Invasive Species Definition Clarification and Guidance White Paper

Submitted by the Definitions Subcommittee of the Invasive Species Advisory Committee (ISAC)

Approved by ISAC April 27, 2006

Preamble: **Executive Order 13112** – defines an *invasive species* as **"an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health**." In the Executive Summary of the National Invasive Species Management Plan (NISMP) the term *invasive species* is further clarified and defined as **"a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health**." To provide guidance for the development and implementation of the NISMP, the National Invasive Species Council (NISC) and the Invasive Species Advisory Committee (ISAC) adopted a set of principles outlined in Appendix 6 of the NISMP. Guiding Principle #1 provides additional context for defining the term *invasive species* and states "**many alien species are non-invasive and support human livelihoods or a preferred quality of life.**" However, some alien species (non-native will be used in this white paper because it is more descriptive than alien), for example West Nile virus, are considered invasive and undesirable by virtually everyone. Other non-native species are not as easily characterized. For example, some non-native species are considered harmful, and therefore, invasive by some sectors of our society while others consider them beneficial. This discontinuity is reflective of the different value systems operating in our free society, and contributes to the complexity of defining the term *invasive species.*

NISC is engaged in evaluating and updating the 2001 NISMP and is developing comments for a revised action plan as required by the EO 13112. While there have been numerous attempts to clarify the term *invasive species,* there continues to be uncertainty concerning the use and perceived meaning of the term, and consequently over the prospective scope of actions proposed in the NISMP. Options related to private property use, pet ownership, agriculture, horticulture, and aquaculture enterprises may be affected depending upon the definition, use, and policy implications of the term.

Weeds As Examples

Weeds provide good examples to clarify what is meant by an invasive species because most people have a concept of what constitutes a "weed."

Invasion can be thought of as a process that in our example, a plant must go through to become a successful, yet harmful invader. Several barriers must be overcome for a plant to be considered an invasive weed. Invasive weeds are invasive species.

Large-scale geographical barriers

First, a geographical barrier first must be overcome, which often occurs as a mountain range, ocean, or similar physical barrier to movement of seeds and other reproductive plant parts. Plants that overcome geographical barriers are known as alien plants or alien species. Alien plants are non-native plants and alien species are non-native species. Therefore, non-native plants are those that occur outside their natural range boundaries, and this most often is mediated by humans either deliberately or unintentionally.

Survival barriers

The second set of obstacles that a non-native plant must overcome is barriers to germination and survival in its new location. These typically are environmental barriers such as adequate moisture availability to allow successful germination and survival of seedlings that will continue to grow to maturity. Other physical barriers might be soil pH, nutrient availability, or competition for resources from neighboring plants.

In particular, the desire to consider a non-native species as 'invasive' may trigger a risk/benefit assessment process to determine whether regulatory action is warranted. All these uncertainties have stood and could continue to stand in the way of progress in actions and policy development to prevent new invasions and manage existing invasive species. While it is not the purpose of this white paper to define a risk/benefit assessment process, development of such a process must be open and efficient to minimize the uncertainties.

This white paper is intended to provide a non-regulatory policy interpretation of the term *invasive species* by identifying what is meant, and just as important, what is not meant by the term. ISAC recognizes that biological and ecological definitions will not precisely apply to regulatory definitions. We believe, however, that our clarification will apply to *all taxa of invasive species in all habitats* and furthermore, our explanation will be functional and acceptable to most stakeholders. ISAC simply wants to clarify what is meant and what is not meant by the term invasive species in the technical sense and to provide insight into those areas where societal judgments will be necessary to implement effective public policy.

The utility of our clarification should be in education, conflict resolution, and efficiency in the planning, prevention, control/eradication, and management of *invasive species.*

ISAC recommends that NISC adopt the clarifications presented in this white paper to foster progress for invasive species management in the United States.

