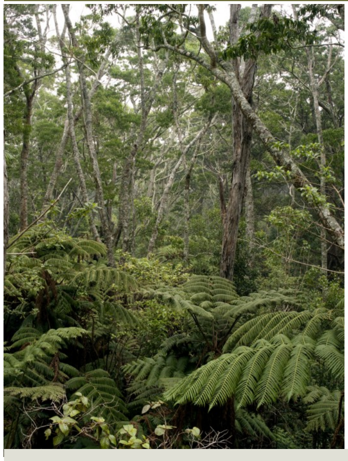
In the face of accelerating biological invasion by non-native predators and habitat fragmentation, little is known about how predators and ecosystem size may interact to influence food webs at landscape scales.

We have assembled a broad team of scientists to investigate interactive effects of non-native omnivorous rats and forest fragment size on arboreal arthropod food webs.

This system of over 300 forest fragments of varying size – with its biotic simplicity, stability and homogeneity of matrix, and control over confounding variables – qualifies as a model system for asking fundamental questions about food webs.

Fig 1. `Ohelo (*Vaccinium reticulatum*) and forest fragment in front of Mauna Kea, Hawai`i.

Objectives



- Investigate interactive effects of non-native omnivorous rats and forest fragment size on arboreal arthropod food webs.
- Integrate fundamental principles of island biogeography, trophic omnivory, and food-web complexity toward a mechanistic understanding of food-web dynamics.
- Estimate forest productivity, composition and structure using Light Detection And Ranging remote sensing technology (LiDAR).
- Create educational opportunities in community and ecosystems ecology for university undergraduate students, graduate students, and post-doctoral fellows through their active participation and collaboration in research.

Fig 2. An inside look at a forest fragment composed of predominantly native flora.

Describing the Project Area: Kīpuka

Model systems are needed to examine fragment area effects on food web structure where other factors are relatively constant. Human-induced fragmentation is typically associated with human activities, which may complicate interpretation of results from fragmentation studies. Forests on Hawai`i Island periodically experience a unique natural disturbance where lava flows into forests, leaving behind forest fragments of various sizes, which are called kīpuka. Located on the slope of Mauna Loa, we identified a system of kīpuka formed by two recent flows (1855 and 1886) creating a matrix similar in vegetative composition and stature. They represent a highly replicated gradient of forest ecosystem size distributed over a narrow elevation band confined to a single vegetation life zone (1500-1800m). These kīpuka occur within the State of Hawaii Forest Reserve System, an area subject to limited anthropogenic disturbance and whose flora and fauna are relatively simple and well-characterized. In summary, this series of more than 300 forest fragments of varying size is biotically simple, is surrounded by a stable and homogeneous matrix, and limits many confounding variables, making it a model system for research on food web dynamics.

Fig 3. Google Earth image of kīpuka study area on the flank of Mauna Loa, Hawai`i.

Project Partners

- Stanford University
- Carnegie Institute for Science
- University of Maryland
- Michigan Technological University
- USDA Forest Service, Pacific Southwest Research Station

Inside this issue:

Establishment of Study Sites and Project Design

We selected a total of 34 kīpuka (0.07 – 10.2 ha), half from which rats will be "removed" and half from which no rats will be removed. In treated kīpuka, lethal snap traps will be checked and reset on a regular basis. We will also deploy ground and tree tracking tunnels periodically to detect the presence of rats after initial control.

Fig. 4. Technician climbing an `ohi`a (*Metrosideros polymorpha*) tree to access canopy arthropods.

Plots have been established at the center and edge of each kīpuka for litter, plant and arthropod measurements. Litterfall is collected regularly from litter traps at each plot as an index of net primary production. A fraction of collected specimens and leaves of *Metrosideros polymorpha* will be analyzed for $\delta^{13}C$ and $\delta^{15}N$. A before-and-after seedbank study will inform us about the impact of rats on forest seeds and regeneration.

In the face of accelerating biological invasion by non-native predators and habitat fragmentation , little is known about how predators and ecosystem size may interact to jointly influence food webs at landscape scales.

