Invasive forest species

Nonnative organisms that cause a major change to native ecosystems—oncecalled foreign species, biological invasions, alien invasives, exotics, or biohazards–are now generally referred to as invasive species or invasives. invasive species of insects, fungi, plants, fish, and other organisms present a rising threat to natural forest ecosystems worldwide. Invasive animals are transferred to ecosystem in which there are no natural predators to keep them from spreading. Many species escape into the new environment where they become established, upsetting the ecological balance of the native forest ecosystem. Some invasives are competitors or predators of native species, whereas others cause disease.

Transfer into new ecosystems. The transfer of invasive species into new ecosystem can be either unintentional or intentional.

Unintentional introduction. Unintentional introductions of invasive species are generally a result of international trade and global human travel for immigration, business, and tourism. The invasive species problem is becoming a greater threat to native forests worldwide because international trade and human mobility are increasing, leading to an increase in entry pathways for invasives. Pathways for unintentional introduction of invasive species to new ecosystems include world trade of products (unprocessed wood logs, timber, lumber and chips; seeds; soil and plants for nursery stock; and biological organisms) and product packaging (wood pallets, crates, spools, and dunnage). For example, the Asian longhorned

Perennial vine legume kudzu (*Pueraria lobata*) growing in California. (*Reprinted with permission, © 2001 CDFA*)

beetle was introduced into the United States on wood packing material, and invasive earthworms were unintentionally introduced into many countries in ballast water dumped from ships or from rooted soil of imported plants. Another pathway for unintentional introduction is the natural movement of species from one ecosystem to another within the same geographic region.

Intentional introduction. Some invasive plant species have been intentionally transferred to new areas as ornamentals, food, fiber, and erosion control agents. Several plants introduced into the United States are now causing problems on a monumental scale. Though not all nonnative species become invasive threats to forests, examples that do include the perennial vine legume kudzu (see **illustration**), which was introduced for erosion control; Johnson grass, introduced as an agricultural crop; purple loosestrife, originally introduced as an ornamental in the nineteenth century; and the gypsy moth, introduced for silk production.

Impact on forests. Invasive species are a force of global change. They negatively affect natural ecosystems throughout the world by outcompeting native species for habitat, resources, and growing space. The problem is wide-ranging, impacting almost all terrestrial and aquatic forest habitats. Some invasives are predators to native species; others cause or spread disease. Invasives spread quickly because there are no natural predators or consumers to prevent their population growth. They disrupt native ecosystem function by altering nutrient cycling and habitat quality of native species. Alteration and loss of habitat can lead to displacement and reduction of native species, with major impacts on ecosystem diversity. Displacement of natural species can be permanent. Invasive species negatively impact already threatened and endangered species, further reducing the biodiversity of native organisms.

Invasive species also cause major spatial and temporal landscape level changes to native forest ecosystems. They are known to remove impOrtant ecosystem elements, altering forest composition at all levels. Trees, microorganisms, and animals (in. cluding fish, birds, amphibians, and reptiles) are affected as food webs are disrupted. Invasives call eliminate tree species as a functioning component of forests. Removal of bird habitats threatens extinction of rare species in isolated ecosystems. For example, earthworms from Europe, Asia, and South America became invasive species in the Philippines, Russia, and the United States. Brazilian earthworms are harming Philippine rice terraces. Nonnative earthworms degrade the leaf litter on the forest floor, disturbing the biodiverse habitat of insects, isopods, bacteria, fungi, and other litter-inhabiting organisms. The ecosystem food chain is removed for ground-nesting birds and for small mammals such as shrews and voles. Populations of native microorganisms are at risk of becoming extinct in some areas, especially fungi that are needed for nutrient uptake by roots of trees and other forest plants. The decrease in nutrient cycling is harmful to trees and plants in the forest understory.

Disease. Invasive insects and fungi degrade forest health by causing or contributing to disease outbreaks. The majority of the most devastating and destructive forest diseases are caused by invasive species. Tree diseases have practically eliminated the dominant native species from some of the world's major forest ecosystems. For example, chestnut blight and Dutch elm disease have killed the American chestnut and elm trees, dramatically eliminating forest ecosystems in the eastern United States. At least 26 invasive insects (such as the Asian longhorned beetle, hemlock woolly adelgid, emerald ash borer, and gypsy moth) and fungi (such as *Discula destructiva,* which causes the disease dogwood anthracnose) threaten to wipe out 70 million acres of forests in the United States.

Forest fires. Tree diseases contribute to increased fire risk by causing extensive mortality rates that result in dead and dry trees that can easily burn. This "fuel load" contributes to a high risk of fire and produces extremely hot flames during forest fires. The invasive plant species European cheatgrass contributes to fuel load by competing with natu. ral plants in piñon-juniper forests. Cheatgrass grows faster and dries before native plants, forming highly flammable ground cover that burns completely. This combination of an invasive plant and fire hinders reestablishment of native plants and prevents forest sustainability.

Watershed and riparian areas. Invasive species have invaded land around streams, lakes, and other waterways. Plants and animals that depend on these riparian areas are threatened with extinction. The fast-growing purple loosestrife plant has displaced riparian area species, causing soil erosion and de. pleted soil nutrients. An invasive reed canary grasS is spreading in riparian areas, blocking water floW in streams. Invasive fish in riparian areas and warersheds have disrupred the ecological balance of aquatic ecosystems.

