Attachment A: Landscape Project

New Jersey's Landscape Project

NJ Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program

Wildlife habitat mapping for community land-use planning and endangered species conservation (Version 2.0)

New Jersey's
Landscape Project

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

James E. McGreevy, Governor
Bradley M. Campbell, Commissioner
John S. Watson Jr., Assistant Commissioner

DIVISION OF FISH AND WILDLIFE

Martin McHugh, Director
David Chanda, Assistant Director

ENDANGERED AND NONGAME SPECIES ADVISORY COMMITTEE

Jane Morton Galetto, Chairperson
James Applegate, Ph.D.
Joanna Burger, Ph.D.
Michael Catania
Emile DeVito, Ph.D.
Janet Larson
Rick Lathrop, Ph.D.
David Mizrahi, Ph.D.
Dale Schweitzer, Ph.D.
James Shissias
Clay Sutton

ENDANGERED AND NONGAME SPECIES PROGRAM STAFF

Larry Niles, Ph.D., Bureau Chief
Kathy Clark, Principal Zoologist
Dave Jenkins, Principal Zoologist
Michael Valent, Principal Zoologist
Jeanette Bowers-Altman, Senior Zoologist
Amanda Dey, Senior Biologist
David Golden, Senior Biologist
Kris Schantz, Senior Biologist
Melissa Craddock, Assistant Biologist
Sharon DeFalco, Assistant Biologist
Kimberly Korth, Assistant Biologist
Todd Pover, Assistant Biologist
Larissa Smith, Assistant Biologist
Brian Zarate, Assistant Biologist
Gretchen Fowles, GIS Specialist
Peter Winkler, GIS Specialist
Patrick Woerner, GIS Specialist
Linda Tesauro, Foundation Director
Patricia B. Shapella, Contributions Manager
Keara Gianotti, Development Associate
Terry Terry, Head Clerk

New Jersey Department of Environmental Protection
Division of Fish and Wildlife
Endangered and Nongame Species Program
PO Box 400
Trenton, NJ 08625-0400
(609) 292-9400
Fax (609) 984-1414
www.njfishandwildlife.com/ensphome.htm

The Landscape Project has been supported by:
US Fish and Wildlife Service
Federal Aid in Wildlife Restoration Act (Pittman-Robertson Act)
Partnerships for Wildlife Act

NJ Department of Environmental Protection,
Division of Science, Research and Technology
Division of Watershed Management
Office of Natural Resource Damage Assessment

National Fish and Wildlife Foundation

Geraldine R. Dodge Foundation

Conserve Wildlife Foundation of NJ

The citizens of New Jersey who have purchased the Conserve Wildlife License Plate, checked-off for wildlife on their state income tax return or made a direct donation to the Endangered and Nongame Species Program (ENSP) or the Conserve Wildlife Foundation.

The following Division of Fish and Wildlife staff have contributed to the Landscape Project:
Larry Niles, ENSP Bureau Chief; James Sciascia, Information and Education Bureau Chief; Kathleen Clark, Principal Zoologist; David Jenkins, Principal Zoologist; Michael Valent, Principal Zoologist; Jeanette Bowers-Altman, Senior Zoologist; Amanda Dey, Senior Biologist; David Golden, Senior Biologist; Kris Schantz, Senior Biologist; Jason Tesauro, Senior Biologist; Melissa Craddock, Assistant Biologist; Sharon DeFalco, Assistant Biologist; Kimberly Korth, Assistant Biologist; Todd Pover, Assistant Biologist; Larissa Smith, Assistant Biologist; Brian Zarate, Assistant Biologist; William Bogetti, GIS Specialist; Gretchen Fowles, GIS Specialist; Peter Winkler, GIS Specialist; Patrick Woerner, GIS Specialist; Terry Terry, Head Clerk.

Maps and methodologies described in this document have been peer reviewed by:
Dr. James Applegate, Rutgers University; Dr. Joanna Burger, Rutgers University; Dr. Tim Casey, Rutgers University; Dr. David Ehrenfeld, Rutgers University; Dr. Joan Ehrenfeld, Rutgers University; Dr. David Fairbrothers, Rutgers University; Dr. Michael Gochfeld, Rutgers University; Ernie Hahn, DEP, Land Use Regulation Program; Dr. Colleen Hatfield, Rutgers University; Dr. Marjorie Kaplan, DEP, Division of Science, Research and Technology; Dr. Michael W. Klemens; Wildlife Conservation Society; Kim Laidig, NJ Pinelands Commission; Dr. Richard Lathrop, Rutgers University; Trish Maggio and Jessica Sanchez, NJ Office of State Planning; Dr. Peter Morin, Rutgers University; Larry Torok, DEP, Land Use Regulation Program; and Dr. Robert Zampella, NJ Pinelands Commission.

Please cite this report as:

Niles, L.J., M. Valent, P. Winkler and P. Woerner. 2004. *New Jersey's Landscape Project, Version 2.0.* New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program. pp. 58.

Cover art by Steve Oleszek

Definitions

critical areas - any area ranked as "1" through "5" in the Landscape Project. See the following sections of this document for further information: "General Methodology for Delineating Critical Areas," "Detailed Methodology for Delineating Critical Areas by Habitat Type," and "Detailed Methodology for Delineating Critical Areas by Special Habitat Requirements."

endangered species - a species listed on the official endangered wildlife list that the Department promulgates pursuant to the Endangered and Nongame Species of Wildlife Conservation Act of 1973 (ENSCA).

imperiled species - includes all endangered and threatened wildlife species.

priority species - nongame wildlife that are considered by the Department to be species of special concern as determined by a panel of experts. The term also includes wildlife species of regional concern in regional conservation plans such as Partners in Flight Bird Conservation Plans, North American Waterbird Conservation Plans, United States Shorebird Conservation Plan, etc.

threatened species - a species designated as "threatened" on the list of nongame wildlife species that the Department promulgates pursuant to ENSCA.

Conversions

Area:

1 hectare = 2.47 acres

Distance:

1 meter = 3.28 feet

1 kilometer = 0.62 miles

The Landscape Project

a model for imperiled wildlife protection (Version 2.0)

New Jersey is the most densely populated state in the nation. One of the consequences of this distinction is the extreme pressure that is placed on our natural resources. As the population grows, we continue to lose or impact the remaining natural areas of the state. As more and more habitat is lost, people are beginning to appreciate the benefits — and necessity — of maintaining land in its natural state. For example, we now know that wetlands play an important role in lessening the damage from floods and naturally breaking down contaminants in the environment. Forests and grasslands protect the quality of our drinking water, help purify the air we breathe and provide important areas for outdoor recreation.

Collectively, these habitats are of critical importance to the diverse assemblage of wildlife found in New Jersey, including more than 70 species classified as threatened or endangered. In 1994, the New Jersey Department of Environmental Protection (DEP) adopted a landscape level approach to imperiled species conservation that was created by the Division of Fish and Wildlife's Endangered and Nongame Species Program. The goal is to protect New Jersey's biological diversity by maintaining and enhancing imperiled wildlife populations within healthy, functioning ecosystems.

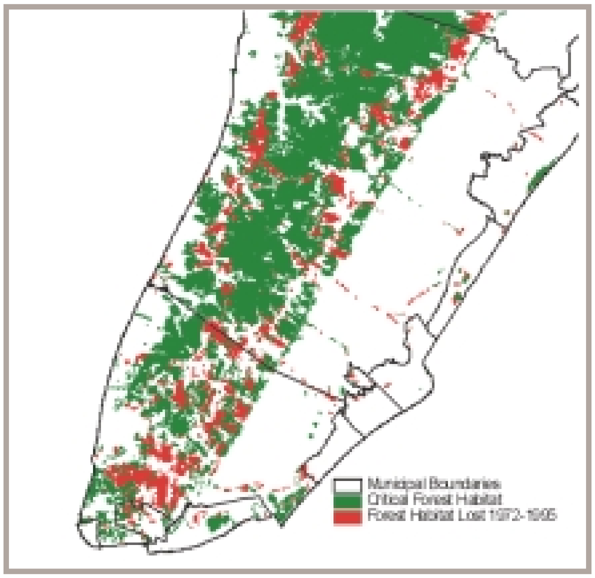


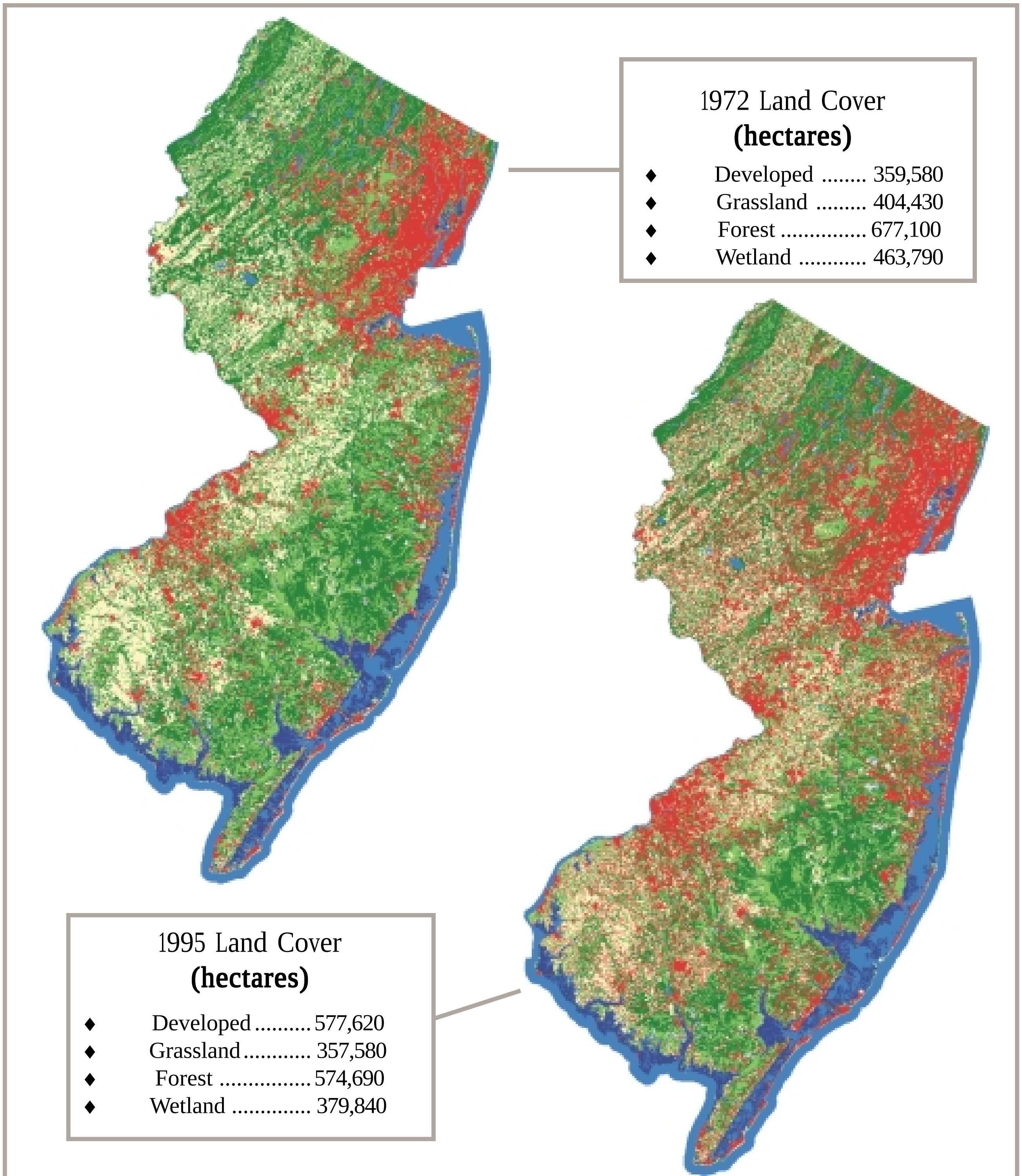
Figure 1. *Over 50% of the state's bog turtle habitat (top) and 40% of the Cape May Peninsula's migratory bird habitat (bottom) has been lost to sprawl in the past three decades. The Landscape Project aims to reverse this trend.*

Why we need the Landscape Project

As people leave our cities to live in the "country," suburban sprawl has consumed land at a rapid rate. Some analysts predict that at current patterns all remaining available land would be developed within 40 years, making New Jersey possibly the first state in the nation to reach build-out (Hasse and Lathrop 2001). In New Jersey, such sprawl is evident as analyses based on aerial photographs between 1985 and 1996 found that rural single unit residential growth was responsible for 30% of the new development in the state (Hasse and Lathrop 2001). See ***Appendix I*** for a discussion of habitat fragmentation.