Introduction

An invasive species is a non-native species whose introduction does or is likely to cause economic or environmental harm or harm to human, animal, or plant health. The National Invasive Species Management Plan indicates that NISC will focus on non-native organisms known to cause or likely to cause negative impacts and that do not provide an equivalent or greater benefit to society. In the technical sense, the term 'invasion' simply denotes the uncontrolled or unintended spread of an organism outside its native range with no specific reference about the environmental or economic consequences of such spread or their relationships to possible societal benefits. However, the policy context and subsequent management decisions necessitate narrowing what is meant and what is not meant by the term *invasive species.* Essentially, we are clarifying what is meant and not meant by "causing harm" by comparing negative effects caused by a non-native organism to its potential societal benefits.

Weeds As Examples (continued)

Establishment barriers

The third obstacle that a non-native plant must overcome to be considered an invasive weed, is to form a population that is self-sustaining and does not need re-introduction to maintain a population base such that it continues to survive and thrive in its new environment. Once this occurs, this population of non-native plants is considered to be established. Environmental barriers to survival and establishment are similar.

Dispersal and spread barriers

Established non-native plants must overcome barriers to dispersal and spread from their site of establishment to be considered invasive plants. Additionally, the rate of spread must be relatively fast. However, this movement or spread alone does not necessarily make this non-native plant an invasive weed or invasive species.

Harm and impact

Finally, a plant is deemed to be invasive if it causes negative environmental, economic, or human health effects, which outweigh any beneficial effects. For example, yellow starthistle is a source of nectar for bee producers. But the displacement of native and other desirable plant species caused by yellow starthistle leads to dramatically decreased forage for wildlife and livestock, which severely disrupts the profitability of associated businesses. These negative effects greatly overshadow the positive effects and thus, define harm caused by yellow starthistle and explain why it is considered an invasive species.

Perception to Cause Harm

Complications concerning the concept of *invasive species* arise from differing human values and perspectives. Differing perceptions of the relative harm caused or benefit gained by a particular organism are influenced by different values and management goals. If *invasive species* did not cause harm, we would not be nearly as concerned. Perceptions of relative benefit and harm also may change as new knowledge is acquired, or as human values or management goals change.

For a non-native organism to be considered an *invasive species* in the policy context, the negative effects that the organism causes or is likely to cause are deemed to outweigh any beneficial effects. Many non-native introductions provide benefits to society and even among species that technically meet the definition of invasive, societal benefits may greatly exceed any negative effects (for example crops and livestock raised for food). However, in some cases any positive effects are clearly overshadowed by negative effects, and this is the concept of causing harm. For example, water hyacinth has been popular in outdoor aquatic gardens but its escape to natural areas where its populations have expanded to completely cover lakes and rivers has devastated water bodies and the life they support, especially in the southeastern U.S. And, there are some organisms, such as West Nile virus, that provide almost no benefits to society at all. Such organisms constitute a small fraction of non-native species, but as a consequence of their ability to spread and establish populations outside their native ranges, they can be disastrous for the natural environment, the economies it supports, and/or public health. Because *invasive species* management is difficult and often very expensive, these worst offenders are the most obvious and best targets for policy attention and management.

The negative impact to a native species caused by an *invasive species* might trigger additional negative interactions for other associated native species; i.e., there could be direct and indirect effects. For example, an invasive weed that is undesirable as a food source may outcompete and displace native grasses and broadleaf plants. These displaced native grasses and broadleaf plants may have been primary forage for animals, which subsequently would be displaced to a new location or have their populations reduced because the weed invasion decreased the availability of food in their native plant and animal community. However, negative effects are not always characterized by a cascade of impacts realized throughout the environment. For example, simple displacement of an endangered species by a non-native species might alone provide sufficient justification to consider the non-native organism an *invasive species*.

