

Globalization of Flora: Inviting Worldwide Ecosystem Disaster

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Introduction

Meeting the needs of expanding human populations has changed land use worldwide and presented a biodiversity crisis. Emerging related concerns are threats to native species from homogenization of world flora and the spread of exotic species by human activities (Soule 1990, United States Congress, Office of Technology Assessment 1993, Wilcove and others 1998, Soule and Terborgh 1999). The benefits to people of domestication and spread of food and fiber plants such as wheat, corn, potatoes, and cotton are well known (Diamond 1998). Catastrophes caused by introduced diseases such as chestnut blight and Dutch elm disease are also well known. Less catastrophic introductions of other organisms that can spread rapidly, from West Nile virus to kudzu (*Pueraria lobata*) to aquatic plants and animals, have provoked local headlines and costly control efforts. Less recognized are the less spectacular effects of introduced species such as cheat-grass (*Bromus tectorum*), which has changed the fire ecology and degraded the quality of rangelands

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in much of the West and starlings (*Sturnus vulgaris*), which have become not only an urban and agricultural pest, but also a threat to some indigenous birds. Damage from introduced exotics exceeds \$138 billion per year (Rossman 2001).

Recent research, however, points to even more pernicious phenomena. Agriculture and timber management deliberately simplify vegetation, in similar fashions around the world, creating homogeneous environmental

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conditions that benefit a few rapidly spreading species to the detriment of many other, especially indigenous, species (Mack and others 2000, Mooney and Hobbs 2000, Mack and Lonsdale 2001).

Large areas of uniform environmental conditions actually select the most aggressive species capable of exploiting that environment. Aggressiveness, in the case of plants, includes abilities to disperse and colonize quickly, to grow quickly, to physically

dominate the site, and to bring about chemical or other changes to the environment that discourage other species. Similar attributes may be ascribed to the microbes, invertebrate pests, and vertebrate pests that attack those plants. Some of the organisms favored by uniformity may be indigenous; others come from around the world. Over time, a number of species have become nearly universal in highly cultivated areas of similar climate, thus the globalization of world flora. Of course, the effects are not limited to flora. The Norway rat (*Rattus norvegicus*) and the house mouse (*Mus musculus*), for example, have spread around the world with human migration and trade.

In forestry and agriculture, mechanical tilling, planting, and fertilizing are used to promote desirable species. Mechanical destruction, herbicides, pesticides, genetically modified crops, alternating selected strains of crop plants, antibiotics, and vaccines are used to control undesirable species. When these effects are practiced on a large scale, undesirable species often adapt or develop resistance to such control efforts. A constant adaptive tug-of-war ensues, with other species suffering collateral damage.

Ecological simplification promotes dominance by a few weedy native and non-native species in intensively managed ecosystems; it also promotes system connectedness that increases susceptibility to catastrophe (wind,

floods, fire, disease, insects) and risk of system collapse over time (Tilman 1999, Holling 2001). In other words, homogeneity produces universal vulnerabilities and promotes epidemics of damaging agents. Ecosystems not only collapse catastrophically; they can shift among alternative stable states. These states differ in the mix of ecological, economic, and social values they provide to people, and the degree of external (managerial) support they need to provide those values. The upshot is that large scale reduction of ecological diversity through cultivation promotes not only globalization of world flora and invasion by exotic species, but also presents threats to native species and to system health, especially to resistance to disturbance and resilience in the face of disturbance. Eventually, the capacity of the system to provide ecological, economic, and social benefits is reduced and the costs of providing these benefits rise. These consequences are inextricably linked.

Various efforts have been made to control the introduction of undesirable species and the damage they cause to agriculture and public health, including inspections at borders, quarantines, and eradication programs.

I became familiar with the interrelationships of system complexity, stability, and susceptibility to invasion in my research on conifer forests and oak woodlands in the Pacific Northwest. I have been particularly interested in restoration of the spotted owl-flying squirrel-truffle-Douglas-fir keystone complex (Carey et al. 1992, 1999a,b, Carey 2000) across the Pacific Northwest and restoration and maintenance of the mosaic of oak woodlands, wetlands, and fescue prairies in the Puget Trough of Washington. The Puget Trough mosaic is a natural-cultural legacy of the Vashon glaciation of 16,000 years ago and subsequent vegetation management by Native Americans (Thysell and Carey 2001a).

