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Reducing the risk of introducing or spreading nonindigenous plants, animals, and microorganisms through science and engineering fair projects[1]

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Science and engineering fairs create unique opportunities for participants to learn and apply scientific methods. In biological and ecological sciences, acquiring knowledge about the organisms under study represents a critical part of the scientific process. In recent years, scientists have recognized that their work can cause biological invasions. Biological invasions involve economic, social and ecological harm arising from the introduction or spread of organisms beyond their native or existing ranges, that is the introduction or spread of nonindigenous organisms. When planning and conducting their work, scientists now consider how to avoid or manage these risks. Participants in science and engineering fairs have the opportunity and responsibility to apply similar considerations.

Nonindigenous organisms can be involved in science and engineering fair projects deliberately or accidentally. For example, projects can investigate the biology, ecology and management of nonindigenous organisms or study them to provide insights into basic biological questions. In addition, nonindigenous organisms can be transported accidentally during field studies or collecting. These interactions generate risks of introducing or spreading nonindigenous organisms and causing a biological invasion. Concerns about the introduction and spread of nonindigenous species and subsequent biological invasions have led to laws, policies, management, education and other efforts to reduce the risk of such events at the local, state, regional, national and international levels. Participants in science and engineering fairs should recognize and address these risks explicitly.

Reasons for concern

A nonindigenous organism is one moved beyond its native range, for example an organism transported to North America during European colonization or between watersheds within a state. We all interact with nonindigenous species because such organisms have provided and continue to provide value in numerous ways, including most of our food, fiber, pets and ornamental landscaping.

Nonindigenous species also represent the starting point in a chain of events that can lead to invasive species (Figure 1). Invasive species cause economic, social or ecological harm. Thus, nonindigenous species represent a key element in the risk of biological invasions.

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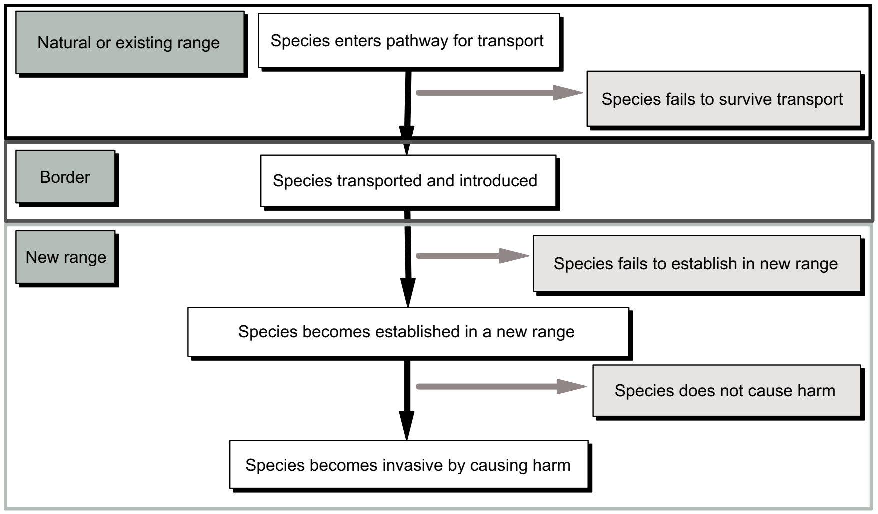

Figure 1. Steps in the process generating invasive species.[1]

Defining the risk

Risk involves two main components: the likelihood that a problem will occur and the potential magnitude of the problem. For nonindigenous species, risk can be defined as 1) the likelihood that an organism will be introduced, become established, which means it creates a self-sustaining population, and cause harm and 2) the amount of harm it can cause.

The likelihood of nonindigenous species being introduced or spread has increased in the recent past in parallel with increased global trade and travel (Figure 2). Along with an increase in the number of introductions, we also have seen an increase in pathways or the ways that species can be introduced (Box 1). Important pathways span the range from accidental releases from industry, such as organisms in ballast water released during shipping to intentional releases by individuals, such as release of a pet.