What We Do Not Mean, What We Do Mean, and the "Gray" Area

Native and Non-native Species

Invasive species are species not native to the ecosystem being considered. Canada geese are native to North America and most of their populations migrate annually. However, in some locations in the U.S. (e.g. suburban Maryland; the Front Range of Colorado) introduced, non-migratory populations of Canada Geese are causing problems – such as fouling lawns, sidewalks, grass parks, and similar areas. While non-migratory populations can cause problems, they are not considered an *invasive species* because they are native. Additionally, Canada geese are of significant financial value to many local economies through waterfowl hunting and simple enjoyment. Mute swans, however, are invasive. Mute swans are native to Europe and Asia but were introduced into North America where their populations have increased dramatically. They compete directly with native waterfowl for habitat, displacing them, and that is why they are considered an *invasive species*. Whitetail deer populations have increased dramatically in the northeastern U.S. and are problems in farms, yards, and natural areas because they consume plants valued by humans; but are not invasive because they are native. Nutria, on the other hand, are another classic example of an *invasive species*. Nutria are native to South America but were introduced into North America where their populations have soared. Nutria

compete directly with native muskrats, beavers, and other similar native species for habitat; often causing the displacement of these native species.

Feral Populations

It is also essential to recognize that *invasive species* are not those under human control or domestication; that is, *invasive species* are not those that humans depend upon for economic security, maintaining a desirable quality of life, or survival. However, the essential test is that populations of these species must be under control. Escaped or feral populations of formerly domesticated plants and animals would be considered *invasive species* if all the concepts and conditions are met as outlined in "Weeds Are Examples." Cereal rye being produced on a farm in Kansas is considered very desirable, but feral rye on the breaks of the Poudre River in Colorado would be considered an *invasive species* because it is displacing native plants and the native animal communities they support. Domesticated goats on a farm in Texas are considered highly desirable, but feral goats in Haleakala National Park on Maui are considered an *invasive species.* Feral goats have severely overgrazed areas and eliminated native Hawaiian plants, which were never adapted to grazing. Areas denuded by feral goats have led to increased soil erosion.

A Biogeographical Context

An *invasive species* may be invasive in one part of the country, but not in another. A biogeographical context must be included when assessing whether a non-native species should be considered an *invasive species*. Lake trout are highly desirable in the Great Lakes where they are native, but are considered an *invasive species* in Yellowstone Lake. They compete with native cutthroat trout for habitat, which decreases their populations. Atlantic saltmarsh cordgrass is an essential component of east coast salt marshes, but is highly invasive on the west coast where it covers mudflats and displaces native estuarine plants and the community of animals they support, including huge flocks of migrating waterfowl. Kentucky bluegrass would be considered an *invasive species* in Rocky Mountain National Park in Colorado, but considered non-invasive a mere 60 miles away at a golf course in Denver. English ivy is considered a good ground cover species in the Great Plains and Midwest, but is a highly invasive weed in the forests of the Pacific Northwest and Eastern U.S. where it outcompetes native plants and displaces the associated animal communities.

The "Gray" Area

There are obvious examples of *invasive species* such as snakehead fish, yellow starthistle, or *Phytophthora ramorum* (the organism that causes sudden oak death); and there are obvious examples of species that are not invasive, namely native plants and animals. There are, however, non-native organisms for which it will be difficult to make a determination and these should be subject to assessment. Whether these non-native organisms will be considered *invasive species* will depend upon human values. For example, European honeybees are cultured to produce honey and pollination services, and even though they form wild populations in many parts of the country and occasionally create problems by building hives in the walls of homes or can be a human health problem for individuals that are highly allergic to their sting, most would not consider them an *invasive species* because they produce a desired food product.

Another gray area example would be native termites v. Formosan termites. No one wants termites in their homes but only Formosan termites would be considered an *invasive species* because they are non-native. Smooth brome also serves as another gray area example. It was imported from Russia in the 1890s for forage and was widely planted. It clearly has escaped cultivation and can be found in many natural areas particularly in the western U.S. but in most situations, smooth brome would not be considered an *invasive species* because of its forage value for wildlife and livestock.