Problems of Homogenization in Forestry

In the Pacific Northwest, second-growth forests are widespread and there is considerable debate about how to manage these forests to meet societal wants and needs. Some of these forests have been so simplified that they have lost the capacity to provide numerous ecological services to people, including providing habitat for a variety of native wildlife, fungi, and plants. In attempting to restore full ecological function to second-growth forests originating through

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originating through clearcutting, I (and others elsewhere) have found surprising resistance to change. Forests with relatively open canopies of evenly spaced trees have homogeneous understory vegetation dominated by clonal, native plants that exclude many of the species common in natural stands. Forests with dense, even canopies have few understory species compared to natural forests and persistent seeds of weedy species in the soil that would germinate in response to further management. Management activities to open the canopy that disturb the forest floor are immediately followed by the invasion of exotic plants (Toney and others 1998, Halpern and others

1999, Heckman 1999, Thysell and Carey 2000, 2001b, Peltzer and others 2000, Wikstrom and Eriksson 2000). These highly invasive species are part of the "pan-temperate ruderal flora" and are attaining global distribution and dominance (Hobbs and Huenneke 1995). More than 300 introduced species are now common in western Washington (Buckingham and others 1995). Ornamental plants have spread from suburbs and farms into forests. English ivy (*Hedera helix*) is beginning to invade many of the lowland forests in Washington. Ivy climbs up and over understory plants and kills them. Ivy may climb to the tops of mature trees and kill them also. Introduced cherry trees (*Prunus* spp.) and English holly (*Ilex aquifolium*) also are invading lowland forest, adding elements of structure that never existed before. Aggressive native shrubs like salal (*Gaultheria shallon*) and blackberries (*Rubus* spp), and ferns like brackenfern (*Pteridium aquilinum*) and swordfern (*Polystichum munitum*) also grow rapidly when forest canopies are even moderately open and form dense carpets that can shade out other plants. Even if tree crowns grow to fill the canopies again, these understory plants persevere in the reduced light. Thus, any management that opens canopies in a uniform way can lead to relatively uniform understories dominated by aggressive native and exotic plants to the detriment of the bulk of the native understory species. Dominance by these few aggressive species can change the ecology of the forest floor, including the nature of the organic component of the soil and soil food webs that are important to the growth of many trees. Thus, historical management has produced undesirable understory conditions that are difficult to alter (Weber 1997, Toney and others 1998, Peltzer and others 2000, Thysell and Carey 2000).

In oak (*Quercus garryana*) woodlands and Idaho fescue (*Festuca idahoensis*) prairies,

attempts to stimulate colonization and growth of desirable native plants often are thwarted by exotic bunch grasses (*Agrostis capillaris* and *Holcus lanatus*) and the extraordinarily aggressive scotchbroom (*Cytisus scoparius*), an evergreen shrub that is classified as a widespread aggressive invader, noxious weed, and a threat to public health, agriculture, and animals. Exotic grasses were introduced as long ago as the mid 19th century, when the Hudson Bay Trading Company established commercial farms and sheep ranching in the present location of Fort Lewis Military Reservation—before the first permanent settlement of U.S. citizens. Settlement also displaced Native Americans and stopped their traditional, intentional burning that maintained the Puget Trough mosaic. The Nisqually Tribe, with the assistance of tribes more than 20 miles distant, periodically burned the prairies and woodlands to push back invading Douglas-firs and promote the growth of camas (*Camassia quamash*), whose roots were an important source of carbohydrate. Native Americans in the Pacific Northwest had diets rich in protein—from salmon, elk, and deer—but lacked grains and root vegetables.

Scotchbroom was introduced as an ornamental and physical barrier for highway median strips. Scotchbroom rapidly invades any open areas—roadsides, vacant lots, pastures, clearcuts, prairies, Mima mounds (a rare land form), and woodlands. Scotchbroom has little value for forage to domestic or wild animals, may be toxic, and can rapidly displace desirable native and introduced plants. It is tenacious and its seeds last in the soil for 30 years. Plants like scotchbroom, bunch grasses, English ivy, and English holly are capable of bringing about fundamental changes in the ecosystems including reduced capacity for indigenous flora and fauna and traditional human use. Scotchbroom and colonial bentgrass