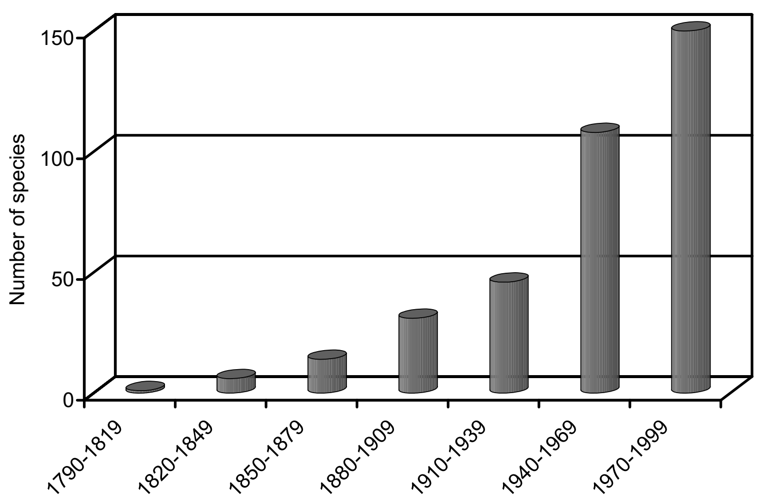

Figure 2. Rate of new invasions by marine invertebrates and seaweeds in the U.S. coastal zone from 1790 to 1999 (374 total invasions).[2, 3]

Box 1. An example of increased pathways for introductions.[2]

- In 1800, *Carcinus maenas*, the European shore crab, could travel across oceans as a "hitchhiker" on ships' hulls and ballast rocks.
- By 1900, these crabs could also travel in ballast water, as hitchhikers on imported oysters and as imported food items.
- By the year 2000, ballast rocks were no longer being used, but six new pathways appeared: bait, aquarium pets, specimens used in schools, specimens used in research, hitchhikers in shipments of lobsters and hitchhikers on oil production platforms.

Box 2. Examples of damage caused by the accidental spread of nonindigenous organisms.[2, 5, 6, 7, 8, 9]

- A tropical alga, *Caulerpa taxifolia*, exhibited an unexpected tolerance of cold after being accidentally released from a European aquarium into the northwest Mediterranean. Its tolerance of winter temperatures helped it blanket tens to hundreds of square kilometers of seafloor and out-compete nearshore plants and animals. There is evidence that this species alters the distribution and foraging of fish, including commercial species.
- Zebra mussels blanket boats, docks, intake and outflow pipes, and other hard surfaces in densities up to 700,000 per square meter. Monitoring and removing this nonindigenous organism costs tens of millions of dollars annually. In addition, zebra mussels smother and out-compete native mussels, many of which are in danger of extinction.
- *Hydrilla verticillata* came into the United States as an aquarium plant. It escaped and spread. A square meter of *H. verticillata* can produce thousands of long-lived tubers that survive poor conditions and grow when conditions are right. In addition, pieces of this submerged freshwater plant tangle in outboard motors or boat trailers. Unintentional transport of such pieces has spread this plant through many states, where it has out-competed other submerged plants and killed fish and other aquatic life by stopping dissolved oxygen from mixing into some waterbodies. The plant is very difficult to eliminate, and around a hundred million dollars will be spent on control measures each year for the foreseeable future.

The average likelihood that an introduced organism becomes established and causes harm is low. Some scientists estimate that 5–20% of introduced species become established and 5–20% of established organisms become invasive.[4] This "rule" is not hard and fast, with selective breeding and other situations creating more or fewer invasions than predicted. Regardless of the actual rate, more introductions translate into more invasions.

Introduced and established organisms can become invasive, which means they cause harm. Among other impacts, invasive organisms overgrow or out-compete native organisms, alter ecological systems, or foul water intakes, buoys or other structures (Box 2). In general, the costs of biological invasions are poorly known, hard to calculate and difficult to evaluate relative to direct economic benefits derived from nonindigenous species. Although disputed, the direct economic and environmental costs of biological invasions in the United States have been estimated at over $100 billion per year, and another study lists invasions as second only to habitat loss in pressuring threatened and endangered species.[10, 11] Indirect costs, such as changes to biodiversity, ecosystem functioning or aesthetics, are not included in these estimates.

