Table 3. Threats to biodiversity in the Hudson River Estuary corridor and program areas designed to address each threat.

Threat	Program Area
Lack of Scientific Knowledge of Biodiversity	• Biological Inventories & Ecological Research
Pollution (Air, Water, Soil Quality)	• Biological Inventories & Ecological Research • Land Management & Environmental Quality • Education
Invasive and Overabundant Species	• Biological Inventories & Ecological Research • Land Management & Environmental Quality
Management Conflicts on Public Lands	• Land Management & Environmental Quality • Education
Habitat Change and Fragmentation	• Biological Inventories & Ecological Research • Land Management & Environmental Quality • Education
Lack of Public Awareness and Understanding	• Education

Conservation Program Areas & Strategies

The section below is organized from general to specific. Broad conservation program areas (biological inventories and ecological research, land management and environmental quality, and education) are described, followed by specific activities within those program areas that address threats to biodiversity. Recommended strategies are provided at the end of each section.

Program Area: Biological Inventories & Ecological Research

In a broad sense, strategies addressing the need to increase our overall knowledge about biodiversity and how to manage for it include identifying key areas where information is lacking, promoting research opportunities, and seeking new sources of

funding. It is important that conservation practices are based on current information. Continuing applied research efforts and inventories that update our knowledge of the occurrence of species and habitats will provide an objective basis for biodiversity conservation. Research and inventories provide data and information necessary for developing techniques that will improve land management and environmental quality, and the information base for education and outreach activities. Scientific information is also needed to develop conservation and management priorities that maximize the effectiveness of limited funds.

- **Biological Inventories**

  Inventories of common and rare plants, animals, and ecological communities (habitats) within the uplands and wetlands of the region should be continued and expanded. Biological inventories provide the foundation for other program areas and allow us to establish baseline information and monitor trends and accomplishments. Adequate knowledge of the abundance and distribution of elements of biodiversity is the foundation of a successful conservation program. The Gap Analysis Project and the New York Natural Heritage Program have been integral to the early success of the Hudson River Estuary Biodiversity Program. Using different methodologies, these projects have inventoried the presence and distribution of species and ecological communities. In addition, the NY Natural Heritage Program tracks the quality of biodiversity element occurrences. Two large atlas projects have provided additional inventory data. The NYS Amphibian and Reptile Atlas Project collected data for all species of amphibians and reptiles occurring in the wild in New York for the period 1990 - 1999. The information has been mapped at the county, town and USGS topographic quadrangle scale and in the future more specific location data will be available. The NYS Breeding Bird Atlas is a comprehensive, statewide survey of breeding birds that reveals the current distribution of breeding birds in New York. The Breeding Bird Atlas was expanded and refined in the Hudson River Estuary corridor. The Atlas 2000 Project began in January 2000 and was completed in 2005. The first Breeding Bird Atlas was conducted from 1980 to 1985. These research and inventory programs allow us to assess the extent and quality of biodiversity occurrences and illustrate where conservation is most needed and would be most effective.

  While the inventory programs above operate within the entire Hudson River Estuary corridor, intensive inventories at the local scale have also been completed and are underway. Examples include a town-wide assessment of biodiversity resources completed for the Town of East Fishkill (Dutchess County) by Hudsonia, Limited (Figure 13); and the identification of landscape components important for biodiversity conservation within selected towns of the lower estuary corridor by the Metropolitan Conservation Alliance (a program of the Wildlife Conservation Society). Both of these projects support municipalities and towns in carrying out biodiversity conservation planning.

