Non-native and Invasive Plants

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Introduction

This chapter will cover what non-native and invasive plants are, why they are important, how to prevent them from spreading, and how to manage them once they are established. The focus of this chapter is on invasive plants, but much of this information also applies to other organisms such as invasive pathogens and animals. Most of the information in this chapter is from the following books: *Invasive Plants of California's Wildlands* (Randall et al. 2000), *Weed Control in Natural Areas in the Western United States* (DiTomaso et al. 2013), and *California Grasslands: Ecology and Management* (D'Antonio et al. 2007). A list of organizations involved in weed management in the Santa Cruz area is included at the end.

Terminology

Native plants are those present in their natural range, or where they have evolved. In North America, a plant is often considered native if it was present before European contact. Natural ranges should not be confused with political boundaries. For example, yellow bush lupine (*Lupinus arboreous*) is considered a California native, but it is not native along the coast of California north of San Francisco where it has been introduced. Synonym: indigenous.

Non-native plants are those present beyond their natural range. This includes domesticated species, feral species, and hybrids with at least one non-native parent species. This term reflects species origin and does not have implications for the impact on native species or ecosystem functions. Introduction of non-native species is often linked to human activity. For example, people often plant non-native ornamental plants in their gardens, and these ornamentals sometimes escape into the wild. Synonyms: exotic, alien, introduced, non-indigenous.

Invasive plants are those in the process of spreading into areas where they are not native. Some researchers consider a species invasive if it negatively influences community or ecosystem properties, while others think that the term "invasive" should not imply any impact. Not all non-native plants are invasive; a non-native species may be present in the wild without actively spreading into other areas. Again, natural ranges should not be confused with political boundaries; a plant species native to a certain state can still be invasive in that same state, as long

as the species is spreading outside of its native range. Some species that are native and even threatened in one location can be invasive elsewhere (e.g. Monterey pine [*Pinus radiata*] in New Zealand).

Weeds are plants that are undesirable because they interfere with management goals. They can be native, non-native, or invasive. This is a general term for any plant that is undesirable.

Impacts of invasive plants: why are they important?

Invasive plants can negatively impact both the natural world and human activities. Land managers and ecologists are often concerned about invasive plants because they are a major threat to native species and habitats. Invasives can outcompete native species for resources such as space, water, light, and nutrients. For example, invasive vines such as English ivy (*Hedera helix*) damage forests across the continent by smothering native plants and outcompeting them for light. Invasive plants can also degrade or eliminate habitat for native animals that depend on native plants and provide habitat for other non-native plants or animals. In some Mediterranean islands, invasive ice plant (*Carpobrotus* spp.) chokes out native plants and provides food for invasive rats and rabbits, which also have negative impacts on native diversity. Ecosystem processes such as disturbance regimes, nutrient cycles, and hydrological cycles can also be greatly altered by invasive plants. For example, cheat grass (*Bromus tectorum*) has invaded millions of acres in the Great Basin, leading to an increase in fire frequency by increasing fuel load. In this ecosystem, native shrubs cannot withstand more frequent fires and have been largely reduced or eliminated in these areas. By spreading into and dominating new areas, invasive plants cause habitat degradation, species extinction, and lowered biodiversity.

Invasive plants also negatively affect humans by causing enormous problems for agriculture, recreation, and safety. They compete with food crops and degrade rangeland forage for livestock. Invasive plants also negatively affect recreational activities such as hiking, biking, boating, hunting, wildlife viewing, and photography by blanketing landscapes and degrading wildlife habitat. Some species increase the risk of fire by increasing fuel loads, and others can increase the risk of floods by clogging up waterways.

Invasion ecology: why do invasions happen?

Because invasions have such dire effects on ecosystems, invasion ecologists aim to understand the factors that affect invasions. These factors include: resources, characteristics of invaders, characteristics of communities, and natural enemies. Keep in mind that the hypotheses discussed in this section are working hypotheses with mixed support in the scientific literature.

Resources and competition

One factor contributing to an invader's success is its ability to outcompete native species for resources, namely light, water, space, and nutrients. According to Tilman's R* rule, R* is the concentration of a limiting resource that a species requires to survive in a habitat. An invasion will happen if the invader has a smaller R* value than the resident species, or in other words, if the invader can survive with a lower concentration of a resource than the resident. This occurs if the invader uses the resource more efficiently or is better at acquiring the resources than the resident.