Multiple invasions. Native forests can be impacted by a symbi$_0$tic relationship between two invasive species originating from the same ecosystem. An example is the impact on North American maple forests by the two European invasives, earthworms and buckthorn. Earthworms deplete biomass on the forest floor, adding extra nitrogen to the soil. The buckthorn plant spreads rapidly in high-nitrogen soils, providing more native food for the earthworm. The symbiosis between the two species prevents essential carbon cycling and nutrient availability. These impacts cause shifts in biodiversity and threaten extinction of native understory vegetation, maple trees, and species that depend on them.

Human health. In addition to impacting human livelihood, some invasive species can have a direct deleterious effect on human health. An example is the "itchy grub" caterpillar, native to Australia, which has invaded New Zealand. The caterpillars or gum leaf skeletonizers have poisonous hairs that cause a persistent itchy rash. The reaction to the poison varies with each person. The caterpillar causes extensive damage to gum (*Eucalyptus*) trees in New Zealand and Australia.

Island ecosystems. Island ecosystems are especially vulnerable to invasives due to their unique, fragile ecosystems and evolutionary isolation. Ancient palm forests of the Seychelles are threatened by the spread of the tree *Cinnamonum verum*, introduced for commercial and economic reasons. Forests on the islands of Tahiti and Hawaii are threatened by overgrowth of the invasive plant miconia (*Miconia calvescens*). Introduced as an ornamental, miconia grows rapidly with 3-ft-long (90-cm) leaves that shade native plants, blocking needed sunlight. The plant's small seeds contribute to its rapid spread.

Societal effects. Invasive species degrade recreational areas, decreasing access to and reducing the quality of public and private forests. Cultural and ecological losses are compounded by the social and economic loss of jobs, loss of long-term supply of forest products, and monetary costs associated with possible solutions to the problem.

Prevention and control. A global strategy is needed to address the invasive species issue. International organizations are recognizing the ecological and economic problems caused by invasive forest species. The recently established Global Invasive Species Program (GISP) will compile and publish international information about invasive species prevention and control methods, including forest species. The Food and Agriculture Organization (FAO) of the United Nations has an increased focus on destabilization of forest ecosystems by invasive species, promoting appropriate measures for their control. Management of invasive forest species includes several approaches at the international, national, and local community levels.

Risk assessment. Risk assessment involves determination of the potential introduction of invasives; identification of the priority invasives and ecosystems that are at risk; identification of the pathways by which invasives may he transported from one ecosystem to another; assessment of the risks associated with each pathway and invasive species; and recommendation of short-term and long-term control methods.

Prevention. The first step in controlling invasive species is to prevent the transfer of invasives from one ecosystem to another. One way to achieve this is via the establishment of international quarantine standards that require control measures for a given invasive species pathway One successful example is the recent international quarantine standard for heat or methyl bromide treatment to kill organisms on wood packing material, thereby slowing global transport of potential invasives.

Public awareness. An important step toward protecting global forest ecosystems is through awareness and education. The public can help identify and eradicate invasives (especially in urban areas), refrain from transporting invasives during travel, and support international, national, and local efforts to address the invasives problem. New Zealand has a major public awareness campaign that uses "Max the Biosecurity Beagle" as a mascot to provide information about how the public can help with early detection of all invasives that pose a threat to the environment. Although New Zealand has no current forest plantation pests, the forests are at risk from three species (gypsy moth, fall webworm, and gum leaf skeletonizer).

Detection. Detection methods include survey, sampling, and identification protocols. Early detection systems are used to identify newly introduced species that were not intercepted by quarantine methods. Detection strategies are used to survey forest ecosystems and regularly monitor forests for invasives. Deoxyribonucleic acid (DNA) analysis is the identification protocol currently used for *Phytophthora ramoru,* the causal agent of "sudden oak death" disease in California.

Eradication. Removing invasive species from forests includes the use of chemical (insecticides, fungicides, herbicides, and attractants), mechanical (such as harvesting and hand pulling), and biological control methods. Biological control (also known as biocontrol) uses natural enemies to manage and control pests. The commercially available bacterium *Bacillus papillae* was the first insect pathogen to be registered in the United States as a biological control agent against the Japanese beetle. The bacterium *B. thuringiensis* var. *kurstaki* is used as a biological control agent against the gypsy moth. New introductions can usually be eradicated. Containment and control of some established species is necessary when total eradication is not possible.

Restoration. Long-term measures are required to restore degraded ecosystems that have been negatively altered by invasive species. Although many approaches are used around the world to reclaim ecosystems, all require removal of invasives and replanting native trees. Additional approaches have included reconstruction of stream banks in riparian areas and watersheds; addition of soil amendments (fertilizer, erosion control mat, leaf compost, wood

mulch, riparian plants) and root symbionts (mycorrhizae fungi); and reintroduction of native animals, microbes, and other organisms.

For background information *see* ECOLOGICAL COMPETITION; ECOLOGICAL SUCCESSION; FOREST ECOSYSTEM; INVASION ECOLOGY; POPULATION ECOLOGY in the McGraw-Hill Encyclopedia of Science & Technology.

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