Chinese or Oriental clematis serves as another gray area example. Chinese clematis (virgin's bower, orange peel) is a popular ornamental that has been planted worldwide. However, it has escaped cultivation in several western states where its populations can spread, particularly in shrubland, on riverbanks, sand depressions, along roadsides, in gullies, and along riparian forests in hot dry valleys, deserts, and semi-desert areas. Escaped populations of Chinese clematis occur in Idaho, Nevada, Utah, New Mexico, and Colorado but so far, it is considered an *invasive species* only in Colorado where it has spread dramatically from its site of introduction and displaced native plant species.

Environmental Harm

We use environmental harm to mean biologically significant decreases in native species populations, alterations to plant and animal communities or to ecological processes that native species and other desirable plants and animals and humans depend on for survival. Environmental harm may be a result of direct effects of *invasive species*, leading to biologically significant decreases in native species populations.

Examples of direct effects on native species include preying and feeding on them, causing or vectoring diseases, preventing them from reproducing or killing their young, out-competing them for food, nutrients, light, nest sites or other vital resources, or hybridizing with them so frequently that within a few generations, few if any truly native individuals remain. Environmental harm includes decreases in populations of Federally Listed Threatened and Endangered Species, other rare or uncommon species and even in populations of otherwise common native species. For example, over three billion individual American chestnut trees were found in U.S. forests before the invasive chestnut blight arrived and virtually eliminated them. Environmental harm also can be the result of an indirect effect of invasive species, such as the decreases in native waterfowl populations that may result when an invasive wetland plant decreases the abundance of native plants and thus, decreases seeds and other food that they provide and that the waterfowl depend upon.

Environmental harm also includes significant changes in ecological processes, sometimes across entire regions, which result in conditions that native species and even entire plant and animal communities cannot tolerate. For example, some non-native plants can change the frequency and intensity of wildfires, or alter the hydrology of rivers, streams, lakes and wetlands and that is why they are considered *invasive species*. Others can significantly alter erosion rates. For example, trapping far more wind-blown sand than native dune species, or holding far less soil than native grassland species following rainstorms. Some invasive plants and micro-organisms can alter soil chemistry across large areas, significantly altering soil pH or soil nutrient availability. Environmental harm also includes significant changes in the composition and even the structure of native plant and animal communities. For example, the invasive tree *Melaleuca quinquinervia*, can spread into and take over marshes in Florida's Everglades, changing them from open grassy marshes to closed canopy swamp-forests.

Environmental harm may also cause or be associated with economic losses and damage to human, plant and animal health. For example invasions by fire promoting grasses that alter entire plant and animal communities eliminating or sharply reducing populations of many native plant and animal species, can also lead to large increases in fire-fighting costs and sharp decreases in forage for livestock. West Nile virus is a well known human health problem caused by a non-native virus which is commonly carried by mosquitoes. West Nile Virus also kills many native bird species, causing drastic reduction in populations for some species including crows and jays.

Additional Examples of Impacts Caused by Invasive Species

Specific examples of the harm caused by *invasive species* are useful to further clarify the definition. The following list of examples is not meant to be comprehensive, but offers further explanation:

Impacts to Human Health

Respiratory infections: The outbreak of *West Nile virus* in the U.S. began in the Northeast in 1999 and has since spread throughout the country. Infections in humans may result in a flu-like illness and in some cases death. This outbreak has caused illness in thousands of citizens, increased medical costs for affected persons, and decreased productivity due to absence from work. *West Nile virus* also has affected horses and has caused widespread mortality in native birds (U.S. Centers for Disease Control, 2006).

Poisonous plants: Exposure to the sap of *Tree-of-heaven/Chinese sumac tree* has caused inflammation of the heart muscle (myocarditis) in workers charged to clear infested areas. Afflicted personnel experienced fever/chills, chest pain that radiated down both arms, and shortness of breath. Exposure occurred when sap from tree-of-heaven contacted broken skin. Such exposure has caused hospitalization, medical expense, and lost productivity due to absence from work (Bisognano et al. 2005).