Despite New Jersey's protection efforts, which include strict land-use regulations and an aggressive open space acquisition program (Green Acres), we continue to lose critical wildlife habitat at an alarming rate. In just the last three decades we have lost 40% of the remaining critical migratory bird stopover habitat on the lower third of the Cape May Peninsula. During the same period, approximately 50% of the state's bog turtle habitat has disappeared (***Figure 1***). The Landscape Project serves as a tool to help reverse this trend (***Figure 2***).

New Jersey's Changing Landscape



Data Sources: 1972 MSS imagery and 1995 TM imagery classified by Rutgers University Center for Remote Sensing and Spatial Analysis

***Figure 2**. New Jersey's landscape is rapidly changing. Since 1972, more than 8,000 hectares/year of wildlife habitat has been lost. Moreover, much of the habitat that remains is less suitable for wildlife due to habitat fragmentation. This is especially detrimental to imperiled wildlife, as many of these species require large, contiguous blocks of habitat to survive. The goal of the Landscape Project is to reverse this trend by identifying, delineating and ultimately protecting habitat critical to the long-term survival of New Jersey's wildlife.*

The purpose of the Landscape Project

The Landscape Project has been designed to provide users with peer-reviewed, scientifically sound information that is easily accessible and can be integrated with planning, protection and land management programs at every level of government — state, county and municipal, as well as non-governmental organizations and private landowners. As in Version 1.0, Version 2.0 of the Landscape Project has gone through an extensive peer review process. Landscape maps and overlays provide a basis for proactive planning, such as the development of local habitat protection ordinances, zoning to protect critical wildlife areas, management guidelines for imperiled species conservation on public and private lands and land acquisition projects.

Most importantly, the critical area information that Landscape Project products provide can be used for planning purposes before any actions such as proposed development, resource extraction (eg. timber harvests) or conservation measures occur. Proper planning with accurate, and legally and scientifically sound information will result in less conflict. Less time will be wasted, and less money spent, attempting to resolve endangered and threatened species issues.

Uses for the Landscape Project

The ENSP has developed maps that identify critical areas for imperiled species based on land-use classifications and imperiled species locations. The maps will enable state, county, municipal and private agencies to identify important habitats and protect them in a variety of ways:

- **Prioritize conservation acquisitions:** Critical area maps can be used to prioritize land parcels for purchase through acquisition programs such as Green Acres, Farmland Preservation and the US Fish and Wildlife Service's refuge system .
- **Guide regulators and planners:** Critical area maps provide land-use regulators and state, county and local planners with the tools they need to enhance protection through the regulatory and planning process.
- **Provide citizens with conservation tools:** The Landscape Project provides the tools to guide citizen actions to protect imperiled species habitat at the local level. By combining critical area maps with other GIS data layers such as roads, development and publicly owned lands, important areas in need of protection can be easily identified.
- **Guide stewardship of conserved areas:** New Jersey already has more than 400,000 hectares of open space. These lands are managed by a variety of agencies and organizations, both public and private. Critical area maps identify important imperiled species habitats on these lands. ENSP biologists work hand in hand with land managers and landowners to develop appropriate best management practices for the long-term conservation of imperiled species.

Who benefits

Protecting large expanses of fields, forests and wetlands helps to ensure that imperiled species will remain a part of New Jersey's future (***Figure 3***). In addition to providing habitat for the conservation of imperiled species, the Landscape Project will result in more open space for outdoor recreation, as well as public health and additional environmental benefits. Recent surveys by the US Fish and Wildlife Service show that more than 60% of Americans participate in some form of wildlife-related recreation. Open spaces provide places where people can escape the confines of urban and suburban living. Retaining habitats in their natural state provides other benefits such as reducing the threat of flooding, allowing for the biodegradation of environmental contaminants and recharging ground water reserves. In short, everyone benefits from the Landscape Project.

Figure 3. *The Landscape Project aims to identify, delineate and ultimately protect critical areas for all New Jersey wildlife, including the bobcat, pictured above.*

New Jersey's Landscape Regions

A landscape level perspective

Since animals require large expanses of natural habitat for their long-term survival (***Appendix I***), the Landscape Project focuses on large areas called Landscape Regions that are ecologically similar with regard to their plant and animal communities ***(Figure 4***). Utilizing an extensive database that combines imperiled and priority wildlife location information with land-use/land-cover classification data, ENSP has identified and mapped critical areas for imperiled species within each Landscape Region. These landscape maps provide a highly accurate, reliable and scientifically sound basis for habitat protection within each landscape.

One of the Landscape Project's unique features is its focus on the big picture, and not just on individual locations of imperiled species as those areas become threatened. Thus, within large landscapes, the Landscape Project identifies critical wildlife areas that must be preserved now if we want to assure the conservation of New Jersey's imperiled wildlife for future generations.

Skylands Landscape

This landscape encompasses all of Sussex, Warren, Hunterdon, Passaic and Morris counties and parts of Somerset and Bergen counties. The region contains extensive tracts of contiguous upland and wetland forests that support diverse animal populations including red-shouldered hawks, goshawks, cerulean warblers, timber rattlesnakes and long-tailed salamanders. Bog turtles and great blue herons inhabit the extensive freshwater wetland systems found throughout the region.

Delaware Bay Landscape

This landscape encompasses all or parts of Cape May, Atlantic and Cumberland counties. This area features a stable population of bald eagles, tiger salamanders, southern gray tree frogs and 30 other endangered and threatened species. The vast woodland tracts of this region are among the largest in the state and support a large portion of New Jersey's Neotropical bird populations. The extensive saltwater marsh and sandy overwash beaches support a shorebird migration that has worldwide ecological significance. Despite the heavy loss of habitat, the Cape May Peninsula remains one of the country's most important migratory "stopovers" for hundreds of bird and insect species.

Piedmont Plains Landscape

This landscape encompasses all or parts of Burlington, Gloucester, Mercer, Middlesex, Monmouth and Salem counties. It is dominated by the Delaware and Raritan rivers, and is characterized by farmed areas, extensive grasslands, fragmented woodlands and tidal freshwater marshes that are among the most productive in the world. Imperiled species within this landscape include grassland birds such as the endangered upland sandpiper, and woodland raptors such as the barred owl and Cooper's hawk.

Pinelands Landscape

This landscape encompasses all or parts of Atlantic, Ocean, Burlington, Camden and Gloucester counties. An internationally recognized ecosystem, the Pinelands supports extremely diverse reptile, amphibian and invertebrate populations including pine snakes, corn snakes, Pine Barrens treefrogs, Pine Barrens bluets, green darners and arogos skippers. Extensive cedar swamps and wetland systems contain numerous insect species, as well as sustainable populations of many Neotropical birds. Its waterways support aquatic communities unique among the Mid-Atlantic states.

Atlantic Coastal Landscape

This landscape encompasses parts of Monmouth, Ocean and Atlantic counties. New Jersey's Atlantic Coast beaches and marshes are among the most productive coastal habitats in the country. Despite heavy development, they support important portions of Atlantic Coast populations of colonial nesting birds, such as common terns, little blue herons and great egrets, and endangered beach-nesting birds such as least terns and piping plovers. The coastal habitats also support most of the state's ospreys and peregrine falcons, as well as a large number of northern harriers.

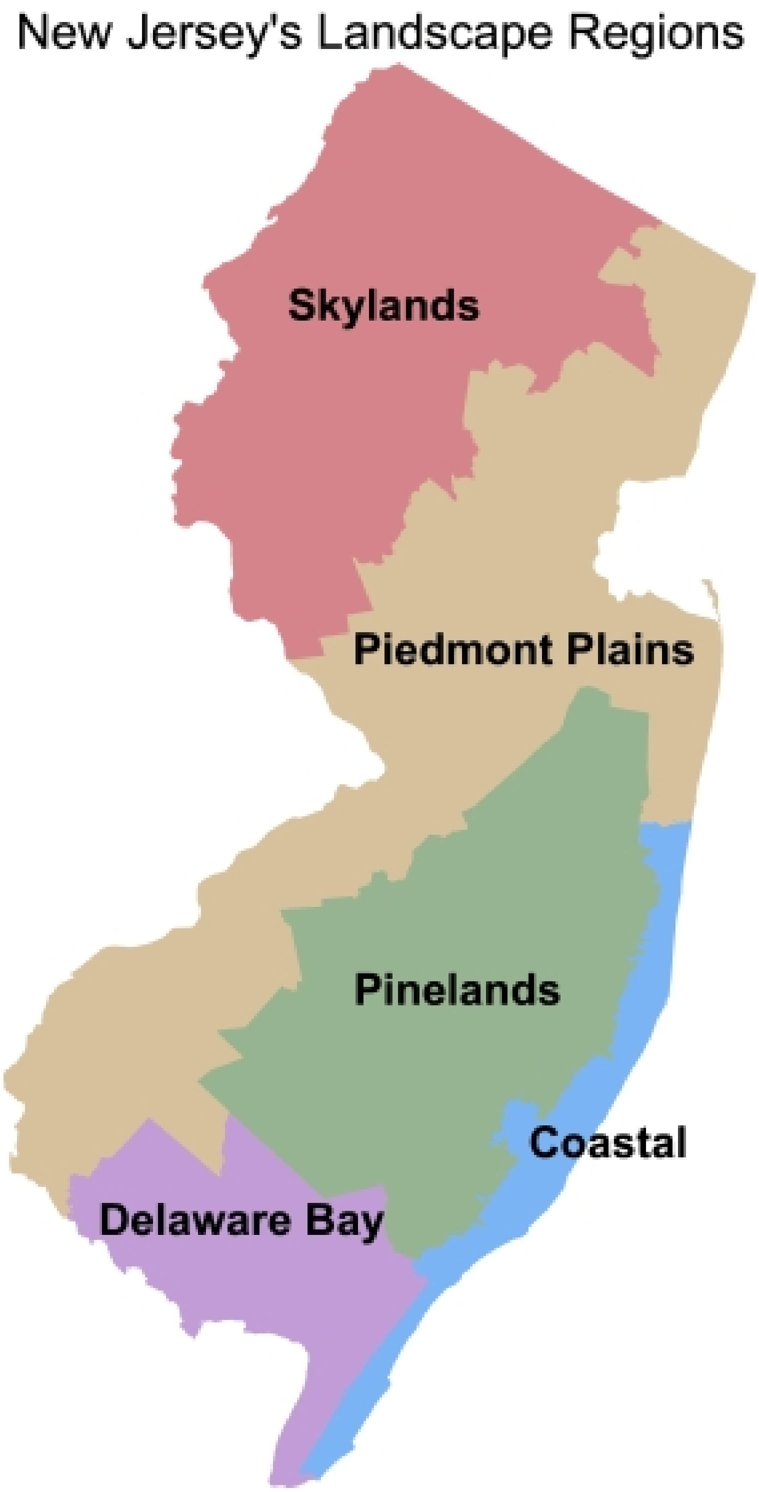


Figure 4. *New Jersey's Landscape Regions.*

Data

Land Use/Land Cover: The land-use/land-cover data that formed the basis of Version 1.0 of the Landscape Project was a raster-based classification developed by Rutgers University Center for Remote Sensing and Spatial Analysis (CRSSA). This dataset was based on Landsat Thematic Mapper imagery that was enhanced with other ancillary data such as US Fish and Wildlife Service wetland maps, New Jersey Department of Environmental Protection (DEP) freshwater wetland maps and Natural Resource Conservation Service county soil maps. ENSP selected CRSSA's raster-based dataset (CRSSA LC) over the DEP's vector-based land-use/land-cover dataset (LU/LC) primarily because it could be easily updated to reflect the rapidly changing habitat conditions within New Jersey. Changes in land use and land cover have a profound influence on wildlife habitat and ENSP biologists wanted the ability to update the Landscape maps on a frequent basis.