(Toney et al. 1998, Ussery and Krannitz 1998, Tveten and Fonda 1999, Thysell and Carey 2001a) present the greatest threat to oak communities by altering regeneration niches, promoting acorn decay and altering litter decomposition, altering soil moisture, precluding oak seedling establishment, and increasing fire intensity and frequency (D'Antonio and Vitousek 1992). At risk of loss with the destruction and degradation of oaks, prairies, and lowland wetlands are the western gray squirrel (*Sciurus griseus*) listed by the State of Washington as Threatened and a Federal Species of Concern; the western pocket gopher (*Thomomys mazama*), a

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Federal Species of Concern; and several species of birds, reptiles, amphibians, and butterflies including the Federal Candidate Species, mardon skipper (*Polites mardon*), and the Federal Species of Concern, valley silverspot (*Speyeria zerene bremnerii*), as well as several plant species, including Columbian whitetop aster (*Seriorcarpus rigidus* [*Aster curtus*]), longhair sedge (*Carex comosa*), greenfruit sedge (*Carex interrupta*), smallflower wakerobin (*Trillium parviflorum*), Torrey's pea (*Lathyrus torreyi*), a Federal Species of Concern, and golden Indian paintbrush (*Castilleja levisecta*), a Federal Threatened Species. Thus, the citizens of Washington are in danger of losing a significant part of their natural heritage, the legacies of the Vashon Glaciation (Ryan and Carey

1995a,b; Thomas and Carey 1996; Thysell and Carey 2000, 2001a,b; Bayrakci et al. 2001).

How Can Negative Effects Be So Similar in Different Ecosystems?

Douglas-fir (*Pseudotsuga menziesii*) forests and the Puget Trough mosaic developed naturally under opposite extremes of natural disturbance frequency. Fire return intervals for catastrophic forest fires in western Washington are around 500 years. Most old-growth forests fall in age classes of 400 years, 500 years, or older. On the other side of the spectrum, the Puget Trough mosaic was maintained through light burning by Native Americans on a 2-3 year schedule. Why were these differing ecosystems suffering from such similar ills? The answer became apparent: disruption of historical patterns of disturbance together with management that simplified the ecosystems (1) made ecosystems more homogeneous, (2) removed small-to intermediate-scale disturbance that creates heterogeneity (patchiness), (3) opened the way to invasion by exotics, and (4) led to the development of novel alternative stable states of low diversity and productivity, and decreased sustainability of the goods, services, and amenities we rely on our natural and semi-natural systems to provide. Thus, diversity, invasibility, and biocomplexity are linked (Levine and D'Antonio 1999, Tilman 1999, Thysell and Carey 2001a,b).

What Can Be Done In Forestry?

Based on my studies involving the induction of spatial heterogeneity, it appears that managerially inducing heterogeneity into canopies in second-growth forests can help develop complexity and promote diversity of native plants while reducing susceptibility to invasion by exotic plants. Managing for biocomplexity,

then, provides a new tool for managing for sustainable forests along with more traditional techniques for multispecies management, integrated pest management, and fire management.

The Puget Trough mosaic is, by definition, complex. Without appropriate managerial intervention, encroachment by Douglas-fir and other invasive species will continue, leading to more homogeneous landscape conditions and precluding development of classical oak communities in the future. The complex relationships among oak woodlands, wetlands, prairies, Douglas-fir forests, introduced exotic plants, and intensively developed urban, suburban, and agricultural areas suggest that both a comprehensive set of conservation objectives and a comprehensive assessment of techniques for promoting indigenous species and techniques for controlling exotic species are needed. For example, exclusion of fire to protect property and air quality, without other managerial intervention, leads to succession to a Douglas-fir community. On oak-prairie margins, fire used to control scotchbroom can pose risks to oaks unless it is used frequently enough to prevent excessive accretion of fuel. If fire is too frequent, however, exotic species may be favored over native species (Tveten and Fonda 1999). The frequency, intensity, and season of burning to control exotic species must be carefully chosen to avoid damaging native species. The mechanical destruction of scotchbroom and Douglas-fir before burning will reduce the potential for negative effects on oaks (Tveten and Fonda 1999, Thysell and Carey 2001a). Currently management is not effectively addressing issues of decreasing land area available for natural communities, maintenance of landscape processes such as dispersal and colonization by western gray squirrels, landscape dynamics, or values attributable to the mosaic as a mosaic. Such

issues transcend any one management group. Landscape processes came to the fore in attempts to formulate management recommendations for the western gray squirrel (Ryan and Carey 1995a,b). The creation, improvement, and expansion of oak communities and native prairies will require long-term commitment and adaptive management.

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