Light Detection And Ranging (LiDAR, 1.2 m-resolution) remote sensing measures of total area, maximum canopy height, canopy height heterogeneity, topographic ground heterogeneity, and total volume will help estimate kīpuka habitat complexity. LiDAR is an optical remote sensing technology that can measure the distance or other properties of a target by illuminating the target with laser pulses. Our approach will make use of fine-grained natural variations within and between kīpuka in habitat complexity as covariates in statistical analyses.

Branch clipping and malaise traps will yield information about arboreal arthropod communities. The data for species composition, abundance and stable isotopes of arboreal arthropods and plants will be used to estimate food chain length, trophic niche width and functional diversity, community-wide compositional similarity, diversity, density and biomass within trophic groups, and the distribution of total biomass among trophic groups.

We will measure bird density and diversity before as well as after two and four years of initial rat treatment. Nesting success will be monitored in a subset of larger kīpuka (>1 ha) where sufficient sample sizes of common species are found. Bird community differences derived from kīpuka size and rat treatment may also have indirect effects on arthropod communities. We plan to construct bird exclosures to estimate arthropod densities and composition, and track bird movement and range using radio telemetry to explore these possibilities.

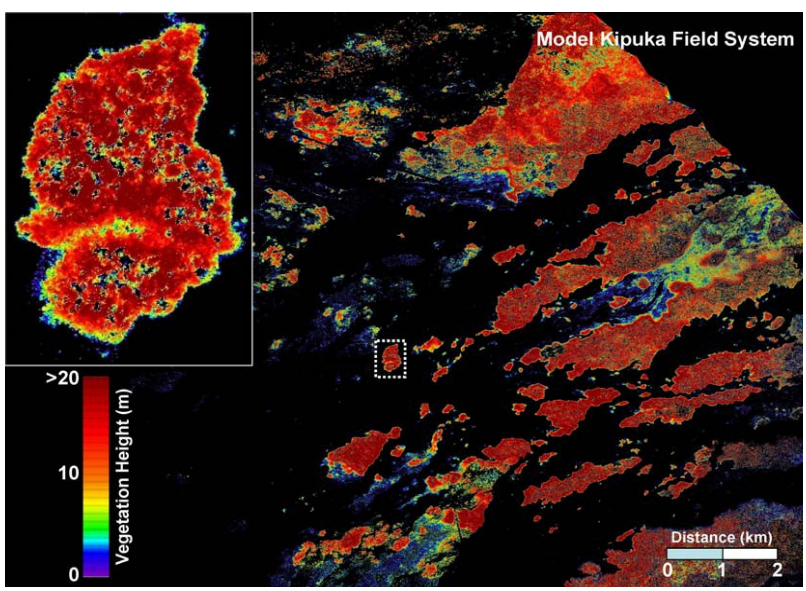


Fig. 5. Airborne CAO-LiDAR image from a January 2008 flight showing vegetation height for more than 100 kīpuka in our model field system on the Island of Hawaii. Inset shows one example kīpuka of roughly 10 ha.

Rats in Kīpuka: Life in Paradise

Fig. 6. Black rat (*Rattus rattus*) in kīpuka after prepping for radio telemetry.

Although Hawai`i is the most isolated island chain in the world, plants and animals have been arriving in and spreading across Hawai`i via wind, wings and waves for millions of years. Many of these plants and animals changed over time, losing their defenses against predators found in continental areas. Rats, introduced by Polynesian and European colonizers, increased exponentially in the absence of significant predators or competitors, feeding on largely endemic vegetation that had evolved in the absence of mammalian predators. Owing to an omnivorous diet and large incisor teeth, introduced rats (*Rattus* spp.) may be the invasive animals responsible for the greatest number of plant and animal extinctions on islands. They are significant predators of numerous native species in Hawai`i, including rare and endangered birds, snails, arthropods, and plants.

Island Biogeography Versus Fragmentation

Fig. 7. Kīpuka forest fragments surrounded by a younger lava flow.