In Version 2.0, the ENSP opted to use the DEP's air photo-based land-use/land-cover data primarily because of the desire for consistency with other geographic data and mapping applications that employ these data across the department. The increased resolution of the aerial photo-based data and the commitment by the DEP to update the 1995 data with 2002 imagery provided additional rationale for using the NJDEP LU/LC data.

DEP's Division of Science, Research and Technology conducted a study with ENSP, other DEP programs (Bureau of Geographic Information Systems; Office of Natural Lands Management; and the Forest Service) and Rutgers CRSSA in which detailed analyses of five geographic data sets that characterize New Jersey's diverse landscape were compared (Lathrop and Hasse 2003). This research revealed several important differences between the NJDEP LU/LC and the CRSSA LC datasets.

Vector-based polygon data is represented by individual points and the line segments that connect them. As a result, line segments can form irregular shapes of varying areas to accurately depict land features in detail. Raster layers are based on a regularly spaced grid with rectangular shaped cells. Since a cell can have only one value, classification involves calculating the land class that makes up the majority of the cell and assigning it that value. Since the cells cannot be divided the result is a jagged, less accurate border around each land-use type. Therefore, the vector-based data has the benefit of topological capabilities as well as database functionality that is better suited for regulation, planning and management applications (***Figure 5***).

In addition, the NJDEP LU/LC was created from visual photo-interpretation and therefore is able to use shape, pattern and context to accurately map land features in detail. The CRSSA LC uses spectral reflectance values to differentiate land covers. Many factors can influence the accuracy of this technique such as climatic conditions, seasonal variation and heterogeneity of spectral signatures for particular land covers.

The NJDEP LU/LC classifies land use and land cover by assigning one of 66 classes described in Anderson et al. (1976). CRSSA LC uses a classification that is based on the physical material covering the earth's surface. Consequently, some areas are classified differently by the two methods. For example, lawn areas in parks are classified by the NJDEP LU/LC as developed. CRSSA LC classifies the same area as grasslands. Due to these differences some of the LU/LC classes had to be modified to include known wildlife habitat (***Appendix II***).

Wetlands also are treated differently by the two systems and may result in different classifications for similar land types. For example, the NJDEP LU/LC classifies wet hayfields as wetlands due to their regulatory status, but CRSSA LC may classify the same area as grasslands.

Mapping resolution and precision of the NJDEP LU/LC maps is slightly improved in comparison to the CRSSA-derived maps, and the ENSP based its decision to use the NJDEP LU/LC on these factors. However, because some of the species models (eg. bald eagle foraging and colonial waterbird foraging) were developed for Version 1.0, they are calculated using raster-based data and then converted to a vector-based polygon for inclusion in the Landscape Project.

For complete details on New Jersey 1995/97 Land Use/Land Cover Update Project consult the DEP's Web site at:

http://www.nj.gov/dep/gis/supfiles.html

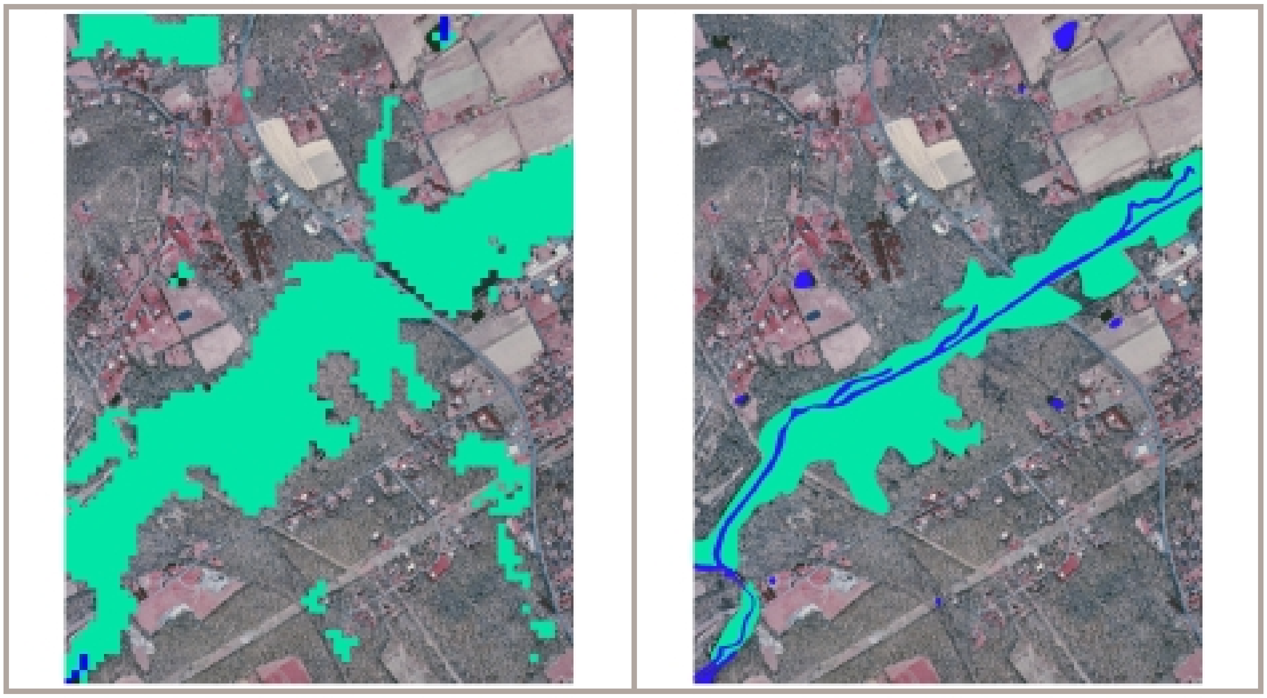


Figure 5. *A comparison of raster-based data (left) versus vector-based data (right). Note the jagged boundary of the raster-based habitat polygon compared to the smooth boundary of the vector-based habitat polygon.*

Species Data: Documented occurrences of imperiled species are used to determine critical areas. The majority of the species data used in the Landscape Project are taken directly from the Natural Heritage Program's (NHP) Biological Conservation Database (BCD) GIS coverage. Wildlife records in the BCD are derived from a variety of sources. These include ENSP surveys, DEP staff reports, private consultant reports and reports from the general public. ENSP staff is responsible for verifying all submitted records prior to acceptance (***Appendix III***). All verified sightings are mapped on 1:24000 USGS 7.5' topographic maps or the most recent color infrared aerial imagery by a staff biologist prior to entry into the BCD. Only seconds precision records (mapped to within one second of latitude and longitude) with a last observation date of 1970 or later are used to delineate and classify critical areas.

Models are applied to all species data that are used to generate the Landscape Project critical area maps (***Appendix IV***). Some models were developed based on home range/territory sizes reported in the scientific literature. Other species models consist of polygons having an area equivalent to one second of latitude and longitude with the actual sighting location at the center, or a digitized polygon that represents the habitat used by the species as defined in the NHP's Element Occurrence Specification Standards.

General Methodology for Delineating Critical Areas

The method for delineating critical areas is relatively straightforward. First, the relevant classes for each habitat type (forest, grassland, forested wetland, emergent wetland and beach) are extracted from the NJDEP's LU/LC data layer. Dissolving the different LU/LC classes for each habitat type creates contiguous habitat polygons. Using boundaries between habitat types and major roads (county level 500 and above), contiguous patches for each habitat type are delineated. Each patch is then assigned a unique link ID. Imperiled species models are then intersected with habitat patches. Habitat patches are classified based on the status of the species present as follows (***Figure 9***):

- **Rank 5** is assigned to patches containing one or more occurrences of at least one wildlife species listed as endangered or threatened on the Federal list of endangered and threatened species.
- **Rank 4** is assigned to patches with one or more occurrences of at least one State endangered species.
- **Rank 3** is assigned to patches containing one or more occurrences of at least one State threatened species.
- **Rank 2** is assigned to patches containing one or more occurrences of at least one non-listed State priority species.
- **Rank 1** is assigned to patches that meet habitat-specific suitability requirements such as minimum size criteria for endangered, threatened or priority wildlife species, but that do not intersect with any confirmed occurrences of such species.

See ***Figure 6*** for a statewide distribution of habitat by landscape region and ***Figure 7*** for a statewide distribution of critical areas (rank 3,4,5) by landscape region.

Detailed Methodology for Delineating Critical Areas by Habitat Type

Forest: Critical area maps for forest-dependent species are generated by selecting specific land-use classes from the NJDEP's LU/LC data set. See ***Appendix V*** for a list of DEP land-use classes and the corresponding habitat types. Using GIS software, the ENSP has developed the following protocols (***Figure 8***):

Outside of the Pinelands

- Extract all appropriate forest types (upland and wetland forests) from the NJDEP LU/LC dataset into one forest layer (***Appendix IV***).
- Combine all of the NJDEP LU/LC forest types that are directly adjacent to one another by dissolving the boundaries between them making a layer of contiguous forest polygons.
- Bisect the resulting forest coverage using major roads (500 level and above) to create ecologically significant boundaries between contiguous forest patches.
- Clip the resulting forest coverage by the Pinelands Area Boundary of New Jersey.
- Identify these patches and sections of patches as Pinelands Area patches.

For Pinelands Area patches proceed to protocol under the subheading "Pinelands." For forest patches outside of the Pinelands Area continue below:

- Identify forest patches that have a core area of 10 hectares or greater. Core area is defined as interior forest greater than 90 meters from the forest edge.
- Buffer all forest patches inward from the perimeter by 90 meters.
- Erase this buffer from each patch.
- If the sum of the remaining area is 10 hectares or greater, then the original patch is recoded as core. These patches receive a minimum rank of 1.

- Combine the Pinelands Area patches and sections of patches with the remaining forest patches that are directly adjacent to one another by dissolving the boundaries between them making a layer of contiguous forest polygons.
- Assign each new patch a unique Link ID used for tracking patches.
- Intersect forest species models with the new forest layer. This intersection results in a new layer with the Link ID from the forest layer and an ID from the species models. From this layer queries can be made to determine the number of records and conservation status of each patch based on the species present.
- All forest patches in the Coastal Landscape Region and the lower 10 kilometers of the Cape May peninsula are considered critical areas due to the importance of these habitats to migrating birds. These patches receive a minimum rank of 1 regardless of whether or not they contain 10 hectares of core forest.
- Habitat patches are classified based on the conservation status of the species present as detailed in the “General Methodology for Delineating Critical Areas,” section.

Pinelands

- Identify Pinelands Area connection corridors. Pinelands Area patches connected by any corridor that is greater than 91.44 meters in length and less than 91.44 meters wide are considered separate patches.
- Buffer all forest patches inward from the perimeter by 45.73 meters. This action eliminates all Pinelands connecting corridors that do not meet the required dimensions.
- Pinelands Area patches that meet the required dimensions are buffered outward from the perimeter by 45.73 meters and merged with any overlapping forest polygons. This buffer brings the forest patch back out to its original extent minus Pinelands connection corridors that do not meet the required dimensions.
- Identify Pinelands Area patches that have a core area of 10 hectares or greater. Pinelands core area is defined as contiguous interior forest greater than 90 meters from the forest edge.
- Buffer all forest patches inward from the perimeter by 90 meters.
- Erase this buffer from each patch.
- If a contiguous section of the remaining area is 10 hectares or greater, then the original patch is re-coded as core and receives a minimum rank of 1.
- Combine the Pinelands Area patches and sections of patches with the remaining forest patches that are directly adjacent to one another by dissolving the boundaries between them making a layer of contiguous forest polygons.
- Assign each new patch a unique Link ID used for tracking patches.
- Intersect forest species models with the new forest layer. This intersection results in a new layer with the Link ID from the forest layer and an ID from the species models. From this layer queries can be made to determine the number of records and conservation status of each patch based on the species present.
- All forest patches in the Coastal Landscape Region and the lower 10 kilometers of the Cape May peninsula are considered critical areas due to the importance of these habitats to migrating birds. These patches receive a minimum rank of 1 regardless of whether or not they contain 10 hectares of core forest.
- Habitat patches are classified based on the conservation status of the species present as detailed in the “General Methodology for Delineating Critical Areas,” section.