Impacts to Natural Resources

Declines in wildlife habitat and timber availability: *Chestnut blight* is a disease of American chestnut caused by a non-native fungal pathogen that was introduced into eastern North America around 1910. The disease eliminated the American chestnut from eastern deciduous forests thereby decreasing timber harvests and wildlife that depended upon the American chestnut for habitat (USDA-APHIS/FS 2000).

European gypsy moth defoliates trees on millions of acres of northeastern and mid-western forests. It currently is found in 19 states causing an estimated $3.9 billion in tree losses and also decreased wildlife habitat (USDA-APHIS/FS 2000).

Decreased soil stabilization and interrupted forest succession: *White pine blister rust* is a disease of white pine species caused by the non-native fungal pathogen *Cronartium ribicola*. It was introduced into eastern North America around 1900 and western North America in 1920. It spread rapidly, killing off native white, whitebark, and limber pines, whose seeds are an important food source for birds, rodents and bears. Elimination of these trees caused by this pathogen alters forest ecosystems, eliminates wildlife forage, and decreases the soil stabilization effects of these trees, snowmelt regulation, and forest succession (Krakowski et al. 2003).

Changes in wildfire frequency and intensity: C*heatgrass* decreases the interval between the occurrences of wildfires in the Great Basin region from once every 70 to 100 years to every 3 to 5 years because it forms dense stands of fine fuel annually. The decrease in interval between wildlfires causes increased risk to human life and property and also places at risk established communities of plants and animals that we consider desirable (Knapp 1996; Pimentel et al. 2000; USFWS 2003; Whisenant 1990).

Excessive use of resources: *Tamarisk* in the desert southwest use more than twice as much water annually as all the cities in southern California, which places this invasive weed in direct competition with humans for the most limiting resource in the southwestern U.S. (Friederici 1995; Johnson 1986).

Suppressors: *Russian knapweed* exudes toxins from its tissues that inhibit the growth of surrounding plants or eliminates them. Desirable plant communities are placed at risk from *Russian knapweed* invasion, which may result in decreased numbers of wildlife species or livestock that the invaded land otherwise could support. *Russian knapweed* also is very toxic to horses (Stevens 1986; Young et al. 1970a and 1970b).

Decreased carrying capacity for wildlife and livestock: Expansion of *leafy spurge*, *yellow starthistle*, or other unpalatable invasive weeds displace desirable forage plants and may allow fewer grazing animals to survive in infested areas (DiTomaso 2001; Lym and Messersmith 1985; Lym and Kirby 1987).

Impacts to Recreational Opportunities and Other Human Values

Decreased property values: *Asian longhorned beetles* first appeared in New York in 1996 and in Chicago in 1998. Larvae burrow into trees causing girdling of stems and branches, dieback of the crown, and can kill an entire tree. It infests many different tree species in the U.S. and is a threat to urban and rural forests (Cavey et al. 1998).

Emerald ash borers were first detected in the U.S. in 2002. They currently are found in Michigan, Ohio, and Indiana. Emerald ash borer larvae tunnel under bark of ash trees and could eliminate ash as a street, shade, and forest tree throughout the U.S. Estimated replacement cost in six Michigan counties is $11 billion and an additional $2 million in lost nursery sales (Chornesky et al. 2005).

Dutch elm disease was first introduced into the U.S. in 1927 and occurs in most states. Dutch elm disease has killed more than 60% of elms in urban settings and decreased the value of urban and suburban properties (Brasier and Buck 2001).

Spotted knapweed and *leafy spurge* expansion in the western U.S. have displaced desirable forage plants thereby decreasing the value and sales price of grazingland in the western U.S. (Maddox 1979; Weiser 1998).

