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Conservation of Local Genotypes When Planting Native Plants on Guam

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Abstract—The invasion of ecosystems by exotic plants and animals is a major environmental threat. Examples of exotic plant species threatening various ecosystems are described within these proceedings. The focus on invasion at the whole-plant and population levels often overlooks a more insidious invasion, that of non-native genes into resident populations of native plants. Native plant species have been and will continue to be used in the urban landscape and ecological restoration. Failure to consider the genetics of native planting stock may lead to failed plantings or to introduction of foreign genes into native plants surrounding a restoration site. Eradication of invasive exotic plants in restoration efforts is costly but achievable. The eradication of escaped genes that have invaded native resident populations, however, may not be achievable. Characteristics of the degraded site, abiotic environment of the disturbance, and genetic structure of the native plant species being considered for re-vegetation are some of the critical concepts to consider in ecological genetics.

Introduction

Urban landscape design and construction typically focus on achieving a particular appearance. Although exotic species are most often used in the urban landscape, native plants are used whenever they fulfill the desired appearance. Similarly, exotic species have been used extensively in ecological restoration activities because they adequately re-establish important system functions of disturbed sites such as soil stabilization and nutrient cycling. But because exotic species do not satisfy many ecosystem attributes such as structure and diversity, the use of native species in restoration projects is becoming more common.

Most professionals involved in the landscape industry are aware of the negative consequences of using planting material that is not adapted to a site. However, some believe that as long as native plants are used, local adaptation is implied. As a result, very little attention has been paid to the genetics of native plant material used in landscape and re-vegetation projects.

Increased interest in using native plant species in the urban landscape and in restoration projects on Guam has created a need for a better understanding of the ecological consequences of these activities. Nursery transplants or seeds from off-island have been introduced to Guam in efforts to meet the demand for native plant material. Very little is known about the genetic issues of the plant species that are native to Guam, and synthesis of knowledge specific to these species will not likely precede the continued or expanded practice of using native plants in the landscape. Thus, this report covers some of the current knowledge about risk factors in terms of ecological genetics. Hopefully it will serve as a foundation for a more informed use of native plants in landscape and re-vegetation activities, if only to serve as a warning that caution should govern the process.

Genetic Variation

H.L. Duhamel de Monceau's reports for the French Navy are considered the first written records indicating that seeds from different geographic regions planted at a single location produce trees that survive and grow differently (Langlet 1971). His work was accomplished in the early 1700s with the widespread planting of Scots pine (*Pinus sylvestris*), and indicated that local genotypes performed better than non-local genotypes.

Variation in genetic structure of a species can be described beginning with the broad genetic range of the world-wide population, then progressing more narrowly in range as one looks at the regional population, specific stands, families of plants, and immediate siblings or half-siblings. Many plants evolve specific genotypes that are highly adapted to their immediate environment (Bradshaw 1972, Linhart & Grant 1996).

The minimal emphasis that has been placed on ecological genetics in restoration work is surprising in light of the long written history concerning the consequences of using planting stock from an inappropriate geographic origin. The costs of ignoring these principles when using native plant material in landscape or restoration projects are varied. They range from performance of the plant material after planting to gene flow with native vegetation surrounding the restoration site.

Adaptation to Site

Death of the plant material shortly after planting may occur when the planting stock is collected from a site that poorly matches the restoration site. Many examples of this have been reported (e.g. Illingworth 1975, Squillace & Silen 1962). However, a more typical result is that the plant material becomes established and remains alive, but never attains the health and growth of the surrounding native vegetation. Moreover, in locations characterized by infrequent but predictable extreme events such as pest epidemics or unusually severe droughts, the non-local planting stock may become established and grow well until one of these extreme events occurs.

The original planting may become established and grow well, but carry-over of adaptation to the next generation may not occur. A successful ecological restoration endeavor creates a self-sustaining system that proceeds without intensive management (Jackson et al., 1995). One way that this self-sustaining system can be lost in time is through use of stock with a narrow genetic base, which can lead to inbreeding depression in offspring. Thus, adaptive characteristics of the original planting may be lost.

Genetic Contamination

The previous paragraphs describe varying levels of failure of the landscape or restoration project. But there is a more threatening and insidious consequence of ignoring genetic variation when native plants are used in restoration work. Integrity of the genetic composition of native vegetation surrounding the restoration site may be compromised by introduction of non-local genes into the ecosystem. This can occur any time the introduced stock is sexually compatible with the resident population of native vegetation. Unfortunately, careful re-examination of the vegetation surrounding the planting site through genetic analysis of offspring is commonly the only way to detect genetic contamination.

Consequences of Gene Flow and Risk Factors

Negative consequences of genetic contamination of the resident population with foreign genes are numerous and varied. The most serious consequence is loss of genetic diversity and possible reduction of fitness of local genotypes (Slatkin, 1985; Vila et al., 2000). This occurs with irreversible loss of genes or gene complexes that confer adaptive characteristics to the resident population because of the introduced genes. This may occur in what Whitham (1989) and others referred to as hybrid zones surrounding the restoration site. In wind-pollinated species this zone would follow the wind direction.