Island biogeography describes the relationship between area and species richness; the theory asserts that larger islands (or fragments) are more species rich than smaller islands. Although profoundly influencing the fields of ecology and conservation, island biogeography theory provides little more than a basic conceptual framework for understanding fragmentation. As a prism for understanding habitat fragmentation, island biogeography theory concerns only the factors that affect species diversity and area while ignoring phenomena such as community composition changes over time, edge effects, matrix effects on connectivity, etc. Habitat fragmentation, on the other hand, has far broader effects on ecosystems, altering diverse processes such as forest dynamics, nutrient cycling, carbon storage, and forest-climate interactions. Our study will integrate core principles of both island biogeography and fragmentation toward a mechanistic understanding of food web dynamics.

Findings from this study will have immediate relevance for conservation and restoration of Hawaiian forests by better understanding how rat removal can be used to restore native-dominated food webs.

Birds in a Naturally Fragmented Landscape

Over the last 1,500 years, converting native Hawaiian forest to agriculture at lower elevations or pasture at higher elevations has confined much of Hawaii's native plants and animals to mid-elevation forest like that which occurs in our kīpuka system. Introduction of rodents has greatly exacerbated the problems associated with fragmentation - rats attack bird nests, killing nestlings and occasionally adults, as well as devouring the fruits of native plants not adapted to the predators. This has lead to the endangerment and even extinction of many native plants and bird species in Hawai`i. For example, 24 species of 44 known species of Hawaiian Honeycreepers are extinct and nine of the 20 remaining are federally listed as endangered. Because of its arboreal lifestyle, the black rat (*Rattus rattus*) is considered to be the most significant avian predator among the three rat species introduced to Hawai`i. Nest predation is one of the most important factors shaping the life histories of birds, potentially influencing the abundance and distribution of bird species. Birds, in turn, are predators on arboreal arthropods, playing an important role on food webs involving arboreal arthropods.

Fig. 8. Pre-release photo of a banded `I`iwi (*Vestiaria coccinea*), an endangered honeycreeper endemic to Hawai`i.

Climate Change & Pacific Island Water Resources

Lehua flower in bloom of the `ōhi`a ltree (*Metrosideros polymorpha*), the most common native tree of Hawai`i

Arthropods and Food Webs

Many biological processes critical to forest ecosystem function such as seed predation, pollination and decomposition, are mediated by arthropods. Rats are opportunistic omnivores that feed on a combination of plant tissues and seeds, arthropods, and birds. If rats forage more heavily on large spiders in small kīpuka with shorter, more accessible canopies than in large kīpuka, rats may affect food-web complexity dissimilarly in kīpuka of different sizes. In fact, preliminary data show that spider density is lower in smaller kipuka. By removing rats from this system, we can investigate some fundamental questions about food webs within the context of island biogeography and fragmentation.

Fig. 9. View under a microscope of an arboreal spider found in a kīpuka,

Fragmentation and Productivity

This study will integrate core principles of island biogeography, trophic omnivory, and food-web complexity toward a mechanistic understanding of food-web dynamics.

Forest productivity and nutrient dynamics may vary in differently sized fragments. Using litter traps placed at the center and edge of each kīpuka we have been monitoring leaf litter production, which relates closely to net primary productivity (NPP), and nutrient return through litterfall, which is a key index of nutrient cycling. Estimating fragmentation effects on NPP and nutrient cycling is useful because these processes influence both plant and animal community composition and dynamics, which ultimately affect forest composition and vitality.

We will also use Light Detection And Ranging (LiDAR) data to explore relationships between structural complexity, productivity and other habitat characteristics with ecosystem size and food-web structure.

Figs. 10-11. Forest floor litter (left) and dominant `ohi`a tree (*Metrosideros polymorpha*) (right) in kīpuka.

Photos taken by various partners on the project.

Timeline and Future Work

2010: (i) Pre-treatment arthropod sampling, (ii) litterfall collection, (iii) rat treatment pilot study

2011: (i) Pre-treatment bird abundance, nesting and movement measurement, (ii) rat treatment deployment, (iii) litterfall collection, (iv) bird exclusion pilot study, (v) seedbank study

2012: (i) Bird abundance and nesting measurement, (ii) arthropod sampling, (iii) bird exclosure deployment, (iv) litterfall collection

2013-2014: (i) Bird abundance and nesting measurement, (ii) arthropod sampling, (iii) litterfall collection, (iv) seedbank study

Fig. 12. Kīpuka on flank of Mauna Loa

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