Eurasian watermilfoil was introduced into the U.S in the 1940s and has since spread throughout much of the country. This submersed aquatic plant can form dense mats at the water surface limiting access, recreation, and aesthetics and thus, has decreased the values of shoreline properties in New Hampshire, the Midwest and elsewhere (Halstead et al. 2003).

Decreased sport fishing opportunities: *Whirling disease* is caused by a parasite (*Myxobolus cerebralis*) that most likely originated in Europe. It was first observed in the U.S. in 1958. The parasite attacks the soft cartilage of young trout causing spinal deformities and causes the fish to exhibit erratic tail-chasing behavior. Heavily infected young trout can die from *Whirling disease* and even if they recover, they remain carriers of the parasite. All species of trout and salmon may be susceptible and angling and the businesses supported by trout and salmon fishing may be at risk if this disease continues to spread (Aquatic Nuisance Species Task Force et al. 2005; Colorado Division of Wildlife 2006).

Smallmouth bass fishing in Lake Erie was closed during bass mating because of *round goby* predation of nests. Fishing was closed because male smallmouth bass aggressively guard nests from predators and are easier to catch by anglers during this time of year. Removal of males by anglers decreased the number of bass offspring because of increased *round goby* predation of unguarded nests (Steinhart et al. 2004). Businesses that smallmouth bass anglers patronize could be adversely affected by such closures.

Altered business opportunities: The concern over *Sudden Oak Death Syndrome* caused by the pathogen *Phytophthora ramorum* is causing drastic changes in available nursery stock by nurseries and landscape businesses. This clearly impacts the profitability of these businesses and choice by consumers and could devastate oak forests nationwide (Chornesky et al. 2005; Rizzo and Garbelotto 2003).

Annual harvests of oysters in Long Island Sound averaged over 680,000 bushels during 1991 through 1996. After *Haplosporidium nelsonii* (MSX) invaded in 1997 and 1998, oyster harvests decreased from

1997 through 2002 to an average annual harvest of 119,000 bushels with a low of 32,000 bushels in 2002. The overall ex-vessel value of oyster farming dropped 96% in 10 years from $45 million in 1992 to $2 million in 2002 (Sunila et al. 1999).

Non-native algae introduced into the Hawaiian Islands costs Maui alone about $20,000,000 annually due to algae fouling the beaches and subsequent lost tourism (Carroll 2004; Keeney 2004; Univ. Hawaii 2006).

Sea lampreys were introduced into Lakes Ontario and Erie during the construction of the Welland Canal and quickly spread to the other Great Lakes. The *sea lamprey* is a parasite that attaches itself to fish, eventually killing them, and has devastated commercial and recreational Lake Trout fishing in the Great Lakes (Lawrie 1970).

Australian spotted jellyfish were introduced into the Gulf of Mexico in 2000 and occurred in such massive numbers that shrimping operations were shut down because jellyfish clogged shrimp nets (Graham et al. 2003).

Altered ecosystems and recreational opportunities: The submersed aquatic plant *hydrilla,* forms dense canopies at the water surface that raise surface water temperatures, change pH, exclude light, and consume oxygen, resulting in native plant displacement and stunted sport fish populations. This example of an altered aquatic ecosystem caused by an invasive aquatic weed also negatively affects recreation and businesses that depend upon that human activity (Colle et al. 1987).

Summary

Invasive species are those that are not native to the ecosystem under consideration and that cause or are likely to cause economic or environmental harm or harm to human, animal, or plant health. Plant and animal species under domestication or cultivation and under human control are not *invasive species*. Furthermore for policy purposes, to be considered invasive, the negative impacts caused by a non-native species will be deemed to outweigh the beneficial effects it provides. Finally, a non-native species might be considered invasive in one region but not in another. Whether or not a species is considered an *invasive species* depends largely on human values. By attempting to manage *invasive species*, we are affirming our economic and environmental values. Those non-native species judged to cause overall economic or environmental harm or harm to human health may be considered invasive, even if they yield some beneficial effects. Society struggles to determine the appropriate course of action in such cases, but in a democratic society that struggle is essential.