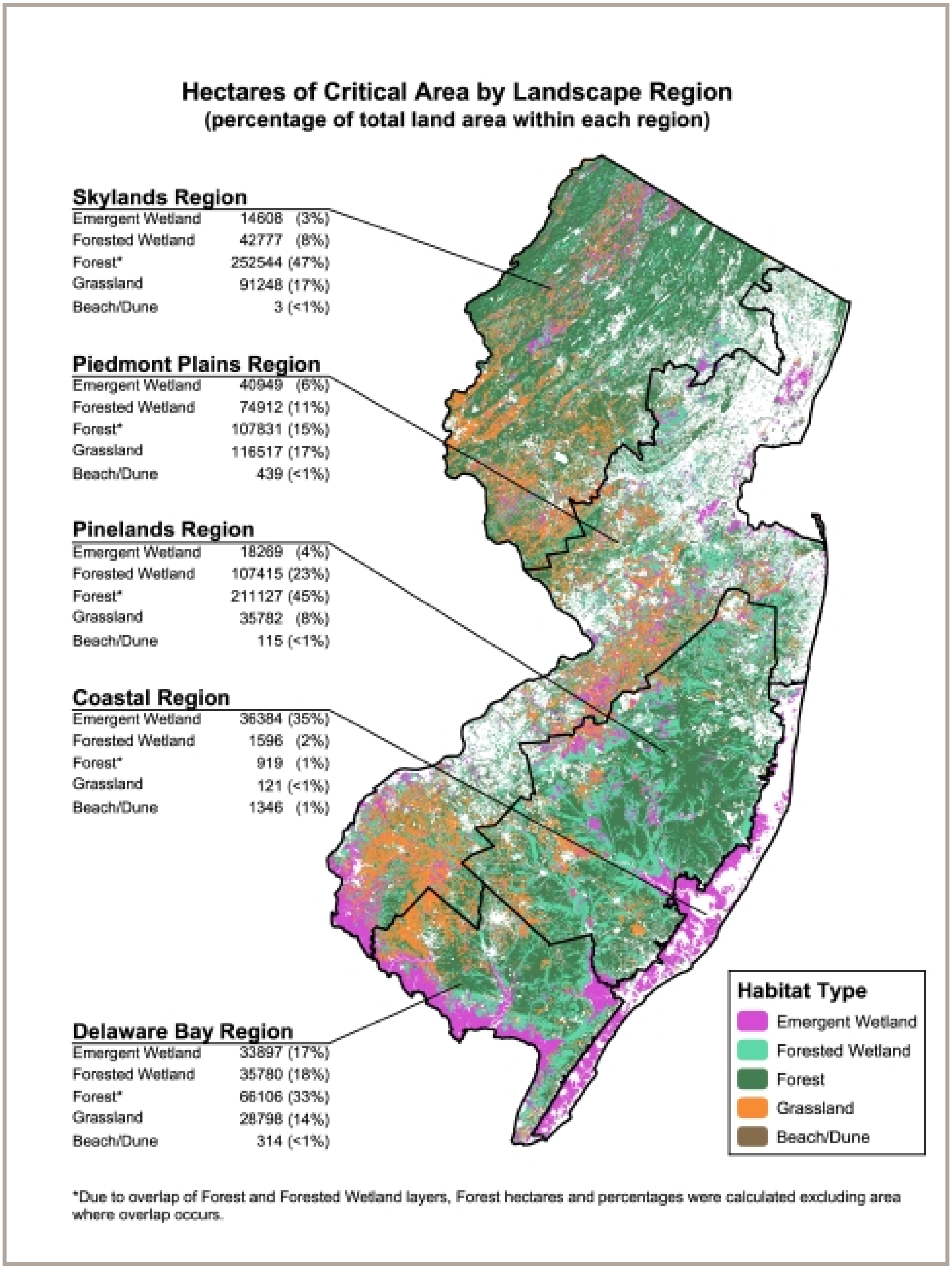


***Figure 6**. Hectares of each habitat type expressed as a percentage of the total land area within each Landscape Region.*

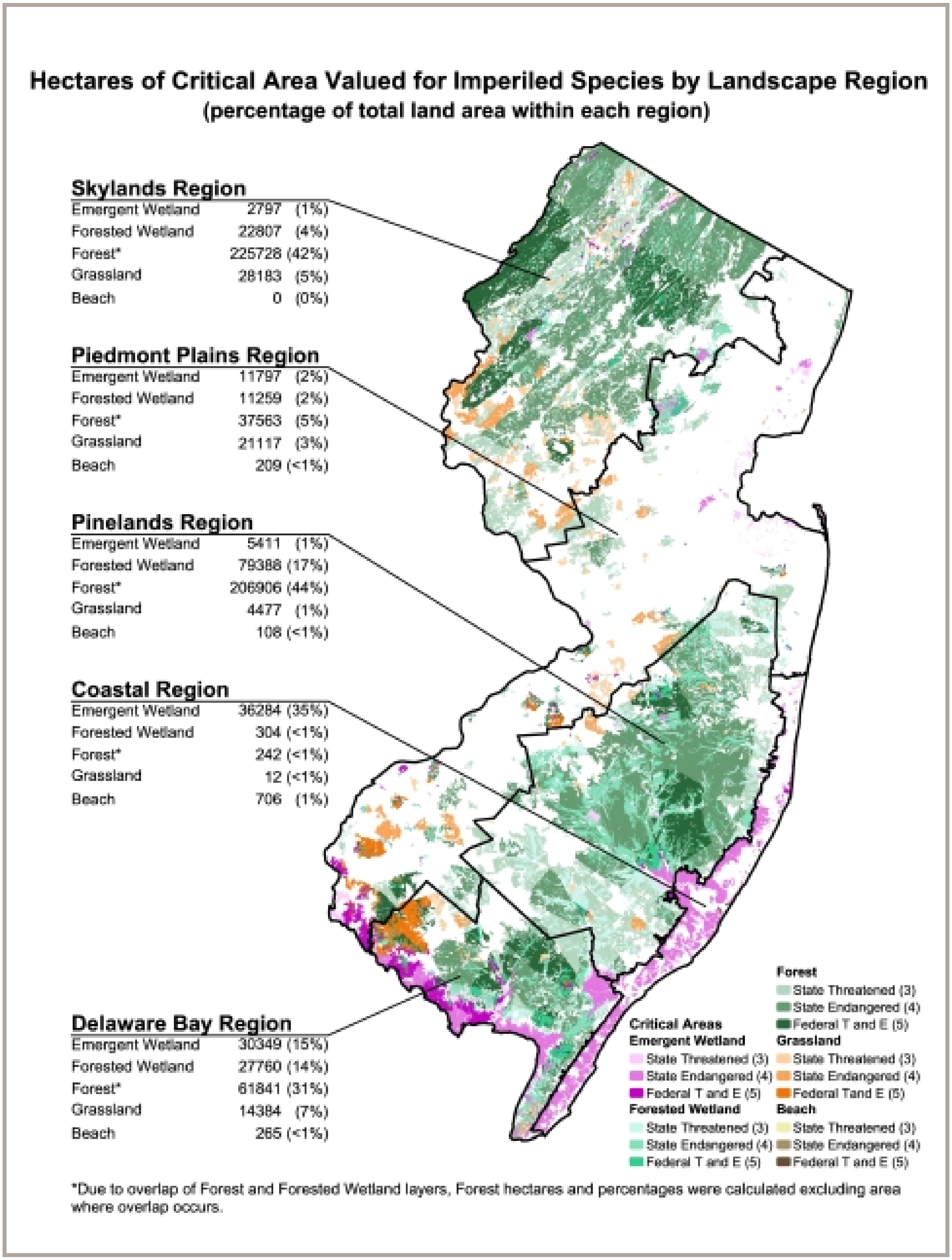


Figure 7*. Total hectares of critical area by habitat type within each Landscape Region.*

Forested Wetland: Critical area maps for forested wetland dependent species are generated by selecting specific land-use classes from the NJDEP's LU/LC data set. See ***Appendix V*** for a list of DEP land-use classes and the corresponding habitat types. Using GIS software, the ENSP has developed the following protocol:

- Extract all appropriate forested wetland types from the NJDEP's LU/LC data set into one forested wetland layer (***Appendix V***).
- Combine all of the NJDEP LU/LC forested wetland types that are directly adjacent to one another by dissolving the boundaries between them making a layer of contiguous forested wetland polygons.
- Bisect the resulting forested wetland coverage with major roads (500 level and above) to create ecologically significant boundaries between contiguous forested wetland patches.
- Assign each new patch a unique Link ID used for tracking patches.
- All forested wetland patches are considered critical areas regardless of size. Therefore, all forested wetland patches receive a minimum rank of 1.
- Intersect forested wetland species models with the new forested wetland layer. This intersection results in a new layer with the Link ID from the forested wetland layer and an ID from the species models. From this layer queries can be made to determine the number of records and conservation status of each patch based on the species present.
- Habitat patches are classified based on the conservation status of the species present as detailed in the "General Methodology for Delineating Critical Areas," section.

Emergent wetland: Critical area maps for emergent wetland dependent species are generated by selecting specific land-use classes from the NJDEP's LU/LC data set. See ***Appendix V*** for a list of DEP land-use classes and the corresponding habitat types. Using GIS software, the ENSP has developed the following protocol:

- Extract all appropriate emergent wetland types from the NJDEP's LU/LC land-use/land-cover data set into one emergent wetland layer (***Appendix V***).
- Combine all of the NJDEP LU/LC emergent wetland types that are directly adjacent to one another by dissolving the boundaries between them making a layer of contiguous emergent wetland polygons.
- Bisect the resulting emergent wetland coverage with major roads (500 level and above) to create ecologically significant boundaries between contiguous emergent wetland patches.
- Assign each new patch a unique Link ID used for tracking patches.
- All emergent wetland patches are considered critical areas regardless of size. Therefore, all emergent wetland patches receive a minimum rank of 1.
- Intersect emergent species models with the new emergent wetland layer. This intersection results in a new layer with the Link ID from the emergent wetland layer and an ID from the species models. From this layer queries can be made to determine the number of records and conservation status of each patch based on the species present.
- Habitat patches are classified based on the conservation status of the species present as detailed in the "General Methodology for Delineating Critical Areas," section.

Grassland: Critical area maps for grassland dependent species are generated by selecting specific land-use classes from the NJDEP's LU/LC data set. See ***Appendix V*** for a list of DEP land-use classes and the corresponding habitat types. Using GIS software, the ENSP has developed the following protocol :

- Extract all appropriate grassland habitat types from the NJDEP's LU/LC data set into one grassland layer (***Appendix V***).
- Combine all of the NJDEP LU/LC grassland types that are directly adjacent to one another by dissolving the boundaries between them making a layer of contiguous grassland polygons.

