THE THREAT TO THE CALIFORNIA FLORA FROM INVASIVE SPECIES; PROBLEMS AND POSSIBLE SOLUTIONS

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ABSTRACT

Non-native invasive plant species continue to threaten the persistence of native plant species and communities in California. Progress toward the control of non-native invasive species can only be made through the combined consideration of ecological and political solutions. These solutions require greater cooperative effort between the academic and lay botanical communities toward understanding the specific impacts and habitat requirements of invaders on a per species basis. Only thorough ecological understanding will lead to the effective implementation of habitat management plans that discourage invaders and encourage the proliferation of native species. Although these recommendations are long-standing, applied and theoretical research on invasive plant species, their habitat requirements and ecological impacts, remains low. Until more data can be gathered and disseminated, the interim solution of local invasive species removal is essential in controlling nascent and potentially aggressive populations. Effective control measures must be combined with the continued education of governmental agencies, horticultural organizations, lobbying groups, and the gardening public regarding the importance of discouraging the use of invasive exotic species for horticultural or land management purposes.

The deterioration of geographic and biological obstacles to the global dispersal of species and human-caused disturbance have dramatically increased in this century and with these changes, plant communities have become more susceptible to invasion from non-indigenous species (Elton 1958, D'Antonio and Vitousek 1992). Although the threat of non-indigenous species to the integrity of native plant communities and species diversity has been recognized for decades (Baker 1962, Dasmann 1966), the urgency of the problem has finally become apparent (Huenneke 1988, Temple 1990). As disturbance to natural ecosystems becomes a more widespread phenomenon, a clearer understanding of the biology and ecological relationships of invasive species is critically important to the conservation of native plant communities.

In California, population growth and its associated commerce and agriculture have led and continue to lead to the introduction and establishment of invasive non-native species since the mid-18th century (Mooney and Drake 1987). These factors disrupt native ecosystems through the direct removal or degradation of native vegetation and result in both the intentional and unintentional intro-

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duction of new species (Kruger et al. 1989). The moderate climate throughout much of California, combined with the early and continued importation of garden ornamentals contribute to the foray of exotic species (Mack 1991). Traits favored for hardy garden ornamentals are often traits repeatedly suggested as important to successful invaders; these traits include continual sexual reproduction, rapid establishment, and hardy growth under a variety of climatic and edaphic conditions (Baker 1974). Rapidly growing and reproducing species often favored for the stabilization of landscapes following fire and landslides have resulted in some of California's worst invaders; these include *Cortaderia jubata, Carpobrotus edulis, Ammophila arenaria* and *Lolium multiflorum.*

The potential impacts from invaders on the native flora and plant communities include genetic contamination (Ellstrand 1992), the reduction of species diversity, alterations to successional patterns (MacDonald et al. 1988), and changes to the physical characteristics of ecosystems and ecosystem processes (Vitousek 1986). Hybridization and introgression between native species and their invasive congeners has been substantiated in species of *Helianthus* (Rieseberg et al. 1989) and with one of the rarest tree species in California, *Cercocarpus traskiae* (Rieseberg et al. 1989). There is, however, little information on the extent of hybridization between native and introduced species and its possible consequences at the community or ecosystem level (Ellstrand 1992). Although it is debatable whether *Carpobrotus chilensis* is native to California or to Chile (Bicknell and Mackey 1988, Vivrette 1993), its hybridization and introgression with the aggressive South African native, *C. edulis,* is one of the most widespread examples of hybridization between previously allopatric species. Current research is exploring the potentially important genetic and ecological implications of this hybridization (D'Antonio and Schierenbeck unpublished data).

Establishment of an invader in a community can result in the loss of species diversity and the alteration of successional patterns (MacDonald et al. 1988). Although much anecdotal evidence exists in California (see *Fremontia* vol. 12, no. 4 and vol. 13, no. 5), little is known about which native species are most susceptible to encroachment from an invasive species or the measurable extent of change an invader can bring to a plant community.