In summary, we are introducing an increasing number of nonindigenous organisms. This increased number of introductions is likely to lead to an increased number of invasions. In total, invasions cause substantial harm even when harm is defined narrowly. Some introductions and invasions come from activities similar to those undertaken by participants in science and engineering fairs, with escape or release of a few organisms from aquaria being two key examples. In addition to intentional interactions, science and engineering fair projects can interact with nonindigenous species accidentally. Participants have the opportunity and responsibility to recognize and address the risks of introducing or spreading nonindigenous species.

Managing nonindigenous organisms

Eliminating the use and movement of nonindigenous species is unlikely because we have woven such species into our lives. However, managing the movement and use of nonindigenous organisms represents a valuable approach to reducing the risk of biological invasion because predicting which nonindigenous organisms will become invasive is difficult in many situations. Lists of species shown to be invasive can guide some choices (Appendix A). However, these hard-won lessons have not and may never yield a foolproof means of predicting or detecting introductions that will cause problems. For example, organisms can cope, adapt, or hybridize, and some nonindigenous parasites and pathogens are not obvious (Box 3).

Scientific studies, in particular those using nonindigenous organisms, create risks of causing an invasion. Risks should be managed to help ensure that costs do not outweigh benefits. For example, participants should take specific measures to ensure nonindigenous plants, animals, viable reproductive products, parasites and pathogens are not introduced or transferred purposefully or accidentally. A risk evaluation flow chart can help identify possibilities for spreading nonindigenous organisms through science and engineering fair projects and point out critical management efforts (Appendix B).

Review at the planning stage represents the best approach for all science and engineering fair projects involving plants, animals or microorganisms. For all species involved in the study, participants should attempt to determine their status as native, cryptogenic or nonindigenous. Such information will guide the design of handling and disposal procedures. In addition, the potential for accidental transfer of nonindigenous organisms should be assessed. Web sites and state and federal agencies can assist (Appendix A and Appendix C).

Box 3. Examples of the difficulties associated with predicting biological invasions.[2, 12, 13]

- Green mussels (*Perna viridis*) invaded Tampa Bay, Florida in 1999, with ballast water being the likely pathway. Their limited ability to survive cold water led to a predicted optimal range that extended south from central Florida. Green mussels have now been sighted in Georgia and South Carolina, but it is too early to know if they will become established.
- A nonindigenous cord grass (*Spartina* sp.) introduced into southern England from North America hybridized with the native cordgrass and produced an invasive strain.
- Asian chestnut blight fungus (*Chryphonectria parasitica*) came into New York as an unseen hitchhiker on imported nursery stock, and the blight destroyed almost all the chestnuts in eastern forests.
- A minute organism, *Myxobolus cerebralis*, was introduced in the United States from the Eurasian continent. This metazoan parasite infects trout, salmon and related cold-water fish. It causes mortality in young fish, skeletal deformities, loss of equilibrium, erratic swimming (thus the name whirling disease), decreased feeding and increased predation. The spores of *M. cerebralis* can be spread by moving infected fish that may not exhibit any outward signs of the disease.

If review indicates that nonindigenous species are or could be involved, the project's methodology should include steps to handle and dispose of them without releasing them into new environments. Controlling nonindigenous organisms may involve physical, biological, chemical, and environmental barriers to confine or contain all stages of the organism's life history. Sampling during the project may need to include methods for cleaning or sterilizing boats and other gear between sampling efforts. Detailed plans should be tailored to the individual project, allow for uncertainties and be based on available guidelines (Appendix D).

In an effort to ensure thorough planning, participants should document the species involved in a project and plans to manage them.

A participant's thorough knowledge of all species involved in their science and engineering fair project increases the quality of the project and provides resources to help avoid accidental introduction or spread of nonindigenous organisms. Suitable documentation for each species in the project should include:

- life history, biology, parasites and pathogens;
- critical environmental tolerances;
- typical ecological interactions;
- performance if previously introduced into a non-native environment; and
- native range and present geographic distribution and status as nonindigenous species.