Many *invasive species* are examples of "the tragedy of the commons," or how actions that benefit one individual's use of resources may negatively impact others and result in a significant overall increase in damage to the economy, the environment, or public health. In ISAC's review of Executive Order 113112, the public domain is specifically represented; however, the implementation of the NISMP has prompted concerns over the rights of personal and private property owners. Property rights are of great importance in the U.S. and one outcome of the NISMP should be to recognize the right to self determination by property owners and promote collaboration on *invasive species* management. The right to self determination is an important concept in a democratic society, however, with that right comes personal responsibility and stewardship, which includes being environmentally responsible. The natural environment that our society enjoys, recreates in, and depends upon to support commerce must be conserved and maintained. Effective *invasive species* management is just one aspect of conserving and maintaining our nation's natural environment, the economies it supports, and the high quality of life our society enjoys.

References

Aquatic Nuisance Species Task Force, U.S. Fish and Wildlife Service, and U.S. Coast Guard. 2005. Protect Your Waters. Harmful Aquatic Hitchikers: Others: Whirling Disease. [Online] http://protectyourwaters.net/hitchhikers/others_whirling_disease.php.

Bisognano, J.D., K.S. McGrody, and A.M. Spence. 2005. Myocarditis from the Chinese sumac tree. Annals Internal Medicine 143(2):159.

Brasier, C.M. and K.W. Buck. 2001. Rapid evolutionary changes in a globally invading fungal pathogen (Dutch elm disease). Biological Invasions 3:223-233.

Carroll, R. 2004. Maui battling seaweed invasion. Assoc. Press. [Online] http://thehonoluluadvertiser.com/artucke/jan/05/ln/ln10a.htm

Cavey, J.F., E. R. Hoebeke, S. Passoa, and S.W. Lingafelter. 1998. A new exotic threat to North American hardwood forests: an asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae). I. Larval description and diagnosis. Proc. Entomol. Soc. Wash. 100 (2):373-381.

Chorensky, E.A., A.M. Bartuska, G.H. Aplet, K.O. Britton, J. Cummings-Carlson, F.W. Davis, J. Eskow, D.R. Gordon, K.W. Gottschalk, R.A. Haack, A.J. Hansen, R.N. Mack, R.J. Rahel, M.A. Shannon, L.A. Wainger, and T.B. Wigley. 2005. Science priorities for reducing the threat of invasive species to sustainable forestry. BioSci. 55(4):335-348.

Colle, D.E., J.V. Shireman, W.T. Haller, J.C. Joyce, and D.E. Canfield. 1987. Influence of Hydrilla on Harvestable Sport-Fish Populations, Angler Use, and Angler Expenditures at Orange Lake, Florida. North American Journal of Fisheries Management 7:410-417.

Colorado Division of Wildlife. 2006. Whirling disease and Colorado's trout. [Online] http://wildlife.state.co.us/fishing/whirling.asp.

DiTomaso, J. 2001. Element stewardship abstract: Centaurea solstitialis L. Weeds on the web: The Nature Consevancy wildland invasive species program. [Onlin] http://tncweeds.ucdavis.edu/esadocs/docmnts/centsols.htm

Friedercici, P. 1995. The alien saltcedar. Am. For. 101:45-47.

Graham, W.M., D.L. Martin, D.L. Fedder, V.L Asper, and H.M. Perry. 2003. Ecological and economic implications of a tropical jellyfish invader in the Gulf of Mexico. Biological Invasions 5(1-2) 53-69.

Halstead, J.M., J. Michaud, S. Hallas-Burt, and J.P Gibbs. 2003. Hedonic analysis of effects of a nonnative invader (*Myriophyllum heterophyllum*) on New Hampshire (USA) lakefront properties. Environmental Management 32(3): 391-398.