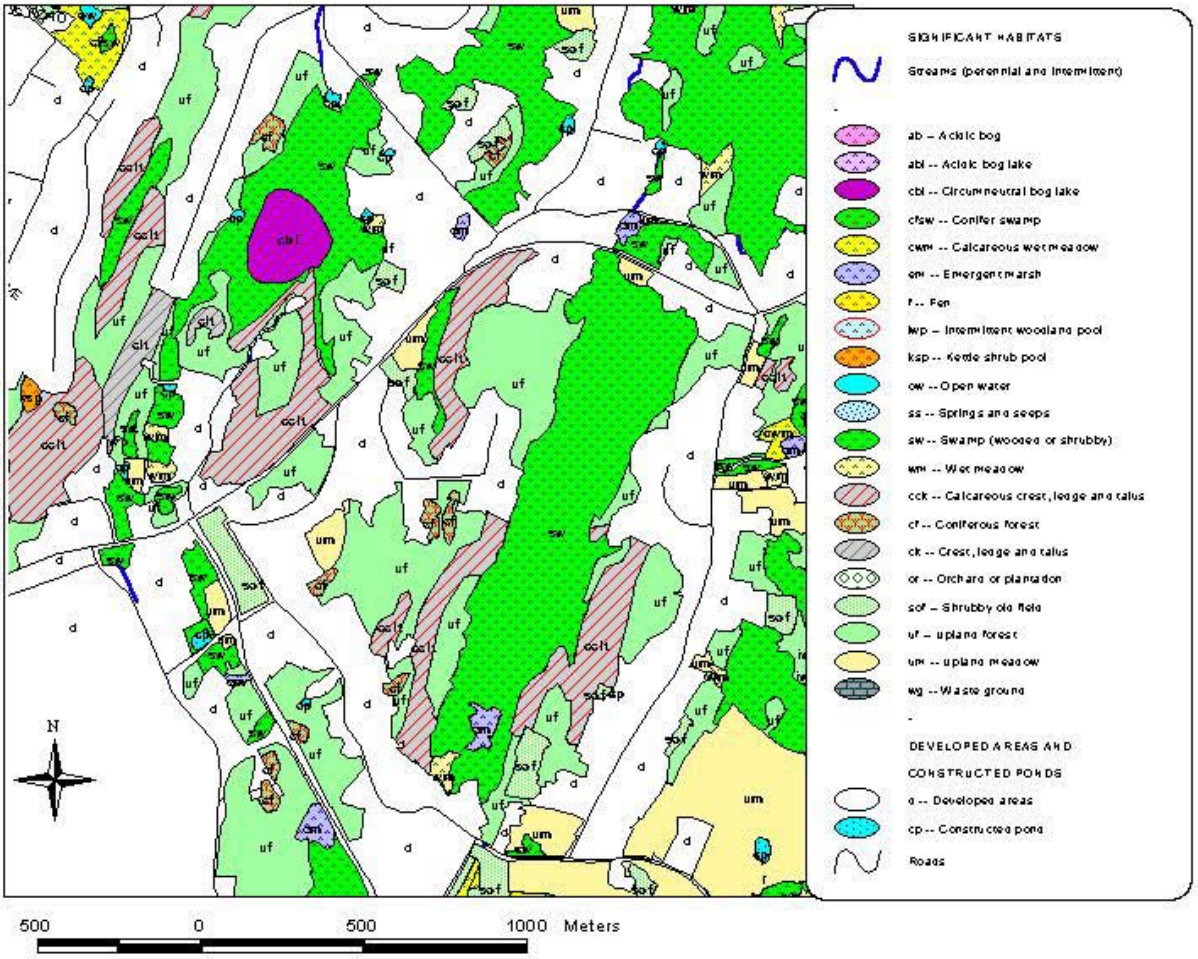

Figure 13. Sample portion of the East Fishkill habitat map, Hudsonia Ltd. 2002. See Stevens and Broadbent (2002) for descriptions of habitats. The habitat mapping project was funded by the Marilyn Milton Simpson Charitable Trusts.

Accurate and current inventory data establishes a baseline for monitoring and evaluation programs, supports local planning for economic growth and biodiversity, facilitates scientific management of public lands, and provides the information base upon which outreach and educational programs should be developed. To date, inventory data have been used for the identification of significant biodiversity areas within the Hudson River Estuary corridor, which in turn have been used for providing recommendations for New York State's Open Space Plan. At another level, inventory efforts have been used to provide baseline data for town planning processes.

Two primary sources of existing inventory data, the New York Natural Heritage Program and the New York Gap Analysis Project, are described next.

New York Natural Heritage Program Approach

The New York Natural Heritage Program is a cooperative effort between The Nature Conservancy and NYS Department of Environmental Conservation (NYSDEC). Its purpose is to facilitate conservation of New York's distinctive biodiversity by identifying, documenting, and mapping the presence and distribution of rare and exemplary elements of biodiversity. The Heritage Program also provides information to the public about rare species and habitat conservation strategies in New York.