Invasive species can also succeed by avoiding competition with native species to acquire resources. For example, the empty niche hypothesis posits that invaders are successful when they utilize resources that are unused by native species. By occupying an empty niche, an invader can escape from competition for its resources. According to the novel weapons hypothesis, some invaders avoid competition by producing allelopathic chemicals that the native species have never encountered. These chemicals kill or inhibit the growth of native species, increasing the resource availability for the invader.

Characteristics of Invasive Plants

Plant traits alone are not enough to determine if a species will become invasive, but there is a suite of traits that may help invasive plants succeed in invading new areas.

Characteristics of invasive plants
High reproduction rate
Short generation time
Pioneer species
Long-lived
High dispersal rates
Vegetative or clonal reproduction
High genetic variability
Phenotypic plasticity
Tolerant of wide range of conditions
Habitat generalist
Close association with humans

Table 1. Characteristics of successful invasive species (modified from Mac et al. 2004).

Characteristics of Invaded Habitats and Communities

There is no clear way to determine which habitats and communities are more likely to be invaded, but there are some pattern and hypotheses. It is generally agreed that anthropogenic disturbances in the biotic or abiotic environment facilitate plant invasions. Native species might not be as well adapted to the changed conditions, freeing resources for invaders. For example, fertilizer for agriculture often runs off into adjacent ecosystems, and many invasive species are better adapted to rapidly take up nutrients than natives are. Human disturbed areas, such as land used for agriculture or recreation, are likely to be invaded by species that are adapted to such human disturbances in their native range. In addition, the novel niche hypothesis posits that anthropogenic changes to the environment produce new niches that invaders can utilize.

Also, the diversity-resistance hypothesis suggests that more diverse communities have fewer unutilized niches, which prevents invasion. Therefore, less diverse communities are

hypothesized to be more susceptible to invasion, although the many experimental tests of this hypothesis show highly variable results. Also related is the maturity concept, which posits that younger communities have had less time for species to assemble and adapt to local conditions than older communities. Younger communities therefore tend to have fewer species with broader niches and lower competitive abilities, making young communities more susceptible to invasion. This concept can be related to succession theory, in which early successional communities (e.g. grasslands) are more prone to invasion than late successional communities (e.g. forests).

Natural enemies

The success of some invaders in a new range can be contributed to the "escape" from natural enemies, such as pathogens, parasites, and herbivores. This is known as the enemy escape hypothesis and occurs when specialist predators (e.g. predators adapted to preying on native species) in the invaded community do not affect an invasive species, and the invasive leaves its own specialist predators from its native range behind. The invasive is therefore exposed to fewer enemies and can reach higher abundances. The opposite may also be true; naïve invaders might not be able to defend themselves against enemies in the invaded community, which reduces the success of the invasion. Also, as discussed above, the biotic resistance hypothesis suggests that native consumers control non-native plant populations to prevent invasion.

Invasion failures

Most non-native species do not become invasive, and invasion ecologists are also interested in why some plants fail to become invasive. Some ideas—the diversity-resistance and the naïve invader hypotheses—were discussed above. Many of these ideas overlap, and more broadly, the concept of biotic resistance describes the ability of the ecological interactions within a community to resist or constrain invasions. Some interactions that might confer resistance include competition from native species, herbivores, and high diversity.

Invasive Species Management

Because of the dire consequences of non-native and invasive species, weed management is often a major part of land management in places like natural reserves and rangelands. These land managers often have weed management plans to prevent and control invasions. Because of

limited time and resources, it is important for land managers to establish management goals and prioritize weed control efforts. For example, preventing, detecting, and eliminating new invasions are high priorities (discussed further below). High priority is also given to species with the most damaging impacts, invasions that are spreading quickly, and invasions that affect highly valued areas. It is also important to acknowledge that the ultimate goal of weed management is to help a species, community, or ecosystem become more functional, rather than simply controlling all non-native and invasive species.

Preventing invasions is the best control strategy. Prevention is less expensive in the long term, and invasive species are difficult to eradicate once they are established. If an invasion is not prevented, there are several strategies that can be utilized to control established invasives. Each method has advantages and disadvantages, so methods that work well in one situation may not work in another. Often, the best approach is to use a combination of methods and to have a long-term weed management program.