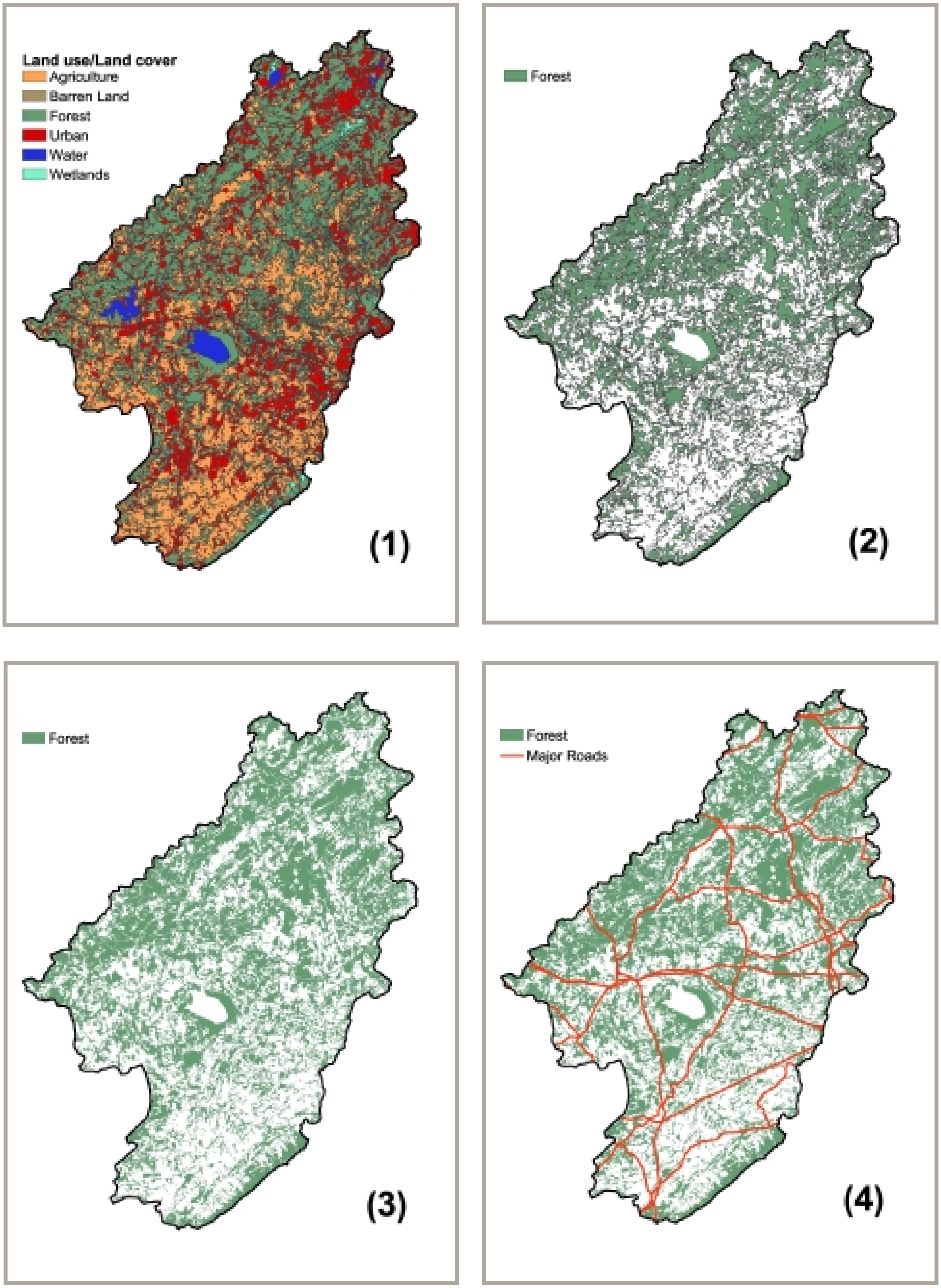


Figure 8. *A multistep process is used to delineate critical forest areas in North and South Branch Raritan Watershed Management Area. (1) NJDEP's 1995/1997 land-use/land-cover types. (2) Extract all forest types from the land-use/ land-cover data. (3) Contiguous patches are created by dissolving boundaries between adjacent forest polygons. (4) Bisect contiguous forest patches using major roads to create ecologically significant boundaries.*

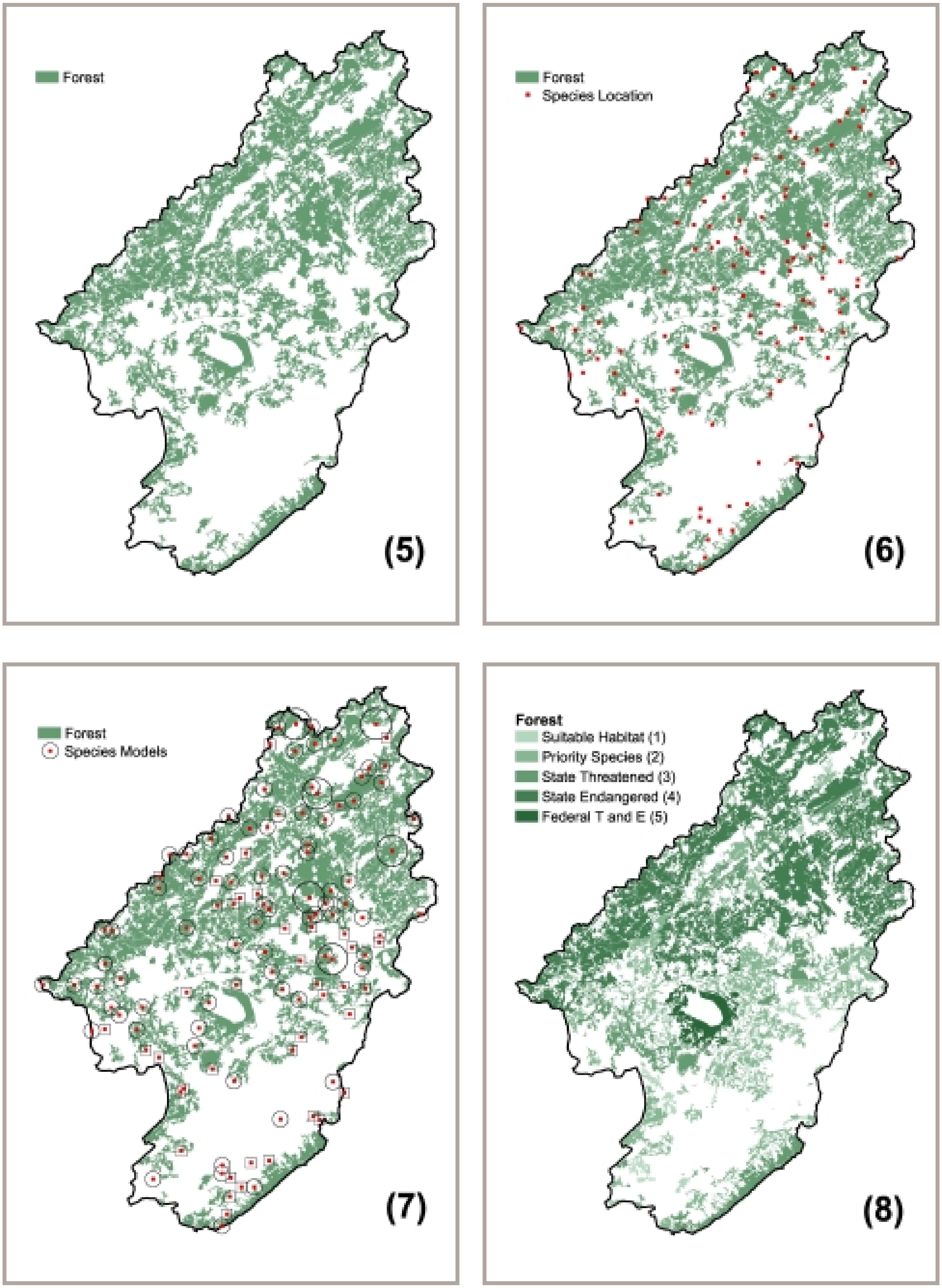


Figure 8 (Cont.). *(5) Select forest patches meeting the minimum core size. (6) Overlay species point locations on the forest coverage. (7) Intersect species models with the forest patches. (8) Rank habitat patches based on the conservation status of species present.*

- Bisect the resulting grassland coverage with major roads (500 level and above) to create ecologically significant boundaries between contiguous grassland patches.
- Assign each new patch a unique Link ID used for tracking patches.
- Select all grassland patches greater than 18 hectares. These patches meet the minimun size requirement for grasslands and receive a minimum rank of 1.
- All grassland patches in the lower 10 kilometers of the Cape May peninsula are considered critical areas. This is due to the importance of this habitat to migrating birds. These patches receive a minimum rank of 1 regardless of whether or not they contain 18 hectares of core.
- Intersect grassland species models with the new grassland layer. This intersection results in a new layer with the Link ID from the grassland layer and an ID from the species models. From this layer queries can be made to determine the number of records and conservation status of each patch based on the species present.
- Habitat patches are classified based on the conservation status of the species present as detailed in the "General Methodology for Delineating Critical Areas," section.

Beach: Critical area maps for beach dependent species are generated by selecting specific land-use classes from the NJDEP's LU/LC data set. See ***Appendix V*** for a list of DEP land-use classes and the corresponding habitat types. Using GIS software, the ENSP has developed the following protocol :

- Extract the beach habitat type from the NJDEP's LU/LC data set. Only one beach class exists in the data set (***Appendix V***).
- Beach habitats are bisected by natural breaks such as inlets and rivers and by hand digitized boundaries around species locations.
- Assign each new patch a unique Link ID used for tracking patches.
- All beach patches are considered critical areas regardless of size. Therefore, all beach patches receive a minimum rank of 1.
- Intersect beach species models with the new beach layer. This intersection results in a new layer with the Link ID from the beach layer and an ID from the species models. From this layer queries can be made to determine the number of records and conservation status of each patch based on the species present.
- Habitat patches are classified based on the conservation status of the species present as detailed in the "General Methodology for Delineating Critical Areas," section.

Detailed Methodology for Delineating Critical Areas by Special Habitat Requirements

For some species, additional specific mapping protocols were developed and are set forth below.

Bald Eagle Foraging Area: All known bald eagle nests are recorded using GPS equipment. To run the model, all water polygons from the DEP LU/LC having an area greater than 8 hectares are converted to a 5-meter grid. A radius around the nest site is incrementally increased, one cell (5 meters) at a time, until an area of 660 hectares of open water has been identified. All emergent wetland patches within 90 meters of the identified water are selected. The emergent wetland patches are merged with the identified open water. A 90-meter buffer is applied to the combined water/emergent wetland layer to protect perching sites. In the previous version (1.0) all habitat patches that intersected with the foraging habitat and 90-meter buffer were designated as critical areas. In Version 2.0 bald eagle foraging habitat, and its associated 90-meter buffer, is no longer used to value patches that intersect with it. The bald eagle foraging model is a stand-alone GIS layer that is not used to value habitat patches.

Peregrine Falcon: In Version 1.0 of the Landscape Project, emergent wetland patches that intersected a

1-kilometer radius area delineated around a peregrine falcon nest were valued as peregrine falcon habitat.

In Version 2.0, peregrine falcon nests are separated into two types, urban and non urban depending on the type of landscape in which they are located. For urban nests a 1-kilometer radius area around the nest is now valued as peregrine falcon habitat regardless of the land-cover type. Urban peregrine nests continue to value emergent wetland patches that intersect with the 1-kilometer radius area delineated around a peregrine falcon nest. Non-urban peregrine falcon nests continue to value only emergent wetland patches that intersect with the 1-kilometer radius area around the nest. The urban peregrine falcon model is a stand-alone GIS layer that values emergent wetland habitat patches.

Wood Turtle: Critical areas for wood turtles are mapped following a four-step process.

A 1.6-kilometer radius is placed around each wood turtle sighting location in the BCD. A 322-meter buffer is then applied to all streams that fall within the 1.6-kilometer radius. The NJDEP LU/LC is then overlaid on the buffered areas and all areas classified as urban, with the exception of powerline rights-of-way, are deleted from the buffer. DEP Freshwater Wetland Maps are overlaid on the stream buffers, and all wetlands that intersect the buffer are clipped within the 1.6-kilometer radius and are merged into the stream/buffer polygon. The final step of the process involves a detailed quality-control check and revision of each polygon to ensure biological accuracy. The wood turtle model is a stand-alone layer that is not used to value habitat patches.

The two principal differences between Version 1.0 and 2.0 are as follows: In Version 2.0, streams classified as 1st order or greater are included, while in Version 1.0 only streams classified by DEP as 2nd order and greater were included. This change was made based upon additional analysis following release of Version 1.0 that revealed a large number of documented wood turtle occurrences were on DEP 1st order streams, which were suitable for wood turtles.

