Restoration's Influence on Aerial Arthropod Diversity

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Abstract The arthropod diversity of restored dunes can provide useful measures of restoration progress. This study, conducted at Fort Funston, Golden Gate National Recreation Area, provides data on the abundance and diversity of aerial arthropods in two dune conditions: restored, native-plant-dominated dunes and unrestored, exotic-plant-dominated dunes. Fort Funston is part of the National Park Service and began restoration of native vegetation in 1991, however scientists have not conducted much research regarding aerial arthropod diversity and restoration status at Fort Funston. Arthropods were sampled for using yellow colored sticky traps over a period of five days in mid-February. I evaluated the data with the Simpson's Index of diversity and non-parametric tests. Results indicated a difference between diversity of the restored and unrestored areas.

Introduction

California's coastal dunes are home to many endemic species of plants and animals, giving the dunes an ecological uniqueness (Powell 1978). Unfortunately, development and human use has impaired the uniqueness of this environment. The result, as Randall and Hoshovsky (2000) note, is that native vegetation of California has been declining in biomass since settlement in 1769. Disturbance of the native ecosystems is a probable cause, but also likely is the decline due to the introduction of non-native species. Species not endemic to the region of California's coastal dunes, but from similar climates, make likely candidates to compete with natives upon introduction. These invasive plants may out-compete natives, and have altered the ecology of the affected landscapes (Randall and Hoshovsky 2000). Now, a common tool to reverse these problems is restoration of the native habitat, to improve the health of plant and other organism communities.

While plants are often affected by invasive species, so are the other organisms associated with the vegetation. Arthropods, including the very important insects, are no exception. In fact, arthropods are considered particularly appropriate for assessing habitat quality because they are sensitive to small-scale changes in habitat conditions. Arthropod monitoring can indicate much about the land they are located in. A study by Mattoni *et al.* (2000) and Laborde *et al.* (1993) indicate that arthropod assemblages can be studied to evaluate habitats and monitor restoration projects. Also, the study of insects provides useful information about an environment because of their importance in the functioning of the natural ecosystems (Rosenberg *et al.*1986). In a study involving butterfly assemblages, the species richness varied by either natural, exotic, or restored (Nelson *et al.*1999). So, it is expected that associated with a change in the vegetation is a change in arthropod species composition.

Restoration can affect a community much like a disturbance. Pre-restoration disturbances, often of anthropogenic origin, present potential stresses on the arthropod community and illustrate how succession is important to this health. Nordstrom *et al.* (2000) note that human based disturbance leads to landforms existing that normally would not and an overall effect of altering succession. Van Aarde *et al.* (1996) studied species richness and found that beetle species richness increased with the increase in age of sites. In a study of a tropical forest termite assemblage response to habitat perturbation, researchers found that the response of the termites depended on the perturbation (Davies *et. al* 1999). The recovery of the termite assemblages illustrate that species will respond differently based on the ecosystem status, i.e. restored, recovering, etc. Essentially, altering succession alters the make-up of the species composition, and restoration alters succession.

One location where these restoration efforts are apparent is the dunes of Fort Funston. Fort Funston comprises a portion of the Golden Gate National Recreation Area (GGNRA) and is home to a large number of native species of plants and animals. Dunes used to stretch far into present day San Francisco (Cooper 1967), but have since been greatly altered by human use largely associated with the Army's fortification and construction in the area. During the 1930's the Army constructed coastal defense batteries, and in doing so altered the dune topography and destroyed much of the native plant community.

I intended to investigate the affects of restoration on the aerial arthropods at Fort Fusnton by measuring arthropod diversity in restored and unrestored sites. Knowing that the species composition responds to changes in the ecosystem makes it possible to focus on specific taxonomic groups. One important study at Fort Funston by Morgan and Dhalsten (1999) addressed the ground-dwelling arthropod diversity in relationship to the removal of the non-native iceplant. They found that iceplant removal leads to greater diversity of ground dwelling arthropods. In my study I expect to discover a measurable difference between arthropod species diversity in restored and unrestored sites. The interaction between insects and vegetation play an important role in the ecology of dunes. My study aims to provide a partial answer on the affects of restoration on the aerial arthropod diversity.

Methods

Fort Funston, GGNRA, spans approximately 230 acres along the coastal region of the northern San Francisco peninsula. It lies south of Ocean Beach and north of Pacifica, bordered to the west by the Pacific Ocean and to the east by a primary coastal highway (figure 1).