The NY Natural Heritage Program considers all plant and animal species as well as ecological communities to be elements of biodiversity. It therefore takes both a species-focused and natural community approach to identifying the presence and distribution of rare and common elements of biodiversity. Inventory efforts begin by compiling lists of all vulnerable native species and classifying all ecological communities in New York State. Sources used to develop the species lists and the community classification include scientific and popular literature, museum collections, state records, and the advice of knowledgeable professionals. The Heritage Program conducts focused field surveys to discover new rare species populations and significant ecological communities, and to verify and update existing information on known occurrences.

The NY Natural Heritage Program maintains an "Active Inventory List" of plant and animal species that it monitors in New York State. This list contains most species that have fewer than 50 populations in the state or that are considered highly vulnerable to extirpation. It also contains species for which only historical collections are known and species thought to be extirpated from the state. For ecological communities, the Heritage Program actively inventories all rare natural community occurrences as well as common natural communities that are of exceptional quality.

Each surveyed element (i.e., species or ecological community) is ranked on state and global rarity scales. State rarity ranks describe the abundance and distribution of a species and are a measure of its risk of extirpation from New York. The global rarity rank is an indication of the vulnerability of a species or community throughout its entire range and is more or less a measure of an element's risk of extinction. These ranks help land-use decision makers understand the degree to which a given species or ecological community is rare and imperiled. In addition, each rare species population and exemplary ecological community occurrence is ranked for its quality. Quality ranks consider size, condition, and landscape context and are an indication of the viability of a given species or community occurrence.

All rare species and significant ecological community occurrences are delineated using a Geographic Information System (GIS) and entered into the Heritage Program biodiversity database. This database, and the methods used to populate it, are consistent with similar databases maintained by Natural Heritage Programs throughout the United States, Canada, and Central and South America. This collaborative network of

databases is coordinated by NatureServe (formerly the Association for Biodiversity Information), and allows for rapid analysis and interpretation of rare species patterns throughout the Hudson River Watershed, New York State, and North America.

The NY Natural Heritage Program has completed inventory and analysis of biodiversity element occurrences within 18 biodiversity areas (Figure 4) of the 10 counties bordering the estuary north of New York City (Howard et al. 2002). Previous inventories covered selected areas within the towns (Finton et al. 1999) and counties (Finton et al. 2000) bordering the Hudson River Estuary. The inventory results demonstrate the importance of the Hudson River Valley to the overall biodiversity of New York State. The surveyed 18 biodiversity areas contained 36% of the rare animal taxa, 27% of the rare plant taxa, and 54% of terrestrial and palustrine (wetland) communities known in the state. The results also indicate the importance of the significant biodiversity areas within the Hudson River Estuary corridor. The surveyed biodiversity areas contained at least one locality for 85% of rare animal taxa, 76% of rare plant taxa, and almost all of the ecological communities known to occur in the Estuary corridor. Several of the notable survey results include rediscovery of the Allegheny woodrat (*Neotoma magister*) in the Palisades (previously thought to be extirpated from the state) and rediscovery of two plants that have not been observed in New York State for over 50 years: the Hudson River water-nymph (*Najas guadalupensis* var. *muenscheri*), and basil mountain mint (*Pycnanthemum clinopodioides*). These surveys expand and refine our knowledge and understanding of rare species and all natural communities and make the Heritage Program database a more powerful information and conservation tool for all New York State citizens.

In the future, priority areas of the Hudson River Estuary corridor will continue to be surveyed by the Heritage Program. The Heritage Program has developed informational products that will help to interpret their extensive survey information for local and regional decisionmakers.

New York Gap Analysis Project Approach

The New York Gap Analysis Project (Smith et al. 2001) is part of a national effort to inventory and digitize into a computer-based, geographical information system (GIS) the distribution of plant and animal species and plant assemblages that are an integral component of national biodiversity. The gap analysis approach compliments that of the Heritage Program inventory by expanding the community focused approach to the entire landscape. In New York, a statewide vegetation map was produced delineating the distribution of native ecological communities. This map was developed from satellite images showing the distribution of distinct vegetation assemblages. The assemblages were classified using a system unique to the Hudson Valley and adapted to conform to the National Vegetation Classification Standard (Federal Geographic Data Committee 1997) organizational hierarchy. The classification system was developed using multiple field data sources and then cross-referenced with Ecological Com-

munities of New York State (Reschke 1990). The resulting land cover map offers the advantage of being able to identify and predict native ecological communities across New York State where field data are lacking. The land cover classification was then combined with wildlife-habitat relationship models to predict the distribution of animal species. Unprotected areas of biodiversity were identified by digitally overlaying maps of public and private conserved lands with maps of predicted species richness. The gap analysis methodology should be useful for guiding future research, biological inventories, and land-use planning at the regional scale.