In Version 2.0, only the identified wetlands together with the streams and stream buffers constitute wood turtle habitat, while in Version 1.0 any patches of upland forest, forested wetland, emergent wetland and grassland that intersected with the wetland and stream buffers were valued as wood turtle habitat. This change was made to limit the delineated habitat to those areas closest to suitable streams because the approach used in Version 1.0 included areas too distant from streams to be considered suitable for wood turtles. As a result of applying both of these changes, Version 2.0 values significantly less area as wood turtle habitat than Version 1.0.

Technical Information

Critical area maps are in ArcView shapefile format and projected to NJ State Plane feet, datum NAD 83, zone 4701. The maps are best viewed using ArcView 3.x or ArcGIS 8.x. These software products allow the user full functionality for viewing and manipulating critical area data. Non-GIS users can view the maps using ArcExplorer, a free GIS data browser that can be downloaded from the ESRI Web site (http://www.esri.com/software/arcexplorer/aedownload.html). ArcExplorer allows the user to view GIS data, zoom in and out, perform simple queries and print maps.

How to get critical area maps: Landscape Project data is available via download or viewing from the following DEP Web sites:

- http://www.nj.gov/dep/fgw/ensp/landscape/index.htm
- www.njfishandwildlife.com
- Interactive i-MapNJ Web site: http://www.state.nj.us/dep/gis/imapnj/imapnj.htm

or by contacting:

New Jersey's Landscape Project
Department of Environmental Protection
Division of Fish and Wildlife
Endangered and Nongame Species Program
PO Box 400
Trenton, NJ 08625-0400
Phone:(609) 292-9400
Fax:(609) 984-1414

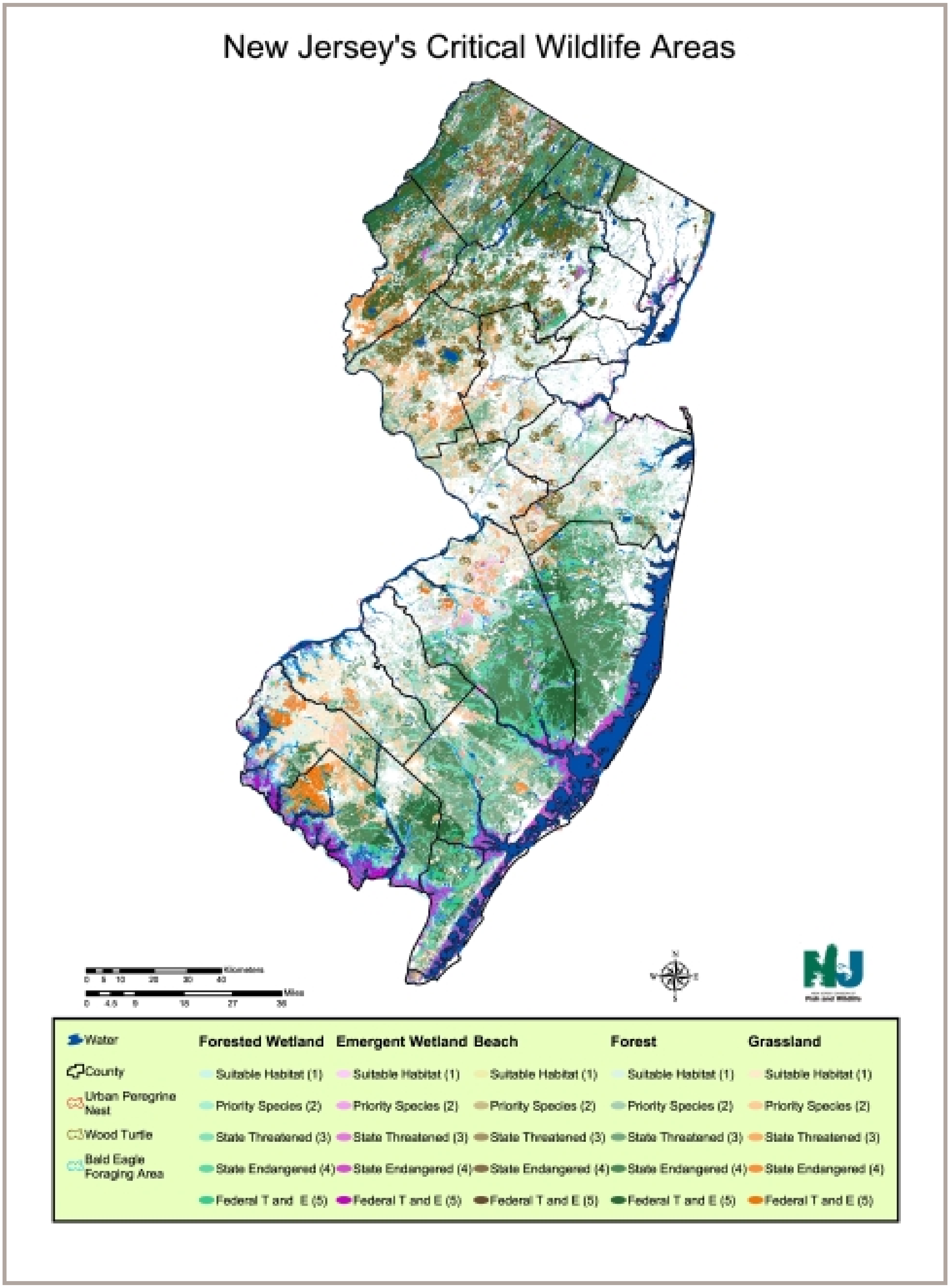


Figure 9. *New Jersey's critical wildlife areas are color coded based on habitat type (forest, forested wetland, emergent wetland, grassland and beach), with lighter to darker shades depicting the rank of patches.*

Appendices.

Appendix I. Habitat Fragmentation and Area Sensitivity

Definitions:

Priority species- means nongame species that are considered by the DEP to be species of special concern as determined by a panel of experts. The term also includes species of regional concern in regional conservation plans such as Partners in Flight Bird Conservation Plans, North American Waterbird Conservation Plan, United States Shorebird Conservation Plan, etc.

Habitat Fragmentation- the process of converting a large, continuous patch of a similar vegetation type into smaller patches of different vegetation types in a way that only scattered remnants of the original vegetation type remains (Faaborg et al. 1995).

Forest-interior birds

Many of the bird species of special or regional concern are forest-interior birds, that is, birds that nest within the interior core of a forest patch (area of forest greater than 90 meters from an edge) (Faaborg et al. 1995). Many forest-interior species are Neotropical migrants that breed in temperate North America and overwinter in the tropics of Central and South America (the "New World" or "Neotropics"). Many resident and short-distance migrant species also require forest interior to breed successfully. Forest-interior birds, as a group, are declining because of loss and fragmentation of forested breeding habitat in North America (from urban sprawl) and wintering habitat in South America; the majority are area sensitive and negatively impacted by forest fragmentation (Table 1). When a forest is fragmented, the abundance of avian and mammalian predators often increases, as well as the frequency of brood parasitism, both of which result in lower nesting success. Forest fragmentation also facilitates the spread of exotic and invasive species, both vegetative and mammalian, that can dramatically change the habitat structure of the forest, affecting the abundance and availability of food and nest sites (DeCalesta 1994, Burke and Nol 1998, McCollin 1998, Hansen et al. 2002).

Grassland Birds

Grassland birds, which are mainly short-distance migrants, have experienced severe population declines throughout the United States and constitute a sizeable proportion of birds listed as special or regional concern. The decline of agriculture, change to mechanized agriculture, and introduction of cool-season grasses in the Northeast have resulted in a fundamental shift in the character of grassland habitats. Loss and conversion of agricultural habitats to development has fragmented farmland into small, isolated patches that cannot support grassland-dependent birds (Bollinger and Gavin 1992). Furthermore, mechanized agriculture with frequent/early mowing causes direct mortality to adult and juvenile birds, and row-crop agriculture does not produce suitable breeding and foraging habitat for most grassland species.

Area Sensitivity

Neotropical migrant birds as a group, and species that prefer forest-interior habitat, tend to be more area sensitive (Whitcomb et al. 1981). In their literature review, Mitchell et al. (2000) found clear documentation of the area sensitivity of more than nine grassland bird species.

Area-sensitive species require a minimum amount of interior, or "core", habitat for successful breeding, and this minimum can vary depending on the habitats in the surrounding matrix. For grassland species, core habitat is the grassland habitat at least 50 meters inward from the grassland edge. For forest species, core habitat is the forest habitat at least 90 meters inward from the forest edge. The minimum core required to provide suitable breeding habitat for area-sensitive species is 10 hectares of forest core and 18 - 50 hectares of grassland core, (Dawson et al. 1993, Franklin 1993, Vickery et al. 1994, Faaborg et al. 1995, Collinge 1996, Dawson et al. 1998). The minimum area required to support breeding of one of the least area-sensitive grassland species (savannah sparrow) is 10 ha. of core habitat, whereas upland sandpipers require habitat in the range of 200 ha. to support a breeding population (Vickery et al. 1994). Area-sensitive birds tend not to occur in forests and grasslands, respectively, that lack core habitat (McCollin 1998, Forman et al. 2002).

The creation of "edge" habitat, resulting from fragmentation of a forest patch, changes the microhabitat of that edge zone so that it is different from the neighboring forest some distance into the interior (Saunders et al. 1991, Murcia 1995, Collinge 1996). More sunlight and wind reach the edge of a forest, thus increasing the local temperature, decreasing humidity, and affecting the local plant community with an increase in invasive exotic species (Murcia 1995, Collinge 1996, Primack 1998). This change in the local climate also can increase the chance of fire (Faaborg et al. 1995, Primack 1998) and adversely affect nesting success and food availability in the forest patch (Burke and Nol 1998, McCollin 1998).

Many forest-interior bird species tend to avoid nesting in forest edges (Hoover et al. 1995, Collinge 1996, McCollin 1998, Miller et al. 1998, Villard et al. 1999, Forman et al. 2002). The presence of a forest edge introduces more generalist species to the area that compete for foraging and nest sites. A forest edge provides favorable conditions for mammalian and avian predators to increase in number and type (Hoover et al. 1995, Murcia 1995, Collinge 1996, McCollin 1998, Faaborg et al. 2002). The number of brown-headed cowbirds (a brood parasite) also increases in forest edges, further reducing nesting success of forest birds (Brittingham & Temple 1983, Robinson et al. 1995, Collinge 1996, McCollin 1998, Primack 1998). Kilgo et al. (1998) found the probability of occurrence of prothonotary warblers, northern parulas, white-eyed vireos, kentucky warblers, and yellow-billed cuckoos to significantly increase ($P<0.05$) with core area. Of these species, the yellow-billed cuckoo and prothonotary warbler were the most sensitive to the amount of core habitat. Villard et al. (1999) found that the hairy woodpecker, least flycatcher, and veery are unlikely to occur in areas with increased edge.

In addition to habitat selection and overall productivity of bird species, the size of a habitat patch affects richness and abundance of species (Forman and Godron 1981, Robbins et al. 1989, Askins et al. 1990, Murcia 1995, Collinge 1996, Golden and Crist 2000, Summerville and Crist 2001). As the degree of forest fragmentation increases, and forest patches become smaller and more isolated, fewer area-sensitive species are present (low species richness). As a result, species assemblages become more unstable, with different species moving in and out of the patch over time (high turnover rate) (Cody 1985, Rosenzweig 1985, Askins et al. 1990, Primack 1998). Area-sensitive individuals attempting to breed in forest fragments begin to experience poor reproductive success and do not return in subsequent years (low site fidelity) (Donovan et al. 1995). Instability in the forest-interior breeding bird community and high turnover of breeding individuals is indicative of a population sink – a marginal habitat where reproductive success is low because of high nest depredation, brood parasitism, lack of adequate nest sites, poor prey availability, or a combination of these factors (Howe 1984, Wilcove 1985, Donovan et al. 1995, Burke and Nol 1998, Primack 1998, Boulinier et al. 2001).

Factors influencing effects of forest fragmentation and area sensitivity

There are many factors that influence the effects of forest fragmentation. When assessing the impacts of forest fragmentation from a landscape perspective, we need to look at the size and number of habitat patches left in the area, how far apart these patches are from each other (degree of isolation), how different the surrounding area (matrix) is from the habitat type, the type and duration of disturbance, and whether there is any type of connectivity or corridor between patches to facilitate animals moving from patch to patch (Wiens 1996, Marzluff and Ewing 2001).