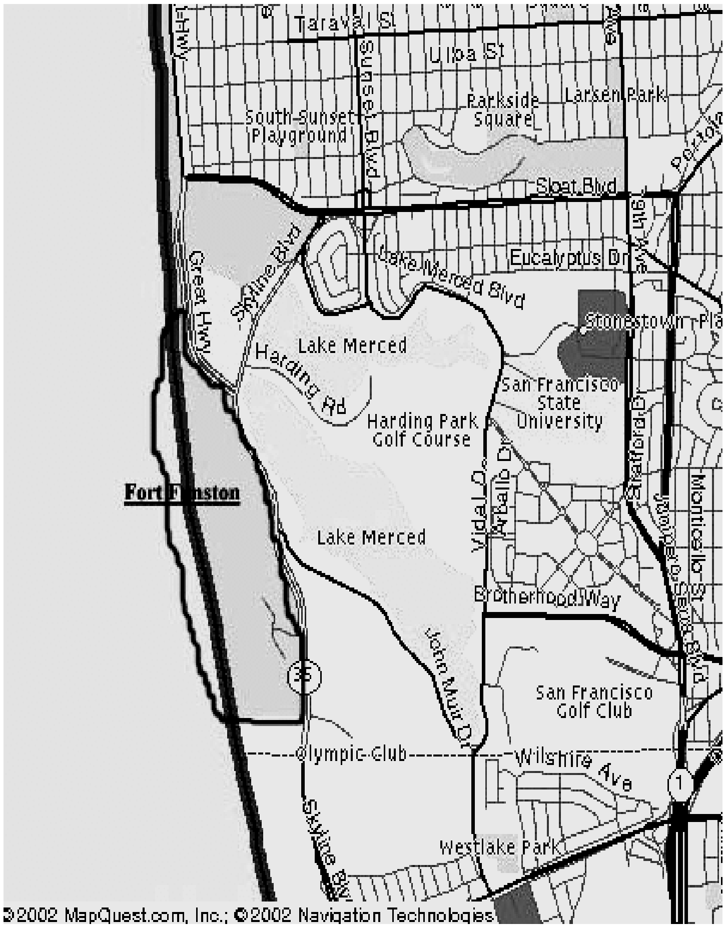

Figure 1: Map showing location of Fort Funston

The non-native plant *Carpobrotus edulis* (iceplant) covers much of Fort Funston, creating extensive amount of monoculture. Originally planted for erosion control, iceplant has succeeded tremendously at establishing itself. Iceplant is a perennial shrub of the fig family (Aizoaceae) native to South Africa. Non-native grasses are also present in the park.

Native plant species occupy a much smaller portion of the park. Some of the native species found at Fort Funston include coastal sage scrub plants such as: silver sagewort (*Atemesia* sp.), coyote bush (*Baccharis* sp.), and *Lupinus* sp. Restoration efforts began in 1991 and consisted of the replacement of non-native vegetation, notably the iceplant, with native vegetation in a portion of the park (NPS 2000). GGNRA began this restoration of native vegetation in approximately 23 acres of the northern portion of the park. My study sites include both the iceplant inundated and restored areas of the park, both regions being closed to general off-trail use. Aerial arthropods inhabit the environments in and around both the native and non-native plants; preliminary data indicated that these include members from the following orders: Diptera, Coleoptera, Hemiptera, Homoptera, Thryps, Lepidoptera, and Hymenoptera.

Sampled areas include restored-with-closure and unrestored-with-closure. The restored area included the 23 acres in the northern end of the park and the unrestored treatment adjacent to the south and of similar size. Twenty-nine points were randomly selected in each sampled area(figure 2) and a trap placed at the corresponding point.

Samples were collected with the use of commercial sticky traps obtained from a local hardware store; the traps are yellow cards about 6"x4" pre-coated with a sticky substance covering both sides. In addition to the cards, small bamboo canes served as support stands for the sticky traps. Traps were placed out with the yellow cards supported approximately 1.0 ft above ground. Selected sites lie in either restored or unrestored areas. Traps were left out for five days in the month of February and then carried back to lab for examination of the collected organisms.

