

The Impact of Invasive Species on Ecosystem Services and Human Well-being

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Non-native Invasive Species and Global Change

- Non-native invasive species (NIS) are widely recognized as a top driver of species extinction.
- NIS, however, also inflict serious damage on ecosystem goods and services which are the lifeline of the human enterprise.
- Overall, there is relatively little science linking invasive species directly to ecosystem services.
- The full economic impact of invasive species on ecosystem services is often incompletely assessed.
- As a result, NIS are an “invisible tax” on ecosystem services that is not accounted for in decision making.

Defining and Quantifying Impacts

1. NIS impacts can be economic, environmental or social

- a. Economic: financial loss or gain
- b. Environmental: biodiversity and ecosystem structure and function
- c. Social: human health, happiness and cultural values

Impacts of NIS on ecosystem services necessarily include all categories

2. Magnitude of impact depends on valuation

How important are ecosystem services to society?



Ecosystem Goods and Services

Ecosystem services are the benefits people obtain from ecosystems

Provisioning

products obtained from ecosystems.

--food, fiber, fuel, fresh water, medicine.

Regulating

Benefits obtained from the regulation of ecosystem processes.

--pollination, water purification, climate, disease, pest, air quality, erosion and natural hazards.

Cultural

Nonmaterial benefits obtained from ecosystems.

--recreation, ecotourism, aesthetic values, cultural heritage.

Supporting

Necessary for the production of all other ecosystem services

--photosynthesis, soil formation, primary productivity.



How do invasive species impact ecosystem services?

Mechanisms:

Competition, predation, herbivory, parasitism, changing soil chemistry, hydrology, fire frequency or nutrient cycling.

NIS affect ecosystem services at four levels of complexity

Species

--result in loss of biodiversity used for food, fiber, fuel, medicine

Communities

--disrupt mutualisms important for pollination and pest control; change physical environment; degrade or enhance aesthetic value

Ecosystems

--alter hydrology and nutrient cycling

Atmosphere

--affect carbon sequestration



Provisioning Services: Food, Fiber and Fuel

- NIS are a blessing and a curse for agriculture and food security

98% of food crops are non-native: +\$800 billion/year

Weeds reduce crop yields by -12%

- Non-crop NIS are sometimes incorporated into local livelihoods

Feral pigs in Hawaii

Prickly pear in South Africa

- **SUMMARY**: Impacts of NIS on food, fiber and fuel are frequently calculated in monetary terms and considered in decision-making. These assessments, however, are usually made at national or regional scales and do not always translate well at local scales and to the livelihoods of rural people.

Provisioning Services: Fresh Water

- Several well-documented examples demonstrate that some NIS can fundamentally change the flow of water for drinking and irrigation.

Tamarisk in the Southwestern U.S. (Zavaleta 2000)

Woody plants in South Africa (Gorgens and van Wilgen 2004)

Pasture grasses in Midwest (Holmes and Rice 1996)

- **SUMMARY**: With these exceptions, few studies document the economic impacts of NIS on water availability. Water is increasingly limited yet indispensable. Understanding how NIS affects hydrology, calculating costs, and making both transparent, is key for gathering important information and support for protecting water resources.

Provisioning Services: Medicine

- **SUMMARY**: NIS probably deplete potential medicinal resources provided by ecosystems by driving native organisms to extinction. Little to no research appears to have specifically addressed the connection between NIS and the lost value of medicinal plants.

Regulating Services: Pollination

- Non-native honeybees are widely used to pollinate crops (Gross 2001).
- Yet, honeybees may displace native bees, potentially better pollinators (Spira 2001).
- Invasive plants can also distract pollinators from native species (Chittka and Schurkens 2001).
- Invasive parasites can lead to the extinction of native pollinators.
- **SUMMARY**: Partly stimulated by recent honeybee deaths, much research is now underway on how non-native and native bees pollinate plants and contribute to a variety of ecosystem services including food, fiber, aesthetic, and cultural values. Little science exists on the impact of other non-native invasive organisms (plants, parasites, etc.) on pollination services.

Regulating Services: Climate

- When NIS replace native species, differences in carbon storage could affect the amount of carbon dioxide in the atmosphere.

Non-native annual grasses replace native sagebrush in the Great Basin (Prater et al. 2006)

Non-native pasture grasses replace rainforest in Brazil (Kaufman et al. 1995;1998)

NIS Woody species replace native grassland (Robles and Chapman 1995)

Non-native timber species may sequester more (or less) carbon than native trees.

- **SUMMARY**: Although there is much focus on how climate change will affect NIS, the extent and implications of the impact of NIS on climate change is poorly understood.

Regulating Services: Water Purification

- Zebra Mussels filter water but have negative impacts on other ecosystem services (Nalepa and Schloesser 1993).
- Golden apple snails alter food webs, transforming Southeast Asia's wetlands from clear to turbid and algae-dominated (Carlsson et al. 2004) and damaging rice production (-12.5-17.8 million/yr in the Philippines; Naylor 1996).
- Common Carp degrade water quality in Spain by increasing nutrient concentrations (Angeler et al. 2002).
- **SUMMARY**: Wetlands are widely recognized as providing free water purification services that would otherwise be costly and chemical-intensive. Zebra mussels and apple snails demonstrate that keeping aquatic areas free of NIS would save millions of dollars in replaced services.

Regulating Service: Erosion

- Introduced ungulates, particularly on islands, cause severe erosion (Laughrin et al. 1994; North et al. 1994; Mack and D'Antonio 1998)
- NIS can impact soil properties, increasing erosion
 - Sphaeroma* in San Francisco bay (Cohen and Carlton 1995)
- When NIS replace native plants, they may increase sediment loss
 - Casuarina* in Florida (Schmitz et al. 1997)
 - non-native forb replaces native bunchgrasses (Lacey et al. 1989)
- **SUMMARY**: Evidence exists that non-native species impact erosion through several mechanisms. These impacts, however, are rarely translated into economic terms.