Johnson, S. 1986. Alien plants drain western waters. The Nature Conservancy News, Oct-Nov 1986.

Keeney, T.R.E. 2004. Written testimony before the Subcommittee on Fisheries Conservation, Wildlife and Oceans, Committee on Resources, U.S. House of Representatives. http://www.ogc.doc.gov/ogc/legreg/testimon/108s/keeney0415.htm

Knapp, P.A. 1996. Cheatgrass (Bromus tectorum L.) dominance in the Great Basin Desert: History, persistence, and influences to human activities. Global Environ. Change 6(1):37-52.

Krakowski , J., S.N. Aitken, Y.A. El-Kassaby. 2003. Inbreeding and conservation genetics in whitebark pine. Conservation Genetics 4:581-593.

Lawrie, A.H. 1970. The sea lamprey in the Great Lakes. Transactions of the American Fisheries Society 99:766-775.

Lym, R.G. and C.G. Messersmith. 1985. Cost effectiveness of leafy spurge control during a five-year management program. North Dakota Farm Res. 43(1)7-10.

Lym, R.G. and D.R. Kirby. 1987. Cattle foraging behavior in leafy spurge infested rangeland. Weed Technol. 1:314-318.

Maddox, D.M. 1979. The knapweeds: Their economics an biological control in the western states, U.S.A. Rangelands 1(4):139-141.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of non-indigenous species in the United States. Biosci. 50(1):53-65.

Richardson, D.M., P. Pysek, M. Rejmanek, M.G. Barbour. F.D. Panetta, and C.J. West. 2000. Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions 6:93-107.

Rizzo, D.M. and M. Garbelotto. 2003. Sudden oak death: Endangering California and Oregon forest ecosystems. Frontiers in Ecology and the Environment 1:197-204.

Steinhart, G.B., E.A. Marschall, and R.A. Stein. 2004. Round goby predation on smallmouth bass offspring in nests during simulated catch-and-release angling. Transactions of the American Fisheries Society 133: 121-131.

Stevens, K.L. 1986. Alleopathic polyacetylenes from *Centaurea repens* (Russian knapweed). J. Chem. Ecol. 12:1205-1211.

Sunila, I., J. Karolus, and J. Volk. 1999. A new epizootic of *Haplosporidium nelsoni* (MSX), a haplosporidian oyster parasite, in Long Island Sound, Connecticut. Journal of Shellfish Research 18(1): 169-174.

U.S. Fish and Wildlife Service, 2003. Costly fires hurt wildlife habitat. [Online] http://www.fws.gov/deerflat/currfire.htm

Univ. of Hawaii. 2006. Invasive marine algae of Hawaii. [Online] http://www.hawaii.edu/reefalgae/invasive_algae/INDEX.HTM

U.S. Center for Disease Control. 2000. Fight the Bite. [Online] http://www.cdc.gov/nicdod/dvbid/westnile/index.htm

USDA-APHIS/FS. 2000. Draft pest risk assessment for importation of solid wood packing materials into the United States. http://www.aphis.usda.gov/ppq/pra/swpm/

Weiser, C. 1998. Economic effects of invasive weeds on land values (From and agricultural banker's standpoint). Proc. Colorado Weed Summit April 7-8, 1998. p. 35-38.

Whisenant, S.G. 1990. Changing fire frequencies on Idaho's Snake River Plain: Ecological and management implications. The Station. Nov. 1990 (276) Ogden, UT: General Technical Report INT – USDA Forest Service Intermountain Research Station.

Young, S, W.W. Brown, and B. Klinger. 1970a. Nigropallidal encephalomalacia in horses caused by ingestion of weeds of the genus *Centaurea*. J. Amer. Vet. Med. Assoc. 157:1602-1605.

Young, S., W.W. Brown, and B. Klinger. 1970b. Nigropallidal encephalomalacia in horses fed Russian knapweed (*Centaurea repens* L.). Amer. J. Vet. Res. 31:1393-1404.