An alternative consequence is that adaptive genes in the introduced plant material may be transferred to the native material. This may be beneficial in some respects, especially if adaptation increases for an anthropogenic pressure such as an introduced arthropod or disease. But from an ecological angle, the existing relationships within habitats may be altered in a negative way.

Characteristics of the Plant

The best approach for determining risk of gene flow as influenced by the plant is to study the genetic structure and breeding systems of each species. This is not going to happen any time soon for species that are important components of the native forest habitats in the Western Pacific. But some generalities may be helpful to keep in mind.

In general, insect-pollinated, wind-pollinated, and species with out-crossing flower characteristics pose high risk situations (Ellstrand & Hoffman 1990). However, even if gene flow occurs the risk may not be very high if the resident population of plants is not replaced very often. When gene flow does occur, this means that the seed bank is comprised in part of exotic genes. But will these genes in the seed bank become permanent residents in the forest mosaic? Annuals or short-lived perennials that are replaced often carry the greatest risk of this occurring in the recruitment phase. In contrast, forest trees are perennial, and are not replaced very often. So even if substantial gene flow occurs, the ultimate risk may be minimal since these trees are not replaced very often.

Characteristics of the Site

In severely disturbed sites, especially when the native soil horizon complex is completely destroyed, greater genetic variation may be needed to achieve successful re-vegetation. These are cases that are so dissimilar from the surrounding habitat, that mimicking the vegetation in that surrounding habitat would be of little benefit. Planting stock derived from any surrounding vegetation would not have adaptive genes for the unnatural edaphic conditions.

In minimally disturbed sites where the abiotic environment has not been substantially altered, adherence to local genotypes is best. This minimizes the chances of genetic contamination but also maximizes the chances for successful re-vegetation.

A greater risk of gene flow also occurs in restoration sites that are large. This is a mathematical phenomenon, where a higher number of immigrants relative to the number of residents increases the chances for gene flow.

General Comments about Guam

Species that occur throughout many varied habitats on Guam are the ones that would probably benefit from collecting seeds near the planting site. Some of these plants may include *Pandanus* species, *Hibiscus tiliaceus*, *Scaevola sericea*, and *Cycas micronesica.*

Cycas micronesica is a member of the *Cycas rumphii* group (Hill 1994). Sexual compatibility within this group is not well understood, but compatibility is highly possible (K.D. Hill, personal communication). Until the relationships are studied in greater detail, introduction of any member of this group to Guam carries with it the risk of genetic contamination of the resident population of the Guam cycad.

Intsia bijuga seeds purchased from Philippines in the recent past have been used for growing seedlings that were planted in Guam's urban landscape. The environmental factor that most greatly reduces growth of ifit on Guam is a native psyllid (Marler & Lawrence 1994). Ifit wood is prized for its hardness and durability, and the very slow growth is possibly causal for these characteristics. Non-local seeds may produce stock that behaves differently in the presence of this local psyllid or other local selective pressures. Caution should perhaps prevail with the use of non-local seeds until the genetics of this species are more fully understood.

Native plants should be used in restoration projects only when origin of the planting stock is known. If a commercial nursery has native plants for sale but cannot supply the information describing the habitat of the maternal parent, then the restorationist should refrain from purchasing the planting stock. Instead seeds should be collected for the project, and preferably collected near the restoration site. If seeds are not available near the site, then seed collection should occur in micro-environments that are similar to those found in the restoration site.

The selection pressures that may be used to define habitats for seed collection are elevation, slope, aspect, soil, proximity to wetland, proximity to beach, and wind exposure. Moreover, rainfall is heterogeneous on Guam, with the eastern slope of the southern mountains and the western side of northern Guam receiving slightly more rainfall than the rest of the island (Mark Lander, personal communication). Clouds with bases as low as ca. 180 m can occur frequently on Guam (Mark Lander, personal communication), which is below much of Guam's terrain. Thus, planting stock should be collected in habitats that match the restoration site in relation to these factors.

Guam's urban landscape plantings are comprised in part of native plants. However, the original habitats from which these plants were obtained were probably not recorded. Using these plants as seed source for further planting should be done with caution unless the original habitat can be determined.

Some valuable native species are climax species and young plants cannot be expected to remain viable if they are transplanted to an open site that is more appropriate for pioneer species. Most restoration sites fit this category. *Elaeocarpus joga* is one example, where seedlings and juveniles persist for many years in the protected environment of the forest under-story. If this species or other climax species are to be used in restoration work, the restoration plan may need to include growth of the initial planting for a number of years before the seedlings of these climax species would have an appropriate environment for survival and growth.

Conclusions

Avoiding the use of invasive exotic species in re-vegetation projects is certainly needed to protect Guam's environment. Increased interest in using native species in landscape, mitigation, and restoration endeavors is valuable for the future of Guam's habitats in need of restoration. However, use of inappropriate planting stock of native species may lead to various degrees of failure. Moreover, in terms of ecological genetics, use of non-invasive exotic species is less threatening to the environment than use of introduced genotypes of native species because of the risk of gene flow into the resident population. With increased awareness of these concepts steps can be taken to better preserve the ecological and genetic balances present in the native communities when native species are used in landscape and restoration efforts.

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