Table 2. Common invasive plant management options for coastal California terrestrial ecosystems - discussed below.

Management options
Prevention
Mechanical/physical control
Manual removal
Mowing or cutting
Soil solarization
Prescribed fire
Biological control
Natural enemies
Grazing
Chemical control

Prevention

The most effective weed control strategies are preventing invasions and quickly detecting new invaders so they can be eliminated or contained before they spread. Once an invasive species that causes severe damage is established and widespread, it can be difficult and costly to control, so preventing or stopping an invader is extremely beneficial in the long run. Long-term vegetation monitoring of a site can detect the arrival of new species, which can then be noted and followed to see if they spread. In addition, agencies such as the United States Department of Agriculture (USDA), California Department of Food and Agriculture (CDFA) and California Invasive Plant Council (Cal-IPC) provide lists of invasive species that are available online, and these lists are helpful for deciding if the arrival of a new species is cause for concern. If a new species in a site is known to be invasive elsewhere, the land manager can quickly take action to remove or contain the species before it can spread and wreak havoc. Eradication is most feasible when the species is just starting to spread, so monitoring and early detection are essential. Cal-IPC and partner organizations have developed an online tool to map invasive weeds in California (http://calweedmapper.calflora.org/) that can help land managers to determine the extent of invasions to help prioritize eradication and management efforts.

There are many other precautions that can be taken to prevent plant invasions. Responsible plant nurseries should not sell plant species that are known to be invasive. Planting invasive species should also be avoided in landscaping and home gardens. When it is essential to plant problematic species, such as in a vegetable garden or a botanical garden, the plants should be monitored and kept from spreading outside of the planted area. Individuals should also refrain from introducing new species into wild areas, either intentionally or unintentionally. For example, washing seeds off of tools or clothing before entering a new area is one way to prevent accidental introductions. Public education and outreach about the non-native and invasive species is also important so that individuals can take steps to prevent and control invasions.

Mechanical/Physical Control

Mechanical control strategies remove entire plants or physically damage the plants to the point where they cannot survive. These strategies include hand-removal, the use of hand and power tools, and the use of heavy equipment like tractors and bulldozers. These techniques can

be labor-intensive and disturb the soil, which can promote reinvasion or new invasions. Nonetheless, these methods have been successfully utilized by volunteer groups and paid workers to control weedy plant species. These methods can also be highly selective and targeted toward specific species. There are many mechanical and physical control strategies, but here we discuss only manual removal, mowing/cutting, and soil solarization.

Manual removal

Hand-pulling, shoveling, hoeing, and using other hand tools are strategies for removing entire plants. They are effective for controlling species that are just starting to spread or small populations of weeds. One advantage of these strategies is that they can be highly selective, so specific individuals can be targeted and the desired plants can be left in place. These strategies are more effective in loose or moist soil so that it is easier to completely remove the crown or root buds, and all reproductive fragments of the plants should be removed from the site to prevent resprouting. Manual removal is easiest for small herbaceous plants or young woody plants, but larger woody species like shrubs are more difficult to remove and require the use of special tools, such as a weed wrench. For illustrations of many weed removal tools and further discussion of manual removal techniques see Holloran et al. (2004). Manual removal would not be suitable for very large woody plants like trees.

Mowing or cutting

Mowing involves using a mower or tractor with a mowing attachment to cut off the above-ground parts of a plant. By removing the shoot of a plant, mowing can prevent or decrease seed set, reduce plant vigor, and deplete carbohydrate reserves. This is especially successful for controlling annual species. For biennial and perennial species, mowing can reduce seed production and suppress plant growth if used repeatedly. Mowing can also be beneficial for certain species by removing litter buildup and increasing light penetration. The effects of mowing are often species-specific, so it is important to consider how each species in a system will respond to mowing to avoid damaging desired species and promoting undesired species. In addition, mowing is often not feasible in steep terrain and in systems with a high density of mature woody plants.

Good timing is critical to the success of mowing. The best time to mow most annual species is in the flowering stage before seed development. In addition, mowing when soil moisture is low will lower the potential for regrowth. Mowing too early does not remove a significant amount of weed biomass, which allows the weed to recover with new growth. Mowing too late will not prevent seed production, which can result in similar or worse weed problem in the subsequent year.