A population that moves between and among patches of habitat via dispersal is called a metapopulation, or a "population of populations" (Forman 1995, Wiens 1996). It may include source populations, which have stable or positive population growth, and sink populations, which are unstable and dependent upon immigration of individuals from source populations for long-term persistence (Primack 1998). Generally, small, isolated forest patches tend to operate as sinks because they have a greater relative proportion of forest edge and little or no core area, which diminishes their ability to support viable populations of area-sensitive species. For birds, the result of habitat fragmentation is an increase in nest predators and brood parasitism, thus decreasing nesting success (Donovan et al. 1995). Large patches of contiguous forest usually act as sources, producing a surplus of individuals from high rates of reproductive success (Donovan et al. 1995). If a source habitat is fragmented, however, reproductive success drops, as does the tendency of the individuals to return to that habitat in subsequent years (Donovan et al. 1995). The results of this impact of fragmentation will not only affect the population in that source habitat, but it also will negatively affect populations in the surrounding sink habitats, as the surplus usually disperses to the neighboring sinks (Donovan et al. 1995).

Immigration and recolonization are critical for long-term, regional survival of local populations, particularly for endangered species. Imperiled species tend to have specific habitat requirements for foraging, nesting and cover (e.g., habitat "specialists"), making them more vulnerable to changes in the landscape. As it is, loss of habitat is the primary cause of the decline in species, affecting 85% of the species of plants, mammals, birds, reptiles, amphibians, fish, and invertebrates, followed by the increase of non-native species (Wilcove et al. 1998). When their habitats are lost or degraded because of fragmentation, individuals of the species also are lost because they cannot utilize habitats other than that which they are specialized for (With and Crist 1995, Collinge 1996). Furthermore, endangered species exist in much lower numbers, so it is critical that areas of suitable habitat are proximate, or connected, and the area of the habitat increased, if possible. This allows individuals to migrate to other sub populations, or into new areas of suitable habitat, while avoiding predators and hostile environments (e.g., roads, development) (Fahrig and Merriam 1985). Connectivity is particularly important for non vagile species (reptiles, amphibians, small mammals and some invertebrates) and large mammals with expansive home ranges, like bobcats (Collinge 1996, Wiens 1996).

Degree of isolation and patch connectivity. For Neotropical migrants, many factors influence how the degree of isolation of habitat patches affect metapopulations; e.g., how long the patches have been separated, how far apart the patches are from each other, how connected the patches are to each other, how different the surrounding matrix is from the habitat, how the species in question is able to disperse (Saunders et al. 1991, Collinge 1996, Bender et al. 1998, McCollin 1998) and the degree of breeding site fidelity. In general, larger forest patches that are closer together are better for the population and patches within 500 meters of each other are beneficial (Villard et al. 1999, Norris and Stutchbury 2001).

Isolated habitat patches, those that are not in close proximity or connected to patches of similar habitat, can present barriers to dispersal because of large distances to suitable habitats and/or impenetrable areas surrounding the patches of suitable habitat (Moilanen & Hanski 1998, Ricketts & Morris 2001,Vandermeer & Carvajal 2001). Isolated habitat patches tend to have a higher turnover rate for bird species than connected habitat patches (Schmiegelow et al. 1997), with fewer Neotropical migrant species occurring in more isolated forest patches (Faaborg et al. 1995).

Mammalian responses to fragmentation differs with body size, but overall, mammals are affected by habitat fragmentation and isolation (Crooks 2002). Bobcats have a home range of approximately 3 kilometers^2 (Crooks 2002) and can be found in habitat patches of 74 hectares, if in close proximity to other forest patches, but more likely in areas over 1,000 hectares. However, smaller carnivores, such as foxes, skunks, raccoons, opossums and domestic cats, have a home range size around 0.5 kilometers^2, and tend to occur in highly fragmented areas created by urban sprawl (Crooks 2002).

The effects of patch size and isolation on a population also depend largely on the amount of available habitat, the suitability of the surrounding matrix, how individuals move within and among patches (Forman and Godron 1981, Andren 1994, Wiens et al. 1997) and the degree of breeding-site fidelity of the species. Depending on the species, the effects of patch isolation may not occur until 10-50% of the original habitat remains. However, the critical threshold of habitat loss where negative effects will become apparent is difficult to predict and varies for different species (With and Crist 1995). For interior-forest birds specifically, the number of species occurring in a forest patch is significantly reduced when 30-50% of the patch is removed (Franklin and Forman 1987). Habitat specialists are affected when less than 40% of the habitat remains, whereas habitat generalists, (those species that tend to persist in a highly fragmented landscape), can withstand a higher degree of habitat loss (With and Crist 1995). Northern spotted owls are area-sensitive habitat specialists, occurring only in large forest tracts of mature coniferous forest in the Pacific Northwest. Lamberson (1994) found that as the amount of habitat decreased, juvenile owls had more difficulty finding suitable habitat while dispersing, regardless of spacing of habitat patches. The breeding pairs exhibited high site fidelity and still produced young in the waning habitat. However, their offspring dispersed into the surrounding matrix, which was unsuitable habitat, and experienced high rates of mortality. The "point-of-no-return" for habitat loss with spotted owls was with less than 15% of suitable habitat remaining in the landscape. At this point there was virtually no probability of owls finding mates or suitable nesting sites, and the population of spotted owls in that landscape would soon be extirpated (Lamberson et al. 1994).

It is important to preserve and maintain large tracts of habitat for the most area-sensitive species. In landscapes where at least 30-40% of the habitat remains, spatial arrangement (proximity and connectivity) of habitat patches also can be very important (Franklin and Forman 1987, Andren 1994, With and Crist 1995, Forman and Collinge 1997, Fahrig 1998), as each species has its own threshold tolerance for habitat loss and fragmentation (Lovejoy and Oren 1981, Monkkonen and Reunanen 1999). There are, however, some species, such as the American marten, that are affected by habitat loss regardless of connectivity (Hargis 1999).

Ability to disperse. For birds and other animals that are very mobile, the effects of isolation on a population may only appear in very fragmented habitats (Andren 1994, With and Crist 1995). Birds are physically capable of dispersing over great distances and through various habitats during migration, which allows them to locate scarce patches of foraging and resting habitat. However, open areas within large patches of forest may act as a barrier to forest-interior species (Belisle and St. Clair 2001). Furthermore, larger distances between patches (>2.4 km) can hinder dispersal and re-colonization of patches during breeding (Bellamy et al. 1996).

Limited dispersal capabilities for non vagile animals (small mammals, reptiles, amphibians, invertebrates) make these species more sensitive to habitat fragmentation (Collinge 1996, Wiens 1996). The degree of isolation can be a more serious problem where the matrix may be a complete barrier to dispersal, cause direct mortality (roads and highways), or severely reduce the likelihood of survival during immigration through this matrix (Noss 1991). Barriers to immigration and emigration result in inbreeding depression from reduction in gene flow causing the isolated population to be more susceptible to disease, genetic abnormalities, and local extinction (Fahrig and Merriam 1985, Simberloff and Cox 1987, Beier 1993, Primack 1998). Roads act as barriers that isolate wetlands, which can cause a reduction in species richness of amphibians (Lehtinen et al. 1999). Roads also change the chemical conditions of wetlands and stream corridors from runoff of road salts, oil and other contaminants (Trombulak and Frissell 2000), which are also known to reduce amphibian populations (Lehtinen et al. 1999).

Existence of corridors. For habitat specialists or species with limited dispersal capabilities, the presence of corridors may provide an effective means to enhance dispersal, thus reducing the effects of isolation and fragmentation on a population (Simberloff and Cox 1987, Collinge 1996, Beier and Noss 1998, Haddad 1999). Habitat corridors are defined as "a linear landscape element that provides for movement between habitat patches" (Rosenberg and Noon 1997) and are predicted to be more beneficial to populations when connecting large patches of habitat (Haas 1995, Desrochers and Hannon 1997, Haddad 2000, Hudgens and Haddad 2003).

Larger mammals have been shown to include corridors in their home ranges (Simberloff and Cox 1987) and use them while dispersing (Beier 1995).

Furthermore, smaller-bodied species and species with high population growth rates that cannot survive outside the preferred habitat, such as some butterfly species, received greater benefits from habitat corridors than larger-bodied species (Fahrig and Merriam 1994, Bowne et al. 1998, Hudgens and Haddad 2003). Although the effectiveness of habitat corridors is disputed, particularly for birds (Simberloff and Cox 1987, Haddad 2000, Norris and Stutchbury 2001, Hudgens and Haddad 2003), studies have shown that corridors are more effective at greater widths (Collinge 1996, Haddad 1999, Haddad 2000). Many species of birds have a higher probability of using corridors as corridors get wider (Keller et al. 1993). Specifically, the probability of occurrence of prothonotary warblers, white-eyed vireos, eastern wood-pewees, red-eyed vireos, scarlet tanagers, kentucky warblers and louisiana waterthrushes all increased with corridor width. The probability of occurrence of acadian flycatchers and wood thrushes also increased with corridor width, but the maximum probability was at a width of only 300 meters for both species (Keller et al. 1993). From this kind of data, Hodges and Krementz (1996) and Keller et al. (1993) recommended that riparian corridors be a minimum of 100 meters wide to provide nesting habitat for area-sensitive species and Neotropical migrants, but priority should be made in preserving the widest corridors possible. Being that habitat corridors are intended to facilitate movement between habitat patches, we agree with Beier and Noss (1998) in their conclusion "that evidence from well-designed studies generally supports the utility of corridors as a conservation tool."

Disturbance. Disturbance is defined as an event that significantly alters the structure or function of a system (Forman 1995). There are generally two types of disturbance: Natural and human. For example, a natural disturbance may be caused by floods, earthquakes, fires, etc., while human disturbances exist as roads, agriculture, silviculture, etc. (Forman 1995).

For bird communities, the type of disturbance can have more of an effect than the extent of disturbance (Rodewald and Yahner 2001). Older forests with larger, fewer trees (large basal areas) and well-developed canopy, subcanopy, shrub, and herbaceous layers with a well-developed component of dead biomass (standing or fallen trees) support the highest diversity of species. Many silviculture practices favor monocultures and/or even-aged stands that are rarely left long enough to develop the necessary vegetative structure to support diverse faunal communities. Clear-cut forests tend to have the lowest species richness (Triquet et al. 1990). Higher numbers of species occur in uncut forests than in forests where best management practices with buffer strips are implemented.

Individual species have different levels of tolerance to different types of disturbance. For instance, blue-gray gnatcatchers, eastern towhees, ovenbirds, scarlet tanagers, and wood thrushes are intolerant to forest disturbance, while warbling vireos, yellow warblers, and field sparrows have a low tolerance to forest disturbance (Stauffer and Best 1980). Rodewald and Yahner (2001) found that agricultural disturbance within forested landscapes negatively affected bird communities in adjacent forests, and silvicultural practices, which produced even-aged forest stands, tended to increase the abundance of edge species and canopy nesters.

For species that require early-successional habitats (grassland and scrub-shrub bird communities), disturbance such as fire or mowing is necessary to maintain these habitats. Here again, vegetation structure is critical. Mechanized, row-crop agriculture does not produce suitable habitat for grassland species, and early mowing of non-row crops destroys nests, nestlings and adult birds. Conversion of farmland into development completely destroys habitat.

Roads have been used to define boundaries of habitat patches, particularly when bisecting a forest patch. Many small mammals and ground-dwelling invertebrates will perceive a roadway 20 meters wide or less as a barrier (Noss 1991). A road bisecting a forest would not affect the physical ability of birds to travel between patches (Hudgens and Haddad 2003), however, roads can impact species that prefer forest interiors and can cause high mortality of all species. Forman and Deblinger (2000) found the population of forest-interior species to be one-third its normal capacity within 650 meters of a four-lane highway. The noise generated from traffic along a major highway caused birds to avoid areas from 40 to 2,800 meters of the road, depending on the amount of traffic (Reijnan et al. 1995).