Any plan to avoid introducing or spreading nonindigenous organisms is only as good as its implementation and adaptation to unforeseen circumstances. Success depends on rigorous and conscientious monitoring and evaluation by participants and supervisors. Participants must follow approved measures and address any unexpected problems quickly and effectively. Efforts must extend to the proper disposal of all materials, which can be as important as experimental or sampling procedures in efforts to contain nonindigenous organisms.

In properly described projects, science and engineering fair officials, supervisors and participants can gain confidence that measures to avoid the spread of nonindigenous organisms have been incorporated by looking to indicators. Although indicators will vary from project to project, they include:

- evidence that all required permits have been obtained and that the project complies with related laws and regulations, including guidelines for use of animals;
- suitable qualifications of adult sponsors, qualified scientists, and associated supervisors;
- description of roles and responsibilities for participants and supervisors as related to handling, using, and disposing of nonindigenous organisms;
- security measures to prevent non-participants from handling nonindigenous organisms;
- precautions during shipping and transport;
- evidence of suitable facilities and procedures to keep nonindigenous organisms isolated;
- documentation of physical, chemical, biological or environmental barriers to prevent escape or release of nonindigenous organisms;
- procedures for completing tasks and the project (including cleaning facilities and equipment and safely disposing of organisms, water, sediment, or other media); and
- an emergency plan, including procedures to terminate the project if necessary.

Science in the real world

Nonindigenous organisms and biological invasions are of great interest and concern to scientists, governments, and businesses throughout the United States and the world. Professional scientists take extra care to avoid introducing or spreading nonindigenous organisms because these actions increase the likelihood of biological invasions that can have significant detrimental impacts.

Science and engineering fair projects can contribute significantly to our understanding of biology and ecology, including management of nonindigenous and invasive species. By incorporating concern for introducing or spreading nonindigenous species, participants gain an opportunity to practice science in the real world.

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[8] University of Florida, Center for Aquatic and Invasive Plants web site:
http://plants.ifas.ufl.edu/seagrant/hydcirc.html
http://plants.ifas.ufl.edu/seagrant/hydver2.html
http://aquat1.ifas.ufl.edu/mcplnt1a.html

[9] Protect your waters web site: http://protectyourwaters.net/impacts.php

[10] Pimental, D., R. Zuniga and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273–288.

[11] Wilcove, D.S., D. Rothstein, J. Dubow, A. Phillips and E. Losos. Quantifying threats to imperiled species in the United States. *BioScience* 48: 607–615.