Of terrestrial vertebrate animals, 272 of 308 species were predicted to have 10% or less of their distribution within protected lands, including all of the region's amphibians. Twenty-three species were not predicted to occur at all on protected lands, including the Eastern mud turtle and 22 bird species. Most of these bird species nest in grassland or water-related habitats. The gap analysis results show that a large portion of the higher elevation lands in the Hudson River Estuary corridor are in public ownership (68% of land above 2,297 ft or 700 m), while the lower elevation lands (areas below 1,641 ft or 500 m) are predominantly in private ownership with no known plans for permanent biodiversity protection. At least 12% of the Hudson River Estuary corridor is public land. Habitat types poorly represented in protected areas (areas managed to stay in a primarily natural condition) include evergreen wetlands, deciduous wetlands, emergent wetlands (wet meadows), shrub swamp, successional hardwoods, successional shrub, Appalachian oak-pine forest and open water (lakes and streams).

The products created by the Gap Analysis Project can be used to further analyze land use patterns and biodiversity distribution. Using data generated by the gap analysis, human population growth models were developed to predict where areas of biodiversity are at risk from encroachment in the Hudson River Estuary corridor (Smith et al. 2004). Gap results are also helping to analyze the contribution of public lands to biodiversity conservation in the Estuary corridor.

Other Approaches

Other organizations use different approaches to assess biodiversity in the Hudson River Valley. For example, the Wildlife Conservation Society's Metropolitan Conservation Alliance tracks focal taxa, which are groups of organisms that are not necessarily rare or endangered, but that provide data on ecosystem health, conditions, and environmental change.

Through use of the Biodiversity Assessment Manual for the Hudson River Estuary Corridor, Hudsonia, Ltd. encourages landowners and decision makers to conduct large-scale and site-specific biodiversity assessments to identify ecologically significant habitats, natural communities, and species of plants and animals of particular conservation concern.