When mowing is not feasible, as in the case of certain perennial and woody species, several other weed control options can be attempted. Invasive trees can often be quickly and easily killed using a technique called girdling. Girdling involves removing the bark and cambial tissues in a strip around the tree's trunk. This inhibits water and nutrient transport in the tree. Although relatively inexpensive and easy, this method alone is often unsuccessful because trees can resprout below the girdle and, in some cases, recover their cambial connections and survive.

Another method involves removing stems using brush cutters, power saws, machetes, loppers, or clippers, but this method is also not enough to prevent resprouting. These cutting methods are more effective when used in conjunction with herbicide.

Soil solarization

Soil solarization involves placing a polyethylene plastic tarp over soil. In warm climates such as the Central Valley of California, clear plastic can be placed over moist soil to create a greenhouse effect under the tarp, producing high temperatures that kill or weaken seeds underneath. In cooler climates such as along the central coast, black plastic can be placed over soil to kill plants by blocking all light. In either case, the plastic should cover the soil for a month or longer. This method is most feasible in flat areas that do not have mature woody plants, unless the woody vegetation is removed beforehand. This method is also non-selective and kills all plants, so it should be used only where there is little or no native vegetation.

Prescribed Fire

Fire can be an effective way to control weeds, particularly in systems that evolved with fire, such as grasslands and chaparral. The main objectives of burning are to kill invasive plants' seeds and reproductive structures and to stimulate growth of native species. The success of burning is dependent on the frequency, intensity, and timing of fire, and these factors should be

carefully considered along with how different species in the system respond to fire. Generally, fire is most successful for controlling late season annuals and shrubs that do not resprout from the base. Fire can also be used to remove thatch and recycle the nutrients in dead vegetation.

Conducting prescribed burns has many risks. Escaped fires can be dangerous near populated areas and damaging to ecosystems that were not intended to burn. There are also concerns about air quality, and it is often necessary to obtain legal permission before conducting a prescribed burn. In addition, fire may promote certain invasive species or make an area more easily invaded. Careful consideration and planning are essential for a successful prescribed burn.

Biological Control

Natural enemies

Classical biocontrol involves introducing natural enemies of invasive species from their native range into their invaded range. These natural enemies are typically insects or pathogens. The goal of this method is to put stress on invasive plants in order to reduce their populations, and the biocontrol agent is expected to permanently establish and spread to control the weed.

It is important that the biocontrol agent has high host-specificity, or in other words, will only prey upon the target invasive species. If the agent is not host-specific, it can potentially attack native plant species and become a disastrous invasive species, which has happened in some cases. Because of this liability, a lot of research is necessary before introducing a biocontrol agent, and the process is often long and costly. However, when a biocontrol agent is successful, the economic cost of developing and testing a new agent is outweighed by the benefits gained from permanent control of an invasive species.

Grazing

Grazing animals such as cattle and goats can be used to control undesired species, especially in grassland systems. The effectiveness of this method is dependent the type of grazer, stocking rates, grazing frequency, and timing. The vegetation composition is also an important factor when designing a grazing system. Although grazing can be successful for controlling weeds, it can also have negative effects such as trampling and higher invasion if the grazing system is not designed well.

Different animals have different preferences for certain plants, so the type of grazer can be selected based on which plant species are present. Stocking rate, or the number of animals on an area of land over a certain amount of time, can also be adjusted to fit management needs. Low stocking rates can be unsuccessful if the weed species are unpalatable and successful if the grazers prefer the weed species over the desired species. High stocking rates can force cattle to eat less preferable plants, resulting in a more uniform vegetation composition and less competition for desired plants. However, overgrazing without periodic rest can reduce the competitiveness of desired species and increase the invasion of less palatable weeds. The timing of grazing is also important, and the ideal time to graze is when undesirable species are most susceptible to defoliation or when the impact on desirable species is smallest.

Chemical Control

Herbicides are chemicals that inhibit or kill plants. There are many types of herbicides, and they differ in their mode of action, selectivity, and application place (soil or foliar). Different chemicals disrupt plant function in different ways, and the type of weed should be considered when choosing a suitable herbicide. For example, several herbicides with auxin-like growth regulators selectively control broadleaf species (as opposed to grass species), while glyphosate inhibits amino acids and is non-selective.