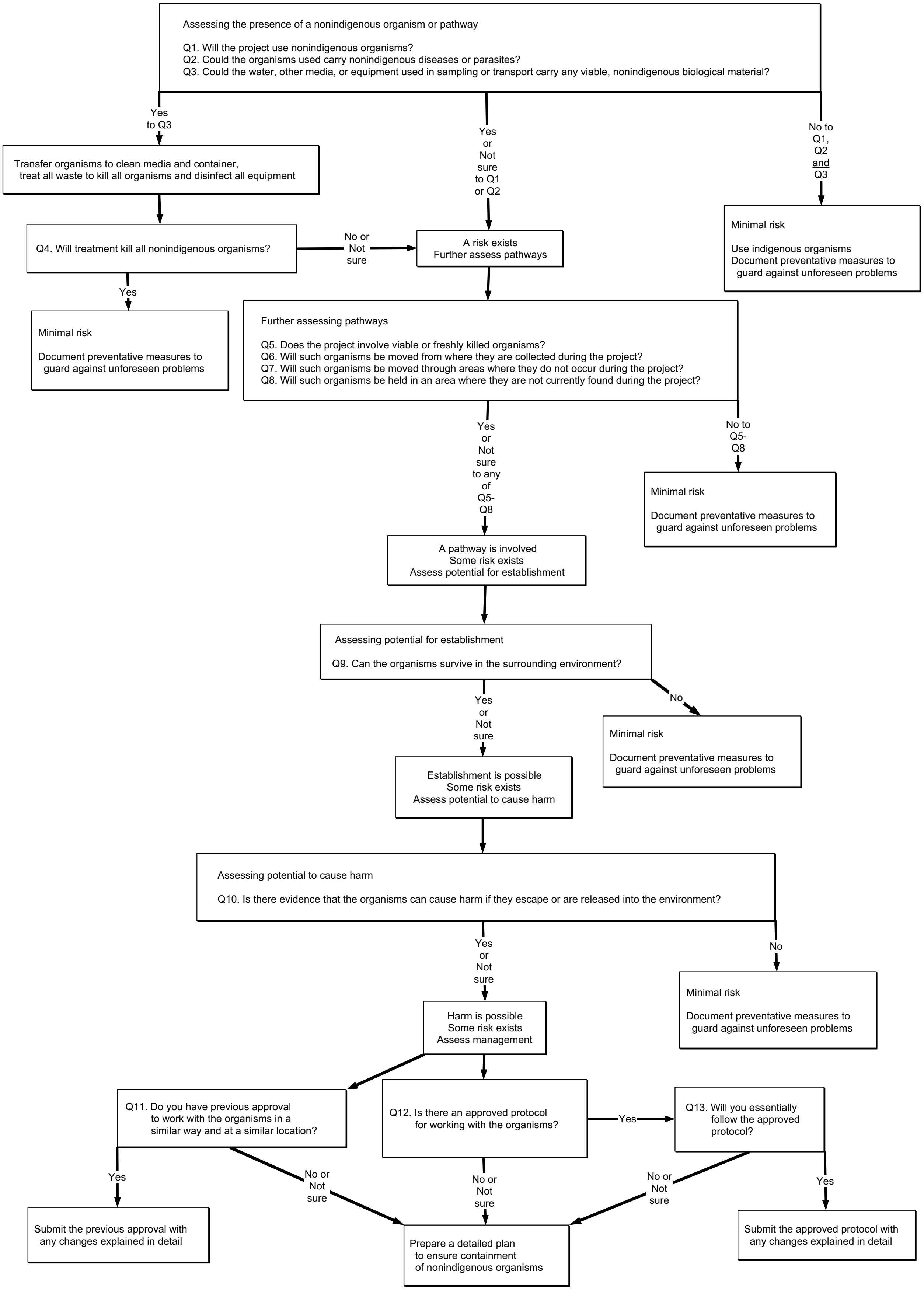
[12] American Chestnut Cooperators' Foundation web site: http://www.ppws.vt.edu/griffin/blight.html

[13] Whirling Disease Foundation web site: http://www.whirling-disease.org/

Appendix A. Web sites to help determine the status of species.

Description	Web site
All states	http://www.invasivespeciesinfo.gov/unitedstates/main.shtml
Federal & state resources by state	http://www.nbii.gov/geographic/us/state.html
All states, aquatic species	http://nas.er.usgs.gov
All states, plants & insects	http://www.invasivespecies.org
Marine species	http://invasions.si.edu/NIS.htm
All states, aquatic invasive plants	http://aquat1.ifas.ufl.edu/aboutplants.html
New England, invasive plants	http://nbii-nin.ciesin.columbia.edu/ipane/
New England, marine species	http://massbay.mit.edu/exoticspecies
California, aquatic species	http://www.elkhornslough.org/invader.htm
Northwest, invasive plants	http://invader.dbs.umt.edu/default.htm

Appendix B. Risk evaluation flow chart for nonindigenous species.



Appendix C. Agencies dealing with nonindigenous species
(continued on next page).