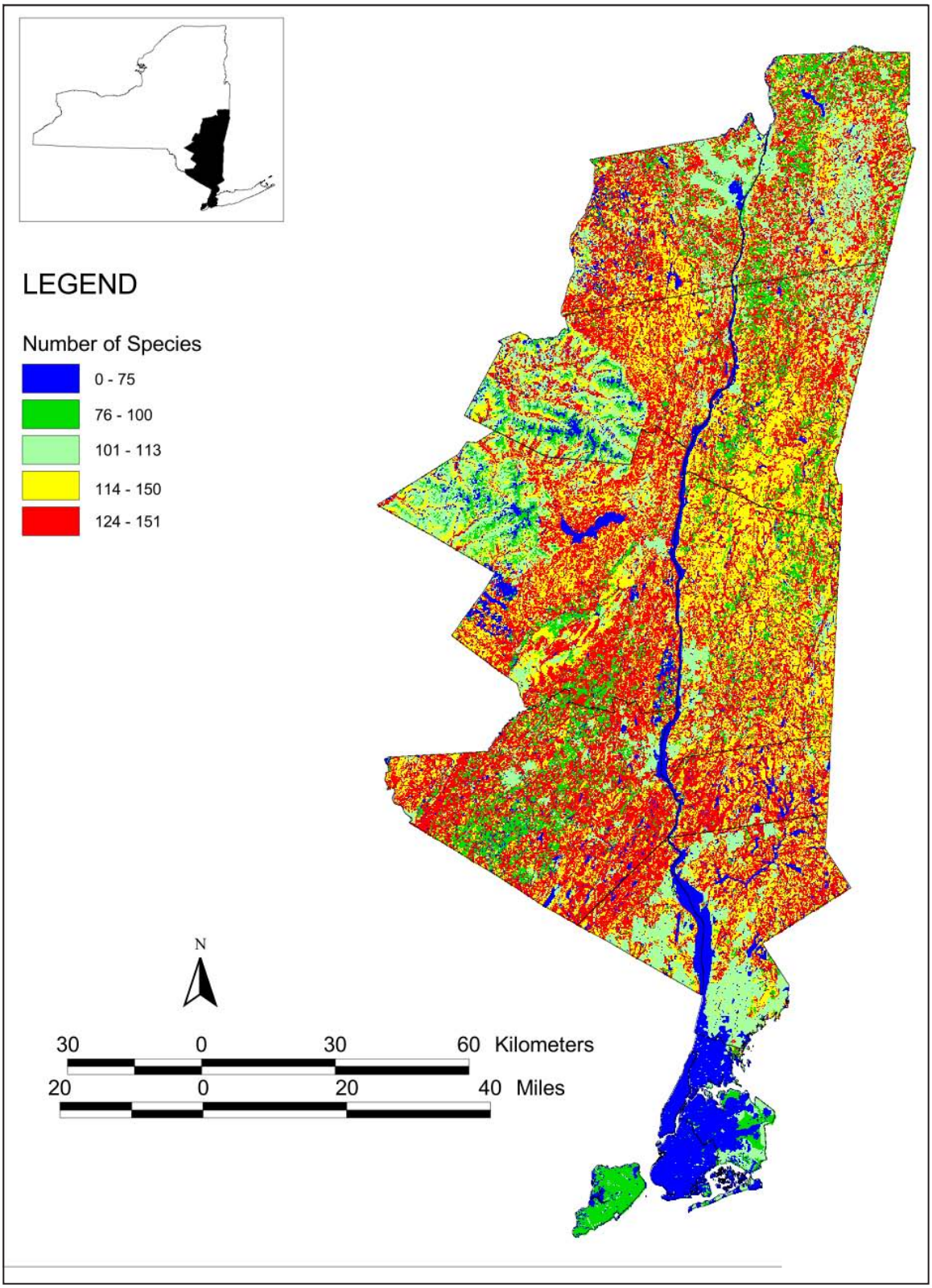

Figure 14. Predicted species richness in the Hudson River Estuary corridor (Smith et al. 2001).

In summary, employing a variety of scientific approaches to inventorying and monitoring biodiversity at multiple scales will produce the most useful and reliable information.

Strategies for biological inventory:

- Address key areas where data are lacking;
- Expand understanding of less known taxonomic groups;
- Conduct biological inventories that improve our understanding of both common and rare species and habitats, environmental health, and responses to environmental change;
- Develop and implement methods for establishing conservation priorities;
- Combine data sets collected at multiple scales.

- **Ecological Research & Monitoring**

An important component of conserving biodiversity in the Hudson River Valley is development of an ecological research and monitoring program. Ecological research allows us to understand how wildlife populations and habitats are maintained and how humans can interact with both to maintain environmental quality. Ecological research and monitoring will help to alert scientists and citizens to regional and site-specific threats affecting the health of the environment in the Hudson River Estuary corridor. Because the principal threats to biodiversity have been identified, a program designed around evaluating and monitoring the impact of these threats and the effectiveness of management strategies should be implemented.

Ideally, this program would also help to identify plants, animals, and ecological communities that are at risk before they become threatened or endangered. As mentioned previously, the NY Natural Heritage Program, NY Gap Analysis Program, NYS Amphibian and Reptile Atlas Project, and the NYS Breeding Bird Atlas Project and other programs have established baseline data that could be extremely useful for future ecological research and monitoring. Monitoring programs are also an excellent opportunity to foster community and volunteer group participation.

Ecological research directly feeds into the development of land management strategies. Land managers and planners require an understanding of the cumulative effects of human activities and natural processes and the possible consequences of planning and management activities. Researchers could examine how various land management activities affect the health of wildlife populations, humans, and ecosystems and use the findings to develop conservation strategies.

An important aspect of biodiversity that is often overlooked is the maintenance of ecological processes that sustain environmental quality, such as clean water, groundwater recharge, or the breakdown and processing of potentially toxic substances by natural systems. The results of research on these subjects can help planning agencies and managers work proactively to prevent degradation of environmental quality and the loss of biodiversity. Ecological research should be carried out at multiple scales

in the Hudson River Estuary corridor, from individual sites to the landscape level. It is important to understand how the entire Hudson River Estuary ecosystem, which includes both terrestrial and aquatic components, supports and is supported by biodiversity.