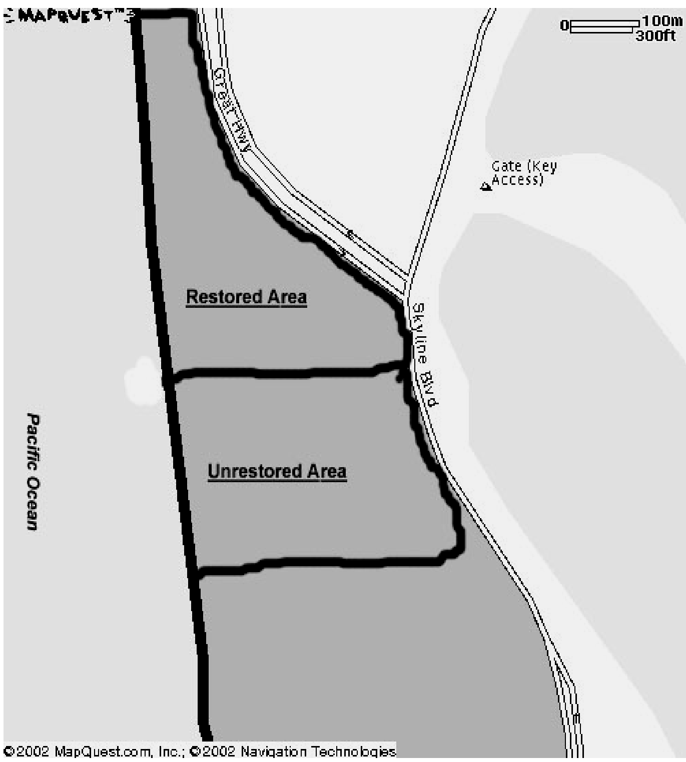

Figure 2: Restored and unrestored areas within Ft. Funston

Dissecting scopes were used to identify all arthropods. The use of field guides provided a valuable resource in identification (Dunn 1998; Borror and White 1970). Preliminary study indicated that feasible identification at the family level presented greater difficulty than anticipated. A morpho-species grouping method was used for classification of arthropods beyond the level of order based on the similarity of physical appearance Physical traits used included the common characteristics used for classifying arthropods to the family level. Such traits included number of wings, venation of wings, pronotum structure, antennae structure, and other distinguishing anatomical features. This method allowed me to distinguish as specifically as possible within a limited time frame and with limited identification expertise. I then tallied counts of morpho-species with this method to determine diversity measures and other species composition information.

All statistical tests were run with JMP v. 3.2.6 statistical software (SAS Institute). The non-normality of data influenced the decision to use non-parametric tests. A test for difference in total arthropod diversity was tested for with the Wilcoxon-Mann-Whitney test. A test for difference in species diversity was made with the same test. The Simpson's Index of diversity was used to determine a measure of diversity. This measure utilizes information including species abundance and species richness.

Results

Sampling revealed 57 different morpho-species from all traps. Originally 29 traps were collected from the field in both restored and unrestored areas, however time limitations forced me to examine 18 traps from each area. The unrestored area contained 48 different morpho-species while the restored area contained 52 different morpho-species. I used the Simpson index to calculate the diversity for each trap. To look for differences between restored and unrestored sites I used a non-parametric Wilcoxon-Mann-Whitney test. This test was run on abundance and species diversity with treatment(either restored or unrestored) as the grouping variable.

The null hypothesis of the Wilcoxon test, that the treated and untreated means would be the same, was accepted for total arthropod abundance ($p=0.0086$). Further examination of descriptive statistics indicated that while the means were not distinct, the medians were. Restored sites had a median total arthropod abundance of 60 while the unrestored sites had a median of 28.

Species diversity did differ significantly between restored and unrestored areas. The null hypothesis for the Wilcoxon-Mann-Whitney stated that the diversity measures would be the same. Running the test resulted in rejecting this hypothesis ($p=0.6016$).

Unfortunately, no data was obtained on the actual vegetation diversity and as such, no test could be run to compare arthropod diversity with vegetation diversity in the restored and unrestored areas. Testing any specific morpho-species in relation to the treatment was not completed.

Discussion

Restoration can change the make up of the species that share the habitat being restored. My study compares diversity of aerial arthropod diversity across restored and unrestored site. Restorations influence at Fort Funston on the local aerial arthropod community is not well known. My study found that diversity did differ between sites. I expected the status to influence whether the diversity is greater or lesser. In a study of an exotic saltcedar-dominated riparian forest, it was found that diversity and richness of arthropods was greater than in natural, non-exotic sites (Ellis *et al.* 2000). This study and the study by Morgan and Dhalsten mentioned earlier in the paper made my results come with no big surprise. Though when first looking at only abundance and richness enough not enough information is given to make a strong statement regarding the difference of the aerial arthropods in the restored and unrestored sites. The results showed that while the restored sites had a richness of 52 species and the unrestored sites had a richness of 48. The results also showed that no difference could be seen between the abundance of individuals.

The prospect of why, beyond simply restoration in general, diversity was higher will require more tests. But, it is likely that restoration provided greater diversity of vegetation and habitat and led to greater diversity of aerial arthropods inhabiting it. Other variables including dune morphology and time of year will likely have an influence on diversity and my study did not account for this. It may be useful to focus more on a single order of insects and more definitively define the habitats by including dune morphology as well as restoration status. Furthermore, including a comparison with a more natural undisturbed system could yield more information regarding restoration and the progress of restoration.

I also feel that succession is overlooked. It would be useful to measure time since restoration and take measures of diversity through time. The results of this study may have been different if the comparisons between restored and unrestored sites had the same temporal starting points.

While testing specific morpho-species could have been done, the results would not indicate enough. This is do to the lumping together of species that may have occurred. Inadvertently lumping species that should not have been could easily have occurred during identification. It seems inappropriate to test a specific morpho-species for differences by site knowing this.

In conclusion, it has been found that differences of aerial arthropod diversity exist between restored and unrestored areas. This is a promising outcome of restoration efforts and hopefully indicates that the inadvertent (or sometimes not) introduction of non-natives to an environment does not spell the end for that environment.

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