State	Agency
AL	Alabama Department of Conservation & Natural Resources
AK	Alaska Department of Fish & Game
AZ	Arizona Game & Fish Department
AR	Arkansas Game & Fish Commission
CA	California Department of Fish & Game California Department of Food & Agriculture
CO	Colorado Division of Wildlife
CT	Connecticut Department of Environmental Protection
DE	Delaware Department of Natural Resources & Environmental Control
FL	Florida Department of Environmental Protection Florida Fish & Wildlife Conservation Commission
GA	Georgia Department of Natural Resources
HI	Hawaii Department of Agriculture
ID	Idaho Department of Fish & Game Idaho State Department of Agriculture
IL	Illinois Department of Natural Resources
IN	Indiana Department of Natural Resources
IA	Iowa Department of Natural Resources
KS	Kansas Department of Wildlife & Parks
KY	Kentucky Department of Fish & Wildlife Resources
LA	Louisiana Department of Wildlife & Fisheries
ME	Maine Department of Environmental Protection Maine Department of Marine Resources
MD	Maryland Department of Agriculture Maryland Department of Natural Resources
MA	Massachusetts Department of Conservation & Recreation Massachusetts Office of Coastal Zone Management
MI	Michigan Department of Environmental Quality
MN	Minnesota Department of Natural Resources
MS	Mississippi Department of Environmental Quality Mississippi Department of Marine Resources Mississippi Department of Wildlife, Fisheries & Parks
MO	Missouri Department of Conservation
MT	Montana Department of Fish, Wildlife & Parks
NE	Nebraska Game & Parks Commission
NV	Nevada Department of Wildlife
NH	New Hampshire Department of Fish & Game New Hampshire Department of Environmental Services

State	Agency
NJ	New Jersey Division of Fish & Wildlife
NM	New Mexico Department of Game & Fish
NY	New York Department of Environmental Conservation
NC	North Carolina Department of Environment & Natural Resources North Carolina Wildlife Resources Commission
ND	North Dakota Game & Fish Department
OH	Ohio Department of Natural Resources
OK	Oklahoma Department of Wildlife Conservation
OR	Portland State University, Center for Lakes & Reservoirs
PA	Pennsylvania Department of Environmental Protection
RI	Rhode Island Coastal Resources & Management Council
SC	South Carolina Department of Natural Resources
SD	South Dakota Department of Game, Fish & Parks
TN	Tennessee Wildlife Resources Agency
TX	Texas Parks & Wildlife Department
UT	Utah Division of Wildlife Resources
VT	Vermont Department of Environmental Protection
VA	Virginia Department of Conservation & Recreation Virginia Department of Game & Inland Fish
WA	Washington Department of Fish & Wildlife
WV	West Virginia Division of Natural Resources
WI	Wisconsin Department of Natural Resources
WY	Wyoming Game & Fish Department
DC	District of Columbia Department of Health

Appendix D. Resources outlining safe handling of organisms in research projects.

Description	Resource
National Invasive Species Information Center management tool kit	http://www.invasivespeciesinfo.gov/toolkit/main.shtml
aquatic species	http://www.invasivespeciesinfo.gov/aquatics/whatyou.shtml
plants	http://www.invasivespeciesinfo.gov/plants/whatyou.shtml
animals	http://www.invasivespeciesinfo.gov/animals/whatyou.shtml
microbes	http://www.invasivespeciesinfo.gov/microbes/whatyou.shtml
laws & regulations	http://www.invasivespeciesinfo.gov/laws/main.shtml
National Biological Information Infrastructure best management practices	http://www.nbii.gov/datainfo/bestpractices
United States Fish & Wildlife hazard analysis and critical control point planning for natural resource management	http://www.haccp-nrm.org/forms.asp
Guidelines for biotechnology and biological control agents	National Institutes of Health (NIH). Guidelines for Research Involving Recombinant DNA Molecules. http://www4.od.nih.gov/oba/rac/guidelines_02/NIH_Guidelines_Apr_02.htm.
	United States Department of Agriculture (USDA) resources for biotechnology. http://www.aphis.usda.gov/brs/
	Biosafety Clearing-house, international efforts to ensure safe handling of biological material. http://bch.biodiv.org/resources/resources.shtml
	Manual for assessing and managing risks associated with genetically modified organisms. http://www.edmonds-institute.org/manual.html
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Cleaning of boats and gear	http://www.protectyourwaters.org/