It has been well-established that invaders can bring change to the physical characteristics of ecosystems (Vitousek 1986, D'Antonio and Vitousek 1992). This phenomenon has been documented with *Myrica faya,* which can alter nutrient cycling (Vitousek et al. 1987), *Tamarix* spp. which can alter hydrological regimes (Brotherson and Field 1987, Loope et al. 1988) and with grasses such as *Schizachyrium condensatum* which can modify the frequency of fire-cycles (Hughes et al. 1991). Despite the number of invaders in California

that are suspected of possessing the ability to alter the physical characteristics of ecosystems, there are few such long-term ecosystem studies.

The obstacles which need to be overcome in making progress in the battle against invasive species are many but include some particularly important aspects. First and foremost, there needs to be stronger recognition of and action taken against the causes of invasive species proliferation. Disturbance is recognized as a major source of entry for invasive species, yet it continues in many forms. Secondly, there is a need for more empirical studies on the biology and ecological interactions of invasive species and the data resulting from such studies need to be more effectively applied to the management of conservation areas. Lastly, increased funding for the eradication of new and old populations of invasive species combined with improved detection and reporting methods of new occurrences will aid in their containment. These hinderances to the understanding and control of invasive species are described in more detail below.

Probably the most significant factor in the continual proliferation of invasive species is the physical disruption of plant communities and alterations to their disturbance cycles (Orians 1986, Hobbs and Huenneke 1992). Disturbance comes in many forms, virtually all of which offer a potential point of entry for invasive species. Examples of types of disturbance include: the disruption of natural disturbance regimes through grazing or fire suppression which can favor non-native species preadapted to the altered condition (Hobbs and Huenneke 1992); the gradual establishment and encroachment of an invasive species which can itself result in the perpetuation of an altered disturbance cycle (Hughes et al. 1991); small conservation areas which, by definition, have large edges and thus large zones of disturbance; and conflict between conservation and recreation within or near a natural area which can maintain low-level disturbance and the continual import of invaders. Considering the plethora of examples of both disturbance and the occurrence of non-native species in California, there have been surprisingly few empirical studies on these phenomena as they relate to ecological interactions within native plant communities.

Often the assumption is made that if an area is preserved it will be maintained in a natural state. However, it has become clear that wilderness or conservation areas, with the exception of those in places like Alaska, are not sufficiently large to maintain the large or even small scale disturbances necessary to maintain community diversity at a level that existed prior to the human perturbation (Brussard 1991). Discerning the ecological relationships between an invader, the community in which it occurs, and disturbance can often require subtle detective work. For example, recent work with

disturbance and pollinator populations in Argentina suggests small conservation areas support primarily those species that accept the most generalist pollinators (a trait common in invaders) (Aizen and Feinsinger 1994). The selection of generalist pollinators in small conservation areas can result in a larger seed set for the invaders and may reduce genetic diversity in those species with more specific pollination systems. The secondary and even tertiary impacts of disturbance and their role in non-native species proliferation needs to be discerned empirically.

Since the first seminal meeting on colonizing species in which the characteristics of invaders were outlined (Baker and Stebbins 1965), there have been attempts to make predictions as to which species have the greatest potential to become invasive (Bazzaz 1986, Newsome and Noble 1986). Recent research suggests the invasiveness of a species is not due to the general traits of the invader per se but to the fit of a species' characteristics with specific habitat characteristics (Bossard 1993, Schierenbeck et al. 1994). Not until there is a thorough understanding of how each invader functions in its new range environment will there be some modicum of control against these pests. The recent finding that *Cytisus scoparius* has differential germination in coastal and Sierra Nevadan habitats provides information that can be used toward its control through prescribed burning (Bossard 1993). Bossard's study underscores the need for understanding the specificity of the relationship between invaders and their new range habitat.