The selectivity of the herbicide application is also an important consideration. One method of application is broadcast application, which is conducted using aircrafts or tractors and can quickly cover a lot of ground. However, broadcast herbiciding is not selective, therefore should be used where there are few or no desirable species present. A more selective method is to use spot treatments, in which herbicides are applied with backpack sprayers or wick applicators.

The appropriate application location should be chosen based on the life stages of the plants that are being herbicided. Herbicides applied to the soil generally target emerging seedlings (pre-emergent), and herbicides applied to foliage target plants ranging from seedlings to mature (post-emergent). Broadcasting foliar herbicide is easiest for herbaceous or young woody species but is more difficult when dealing with larger and taller plants. Spot treating is more effective when controlling tall woody vegetation. In these cases, herbicides are often applied directly to stem tissues such as a cut stump. In general, there are many different

herbicides that can be utilized depending on the characteristics of the weed and the surrounding environment.

Herbicides pose several environmental risks. These risks include: drift, volatilization, persistence in the environment, water contamination, and harmful effects on non-target plants and animals. Herbicides with the least environmental impacts can be used selectively, degrade rapidly, are immobilized on soil particles, do not volatilize easily, and are non-toxic to animals. Herbicides can be extremely effective and efficient for controlling invasive plants, but the environmental risks should be carefully considered when using this strategy.

Local entities who work on controlling non-native and invasive species

There are several academics, agencies, and organizations in the Santa Cruz area who have volunteer and internship opportunities to get experience in weed management.

- **UCNRS (University of California Natural Reserve System).** This is a UC-wide network of protected natural areas designated for research and education. Each campus manages a set of reserves. UCSC manages four reserves: Año Nuevo, Big Creek, Ford Ord, and Younger Lagoon. To learn more about the UCNRS, see http://nrs.ucop.edu/index.htm. To learn more about each UCSC reserve and for contact information, see http://ucsantacruz.ucnrs.org/.
- **UCSC Campus Reserve**. The campus reserve encompasses natural lands surrounding the UCSC campus. This is part of the UCSC reserves, but not the larger UCNRS. These lands are also designated for research and education. To learn more and for contact information, see http://ucsantacruz.ucnrs.org/?page_id=26.
- **UCSC Arboretum**. The arboretum is a botanical garden with rich and diverse plant collections. It is a research and teaching facility that is dedicated to plant conservation. For more information, see http://www.ucsc.edu/index.html.
- **UCSC Site Stewardship Program.** The mission of this program is to involve the university community in the restoration and guardianship of UCSC land. To learn more, see http://ucscplant.ucsc.edu/ucscplant/Grounds/index.jsp?page=Stewardship_Program.
- **UCSC Greenhouses.** This facility has a botanical collection, lab, library, and outdoor classrooms. For more information, see http://greenhouse.ucsc.edu/.
- **CNPS (California Native Plant Society).** This organization works to protect

California's native plants and promotes native plant appreciation, research, education, and conservation. Santa Cruz has its own regional chapter. For information about CNPS, see http://www.cnps.org/. For information about the CNPS Santa Cruz chapter, see http://www.cruzcnps.org/ or to join one of their invasive removal work parties see http://www.cruzcnps.org/habitat_restoration.html.

- **California State Parks.** These parks are run by the California Department of Parks and Recreation. They protect and preserve natural and cultural heritage sites throughout California. To learn about California State Parks, see http://www.parks.ca.gov/. **Friends of Santa Cruz State Parks** funds many programs for the State Parks in the Santa Cruz Area. To learn more about Friends, see http://www.thatsmypark.org/.
- **Land Trust of Santa Cruz County.** This organization protects and manages lands of significant natural resource, agricultural, cultural and open space value. To learn more, see http://www.landtrustsantacruz.org/mission_vision.htm.
- **Coastal Watershed Council.** This Santa Cruz-based organization advocates for the preservation and protection of coastal watersheds through the establishment of community-based watershed stewardship programs. They focus on stewardship, education, and monitoring. For more information, see http://coastal-watershed.org/.
- Professors whose labs study non-native and invasive species: **Karen Holl** (http://people.ucsc.edu/~kholl/people.html), **Ingrid Parker** (http://bio.research.ucsc.edu/people/parker/Home.html), **Greg Gilbert** (http://people.ucsc.edu/~ggilbert/), and **Erika Zavaleta** (http://people.ucsc.edu/~zavaleta/).

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