Pest and Disease Regulation

- Invasive plants can serve as novel habitat for vectors, increasing incidence of disease

Lantana camara is new habitat for tsetse fly in East Africa, spreading sleeping sickness (Greathead 1968)

Tank bromeliads trap water in Florida, creating breeding habitat for disease-carrying mosquitoes (O'Meara et al. 1995)

- Invasive animals can change food web dynamics, making system more vulnerable to disease

Noisy miner bird in Australia excludes native birds, leading to insect outbreaks and reduced tree health (Grey 1998)

- **Summary**: We need to better understand how invasive species make ecosystems less resilient to disease.

Regulating Services: Natural Hazards, Fire and Flood Control

- NIS can alter the frequency, intensity, extent, type and seasonality of fire (Brooks et al. 2004; D'Antonio and Vitousek 1992)

Bromus tectorum in shrub-steppe (Whisenaut 1990)

Melaleuca quinqueunervia in Australia and Florida (Schmitz et al. 1997)

Arundo donax in riparian areas (Jackson 1993; Scott 1993)

- NIS can increase flood-risk by narrowing stream channels and decreasing holding capacity, causing millions in damages (Zavaleta 2000)

- **SUMMARY**: By increasing the intensity or frequency of fires, NIS exclude native species that may provide key ecosystem services, and increase risk to nearby human communities. The “fire-prevention” services that some native ecosystems supply are generally under-appreciated. These services should be accounted for in controlling NIS and paying for ecosystem services.

Cultural Services: Recreation, Ecotourism, Aesthetic Values and Cultural Heritage

- Land and water-based recreation are both impacted by NIS
 - Water milfoil in Lake Tahoe –500,000/yr (Eisworth et al. 2000;2005)
 - Weeds in golf courses -\$1 billion/yr (Pimentel et al. 2000)
 - Feral pigs in Florida -5,331-43,257/ha (Engeman et al. 2003)
- Aesthetic services are difficult to assess because they are subjective. NIS are often imported as ornamentals but accidental NIS such as gypsy moths can be quite unpopular.
- **SUMMARY**: Impacts of NIS on recreation and tourism are far more likely to be quantified and incorporated into policy decision-making compared with cultural services such as aesthetic value and cultural heritage for which it is difficult to assign economic value. Finding ways to account for impacts on these services could help gain broader support for managing invasive species.

Case Studies:

Hawaii, Great Lakes, South Africa



Goal



- To provide integrative examples of the ways that NIS are impacting ecosystem services at three sites that include most major ecosystems on earth: oceans, coasts, freshwater lakes, pastureland, cropland, shrubland and forests.
- To discuss how the types of ecosystem services impacted by NIS may differ between ecosystems.
- To explore the synergies and tradeoffs in managing NIS for different ecosystem services. This is key because particular NIS are likely to have positive impacts on some services and negative impacts on others.

Hawaii Example

Ecosystem	Services Impacted	Invaders	Positive or Negative	Cost (if known)	Description of impact	Citation
Coasts and Oceans	Food					
	Climate Regulation					
	Erosion Regulation					
	Natural Hazards					
	Water Purification	Mangroves	Pos.		Removes sediment from freshwater	Wallentinus and Nyberg (2007)
	Disease Regulation	Mangroves	Neg.		Stagnate water, mosquito breeding	Wallentinus and Nyberg (2007)
	Recreation					
	Tourism					
	Aesthetic Value					
	Cultural Heritage	Mangroves	Pos./Neg.		Lei flowers/clogs fish ponds	Allen (1998)

Hawaii Example continued...

Ecosystem	Services Impacted	Invaders	Positive or Negative	Cost (if known)	Description of impact
Forests	Food	Feral pigs	Pos./Neg.		Subsistence food/damage crops
	Fuel	Feral pigs	Neg.		Girdle trees
	Fresh Water				
	Medicine	Feral pigs	Neg.		Destroy potentially useful plants
	Climate Regulation				
	Erosion Regulation	Feral pigs	Neg.		Churn soil and increase sediment runoff
	Natural Hazards				
	Water Purification	Feral pigs	Neg.		Deposit fecal matter in water
	Disease Regulation	Feral pigs	Neg.		Create pools for mosquitoes; carry leptospirosis
	Recreation	Feral pigs	Pos./Neg.		Hunting/potentially dangerous or unpleasant
	Tourism		?		
	Aesthetic Value	Feral pigs	Neg.		Degrade forest
	Cultural Heritage	Feral pigs	Pos.		Hunting culture; Hawaiian pig god



Science and Policy Recommendations

1. ***Include all relevant ecosystem services in NIS impact assessments:*** decision-makers need full information to strategically allocate limited funds for control.
2. ***Focus new ecological and economic research on regulating and cultural services:*** of all services, these are least accounted for despite their value for human well-being.
3. ***Develop accurate predictions for which NIS groups are likely to have the greatest impact on important ecosystem services.*** It is easier to prevent introductions of NIS than to eradicate them.
4. ***Do better at controlling borders by making impacts of NIS on ecosystem services and human well-being explicit to the public.***
5. ***Treat biological invasions more like global warming.*** Most research in invasion biology focuses on characteristics and control methods rather than negative impacts on ecosystems that result in economic damage to society. Science and policy should reflect the fact that NIS have taken their place next to human-caused global warming as a driver of global environmental change.
6. ***Measure the impacts of NIS using broader criteria than biodiversity.*** Because ecosystem services provide life-support services to society, when using the ecosystem service framework for conservation it is particularly important to incorporate cultural and subsistence values into policy decisions.