Funding for conservation efforts has often centered on the preservation and recovery of rare species. Unfortunately, the conservation of rare species and plant communities cannot be achieved without a better understanding of threats to the survival of the ecosystems in which they occur. In some cases, large amounts of funds and effort have been expended toward removing invasive species in conservation areas as illustrated by attempts to eradicate *Ammophila arenaria* (Van Hook 1985). However, it is difficult to maintain progress against these control efforts without understanding what factors allow an invader to proliferate. Subtle relationships can exist between a species' phenology, response or lack of response to herbivory, and disturbance (Schierenbeck et al. 1994). Where the factors encouraging the expansion of invasive species are unknown, management regimes could inadvertently encourage growth, reproduction and dispersal.

Regional, state and federal parks are under heavy impact from recreational and agricultural use. Although conservation areas are set aside for protection, they are often too small or heavily used to maintain ecosystems in a natural state without heavy management input. Those natural areas in close proximity to urban centers are particularly susceptible to disturbance and to the dispersal of non-

native species. Unfortunately, land use conflict within and around natural areas is a problem without easy resolution. Lands managed by the U.S. Forest Service have recently been issued a respite in the battle against invasive species. The U.S.F.S. has issued a policy on the management of noxious weeds and their control and hopefully will follow through with its strong implementation. The California Department of Food and Agriculture continues to provide leadership in controlling invasive species, however their emphasis remains on those species that have primary impacts on agricultural lands.

The deliberate and continued reintroduction of invasive species is a practice which defies comprehension but continues for political expediency. For example, *Lolium multiflorum* is still being used for reseeding efforts under the auspices of governmental action even though its short- and long-term benefits are questionable (Zedler et al. 1983, Barro and Conard 1987).

It is becoming increasingly obvious that the maintenance of natural ecosystems can require intensive management (Brussard 1991). In summary, obstacles to the effective management of ecosystems in a state that existed prior to European influence are: an underfunding of biological and ecological studies of invasive species and the communities that they invade, a lack of adequate fund sources for the detection and eradication of invasive species in non-agricultural systems, a lack of strong agency policy toward resolving conflicts that influence the effectiveness of control efforts, continued reintroductions of invasive non-native species, and continued and new disturbances.

Where do we go from here? Policy decisions for habitat management must be based on sound data, however, in most cases this is not possible and the problems are immediate. Much of existing knowledge of invasive species exists in the form of anecdotal information in the lay botanical community. Although it in no way diminishes the need for scientific experimentation, the dissemination of anecdotal information on the occurrence and effective control of invasive species needs to be improved. The continued detection and eradication of growing populations of invaders is crucial to their control. Detection efforts could be enhanced through the increased use of geographic information systems as has been successfully demonstrated with the *Centaurea solstitialis* (Parris and Pitcairn unpublished data). Removal efforts should be prioritized based on those species which have been determined to result in the greatest amount of change to community or ecosystem characteristics. The continued education efforts of the California Native Plant Society and the California Exotic Pest Plant Council are vital to informing the lay public of the potential threats from non-indigenous species and as conduits of information to and from the scientific community.

Steps toward lessening the invasive species problem in the man-

aged ecosystems of California are led by the need to gain a clearer understanding of the specifics of each invasive species' biology and ecological interactions within a specific ecosystem, and the relative role of disturbance in the ecosystem of interest. Introduced species must be studied in their host ecosystem; synergistic relationships with native constituents can only be determined empirically. Habitat management plans need to be based on long-term experimentation. Just how are successional relationships and species diversity within a particular community affected by disturbance and invasive species? The opportunities of entry and proliferation for invasive species need to be identified on a case-by-case basis. Is the proliferation of an invasive species due primarily to disturbance or to the combined effects of competition, disturbance and the disruption of ecosystem characteristics? The control of invasive species includes an increased need for the widespread acceptance and implementation of the intensive management of ecosystems. It is unrealistic to expect an ecosystem to remain self-perpetuating with the small sizes and continual disturbances with which we are faced.

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