Ecological research and monitoring in the Hudson River Estuary corridor should focus on four priority areas, including:

1. The status of endangered, threatened, and special concern species

The New York Natural Heritage Program has conducted intensive biodiversity inventories in the Hudson River Valley since 1998, collecting data on rare plants, animals, and ecological communities and documenting threats to these resources. These inventories have provided important baseline data that might be used to assess changes in the populations and habitats of rare species and communities over time.

Monitoring of rare species and communities must occur on a regular schedule that is defined during the planning stages. As a companion to this effort, ecological research could be conducted to study the effects of land-use change on populations and communities of interest. The effects of habitat management on rare species should be monitored (for example, the use of prescribed burning at the Shawangunk Grasslands National Wildlife Refuge for rare grassland birds) and the relationships between landscape configuration and population sustainability explored.

2. Ecosystem health and integrity

Complex linkages exist between biodiversity, ecosystem health, and human health. Monitoring of vertebrate and invertebrate indicator species can be useful for assessing ecosystem health (the functioning and performance of ecosystems). Studies of species health can also provide early indications of threats to human health. Common indicator organisms include amphibians, butterflies, and dragonflies. In general, choosing the appropriate indicator species involves balancing the dual requirements of practicality and accuracy. An indicator must, by definition, be relatively well known or at least easy to study, but it also must be informative, accurate, and reliable. Indicator species should be correlated through research with their associated endpoint.

Indicators that are linked to many other parts of the ecosystem are valuable to track since their decline can result in the declines of numerous species. Indicators of ecosystem stress should respond rapidly to the stress if they are to be used as early warnings. Other stress indicators may not respond as quickly, but may be useful if they accurately and clearly indicate the particular impact. A wider range of criteria can be met using multiple indicators.

An exploratory study should be initiated to assess the feasibility of monitoring indicator species in the Hudson River Estuary corridor. Such a study should investigate which threats to biodiversity can be monitored through the use of indicator species,

the most appropriate species to monitor, cost, duration, methods, and long-term funding opportunities.

Several large-scale efforts have been made to document the occurrence of ecological communities, both common and rare, in the Hudson River Estuary corridor. However, knowing where a species occurs is not the same as knowing why it occurs there. To be effective, ecological communities (i.e., habitats) must be conserved at their natural size scale and in adequate condition and configuration to insure that they contain all their associated species. For conservation purposes, it is critical that the ecological processes and disturbances that sustain a particular ecological community are operating within their natural range of variation. Ecological systems with high biological integrity are able to absorb small perturbations and to prevent them from amplifying into larger disruptions in ecosystem function. They are also better able to return to an original level of productivity and species composition following disturbance. A natural community with high integrity can exhibit resistance, resilience, and persistence over centuries. Continued research and consideration of landscape function and ecological integrity are necessary to ensure the sustainability of biodiversity and environmental quality.

3. Species potentially impacted by contaminants

Bioaccumulation of contaminants throughout the aquatic food chain affects a number of wildlife species in the Hudson River Estuary corridor. Particularly vulnerable are a number of bird (bald eagle, heron) and mammal species (otter, mink) that prey upon fish and shellfish in the estuary.

A sampling program should be established that measures contaminant levels in a selected suite of wildlife species at regular time intervals. Research in this area for a Natural Resource Damage Assessment has been initiated, however, additional research that links contaminant levels to the health and reproduction of these species is also needed.

4. Invasive, exotic, and overabundant species and their impacts on native flora and fauna

There are over 115 exotic species in the Hudson River Valley, and more enter the region each year. Research focused on the use of remotely-sensed satellite imagery could be useful for collecting baseline information on the abundance and distribution of some invasive, exotic, and overabundant plants in the Hudson River Estuary corridor. This research could be used in evaluating control of invasive species over time. Initial progress has been made on developing techniques for monitoring and prediction of purple loosestrife distribution. Coupled with this effort is the development of a management plan for purple loosestrife in the Hudson River Estuary corridor. The research on purple loosestrife may serve as a model for other invasive exotic plants.