As with forest-interior species, recent research has demonstrated that the presence of vehicular traffic can cause otherwise suitable early-successional habitat to become unsuitable. The presence of grassland birds breeding in an area of quality habitat (hayfield, lightly grazed pasture, old field) is affected by the size of the patch and the distance of the patch to a road with moderate or heavy traffic (>8,000 vehicles per day) (Reijnan et al. 1995, Forman et al. 2002). Fewer breeding birds were found in patches of quality grassland habitat within 400 meters of a road with moderate traffic (8,000-15,000 vehicles per day) to 1,200 meters of a road with heavy traffic (= 30,000 vehicles per day) (Reijnan et al. 1995, Forman et al. 2002). eastern meadowlarks, in particular, are less sensitive than other grassland species to traffic volume, being affected by roads with only heavy traffic (= 30,000 vehicles per day), but are more sensitive to the amount of development surrounding the habitat patch (Forman et al. 2002).

Table I. Priority Bird Species Based on Habitat Preference.

Common Name	***Migratory Habit***	***Area Sensitive***	***Vulnerable to Fragmentation***	***Citation ID***
Interior Forest				
Acadian Flycatcher	Neotropical	Yes	Yes	1
Baltimore Oriole	Neotropical	No	No	43
Black-and-white Warbler	Neotropical	Yes	Yes	8
Black-billed Cuckoo	Neotropical	Yes	Yes	6
Blackburnian Warbler	Neotropical	Yes	Yes	14
Black-throated Blue Warbler	Neotropical	Yes	Yes	15
Black-throated Green Warbler	Neotropical	Yes	Yes	5
Broad-winged Hawk	Neotropical	Yes	Yes	10
Canada Warbler	Neotropical	Yes	Yes	11
Carolina Chickadee	Resident	Yes	Yes	44
Cerulean Warbler	Neotropical	Yes	Yes	45
Eastern Wood-pewee	Neotropical	Yes	Yes	9
Gray Catbird	Short distance	Moderate	Moderate	44
Hairy Woodpecker	Resident	Yes	Yes	44
Hermit Thrush	Short distance	Unknown	Unknown	36
Hooded Warbler	Neotropical	Yes	Yes	7
Kentucky Warbler	Neotropical	Yes	Yes	28
Least Flycatcher	Neotropical	Yes	No	18
Louisiana Waterthrush	Neotropical	Yes	Yes	8
Northern Flicker	Resident	No	Moderate	37
Northern Parula	Neotropical	Yes	Yes	25
Northern Saw-whet Owl	Short distance	Yes	No	21
Pine Warbler	Neotropical	Yes	Yes	27
Prothonotary Warbler	Neotropical	Yes	Yes	46
Purple Finch	Short distance	No	Yes	48
Red Crossbill	Short distance	Unknown	Unknown	
Red-breasted Nuthatch	Short distance	Unknown	Unknown	36
Red-eyed Vireo	Neotropical	Yes	Yes	44
Rose-breasted Grosbeak	Neotropical	No	No	49
Scarlet Tanager	Neotropical	Yes	Yes	44
Sharp-shinned Hawk	Short distance	Yes	Unknown	16
Blue-headed Vireo	Neotropical	Yes	Yes	5
Veery	Neotropical	Yes	Yes	12
White-eyed Vireo	Short distance	Yes	Yes	40
Winter Wren	Short distance	Yes	Yes	5
Wood Thrush	Neotropical	Yes	Yes	26
Worm-eating Warbler	Neotropical	Yes	Yes	8
Yellow-billed Cuckoo	Neotropical	Yes	Yes	20
Yellow-throated Vireo	Neotropical	Yes	Yes	4

Table I. (Cont.) Priority Bird Species Based on Habitat Preference.

Common Name	*Migratory Habit*	*Area Sensitive*	*Vulnerable to Fragmentation*	*Citation ID*
Grassland				
American Kestrel	Short distance	Yes	No	31
Barn Owl	Short distance	No	No	35
Dickcissel	Neotropical	Yes	No	29
Eastern Bluebird	Short distance	No	No	3
Eastern Kingbird	Neotropical	No	No	38
Eastern Meadowlark	Short distance	Yes	No	34
Northern Bobwhite	Resident	Moderate	No	17
Horned Lark	Short distance	No	No	13
Shrub-Scrub/Barrens				
American Woodcock	Short distance	No	No	33
Blue-winged Warbler	Neotropical	Unknown	No	19
Brown Thrasher	Short distance	Unknown	Unknown	
Chuck-will's Widow	Neotropical	Yes	No	47
Common Nighthawk	Neotropical	No	No	42
Eastern Towhee	Short distance	Moderate	No	32
Field Sparrow	Short distance	Moderate	Moderate	22
Golden-winged Warbler	Neotropical	Unknown	No	24
Indigo Bunting	Neotropical	No	Moderate	41
Prairie Warbler	Neotropical	Yes	Yes	2
Whip-poor-will	Neotropical	Unknown	Moderate	23
Willow Flycatcher	Neotropical	Unknown	Yes	39
Yellow-breasted Chat	Neotropical	No	No	30

Table II. Literature Citations for Species in Table I.

ID	Citation
1	Askins & Philbrick 1987, Benzinger 1994, Darr et al. 1998, Rich et al. 1994, Robbins et al. 1989, Whitcomb et al. 1981
2	A. Dey unpubl. Data, McIntyre 1995, Staicer et al. 1995
3	Adair & Plissner 1998
4	Askins & Philbrick 1987, Rich et al. 1994, Zeller et al. 1993
5	Askins & Philbrick 1987, Benzinger 1994, Rich et al. 1994
6	Askins & Philbrick 1987, Darr et al. 1998, Deeble et al. 2000, Rich et al 1994, Whitcomb et al. 1981
7	Askins & Philbrick 1987, Darr et al. 1998, Heckscher & Mehlman 1999, Rich et al. 1994, Whitcomb et al. 1981
8	Askins & Philbrick 1987, Darr et al. 1998, Rich et al. 1994, Robbins et al. 1989, Whitcomb et al. 1981
9	Askins & Philbrick 1987, Darr et al. 1998, Rich et al. 1994, Whitcomb et al. 1981
10	Askins & Philbrick 1987, Rich et al. 1994
11	Askins & Philbrick 1987, Rich et al. 1994, Robbins et al. 1989
12	Askins & Philbrick 1987, Rich et al. 1994, Robbins et al. 1989, Whitcomb et al. 1981
13	Beasen 1995, Dinkins et al. 2001
14	Benzinger 1994, Catlin et al. 1999
15	Benzinger 1994, Robbins et al. 1989
16	Bildstein & Meyer 2000
17	Brennan 1999
18	Briskie 1994, Villard et al 1999
19	Brown et al. 1999
20	Brown et al. 1999, Darr et al. 1998, Robbins et al. 1989, Whitcomb et al. 1981
21	Cannings 1993
22	Carey et al. 1993, Dechant et al. 2001
23	Cink 2002
24	Confer et al. 1992
25	Darr et al. 1998, Hammerson et al. 2001, Robbins et al 1989, Whitcomb et al. 1981
26	Darr et al. 1998, Hoover et al. 1995, Robbins et al. 1989, Whitcomb et al. 1981
27	Darr et al. 1998, Rodewald et al. 1995, Whitcomb et al. 1981
28	Darr et al. 1998, Robbins et al. 1989, Whitcomb et al. 1981
29	Dechant et al. 2001
30	Eckerle & Thompson 2001, Thompson et al. 1996
31	Forman et al. 1976
32	Greenlaw 1996
33	Keppie & Whiting 1994
34	Lanyon 1995, Forman et al. 2002
35	Marti 1992, Rosenburg et al. 1998
36	McIntyre 1995
37	Moore 1995
38	Murphy 1996
39	Paige et al. 1998
40	Palis et al. 2001
41	Payne 1992
42	Poulin et al. 1996
43	Rising & Flood 1998
44	Robbins et al. 1989
45	Robbins et al. 1989, Whitcomb et al. 1981
46	Sallabanks et al. 1993, Whitcomb et al. 1981
47	Straight & Cooper 2000
48	Woottan 1996
49	Wyatt & Francis 2002

Literature Cited

Adair, P. and J. Plissner. 1998. Eastern Bluebird. No. 381 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Andren, H. 1994. Area-dependent changes in bird communities and vegetation of southern Wisconsin forests. Ecology 64:1057-1068.

Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71(3):355-362.

Askins, A., J.F. Lynch, and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. Pages 1-57 in D. M. Power (ed.), Current Ornithology Vol. 7, Plenum Press, New York.

Beasen, R.C. 1995. Horned Larked. No. 195 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. Conservation Biology 7:98-108.

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59(2):228-237.

Beier, P. and R.F. Noss. 1998. Do habitat corridors provide connectivity? Conservation Biology 12(6):2352-1252.

Belisle, M. and C. St. Clair. 2001. Cumulative effects of barriers on the movements of forest birds. Conservation Ecology 5(2):9-25.

Bellamy, P.E., S.A. Hinsley, and I. Newton. 1996. Local extinctions and recolonizations of passerine bird populations in small woods. Oecologia 108:64-71.

Bender, D., T. Contreras, and L. Fahrig. 1998. Habitat loss and population decline: a meta-analysis of the patch size effect. Ecology 79(2):517-533.

Benzinger, J. 1994. Hemlock decline and breeding birds. II. Effects of habitat change. Records of New Jersey Birds. Vol XX, No. 2: 34-51.

Bildstein, K. and K. Meyer. 2000. Sharp-shinned Hawk. No. 482 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Bollinger, E.K. and T.A. Gavin. 1992. Eastern Bobolink populations: Ecology and conservation in an agricultural landscape. Pages 497-506 in Hagan, J. M., III and D. W. Johnson (eds.), Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institute Press, Washington, D.C.

Boulinier, R., J. Nichols, J. Hines, J. Sauer, C. Flather, and K. Pollock. 2001. Forest fragmentation and bird community dynamics: Inference at regional scales. Ecology 82(4):1159-1169.

Bowne, D., J. Pales, and G. Barrett. 1998. Effects of landscape spatial structures on movement patterns of the hispid cotton rat (Sigmodon hispidus). Landscape Ecology 14:53-65.

Brennan, L. 1999. Northern Bobwhite. No. 397 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Briskie, J. 1994. Least flycatcher No. 99 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Brittingham, M.C. and S.A. Temple. 1983. Have cowbirds caused forest songbirds to decline? BioScience 33:31-35.

Brown, B., M. Koenen, and D.W. Mehlman. 1999. Species management abstract (element stewardship abstract) for Blue-winged Warbler (Vermivora pinus). The Nature Conservancy, Arlington, VA.

Brown, B., M. Koenen, and D.W. Mehlman. 1999. Species management abstract (element stewardship abstract) for Yellow-billed Cuckoo (Coccyzus americanus). The Nature Conservancy, Arlington, VA.

Burke, D.M., and E. Nol. 1998. Influence of food abundance, nest-site habitat, and forest fragmentation on breeding ovenbirds. Auk 115(1):96-104.

Cannings, R. 1993. Northern Saw-whet Owl. No. 42 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Carey, M., D.E. Burhans, and D.A. Nelson. 1994. Field Sparrow. No. 103 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Carter, M.F., W.C. Hunter, D.N. Pashley, and K.V. Rosenberg. 2000. Setting conservation priorities for landbirds in the United States: The Partners In Flight approach. Auk 117:541-548.

Catlin, D., M. Koenen, and D.W. Mehlman. 1999. Species management abstract (element stewardship abstract) for Blackburnian warbler (Dendroica fusca). The Nature Conservancy, Arlington, VA.

Cink, C. 2002. Whip-poor-will. No. 620 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Cody, M.L. 1985. An introduction to habitat selection in birds. In M.L. Cody (ed.) Habitat Selection in Birds, Academic Press, Orlando.

Collinge, S. 1996. Ecological consequences of habitat fragmentation: implications for landscape architecture and planning. Landscape and Urban Planning 36:59-77.

Confer, J.L., G. Hammerson, and D.W. Mehlman. 1992. Species management abstract (element stewardship abstract) for Golden-winged Warbler (Vermivora chrysoptera). The Nature Conservancy, Arlington, VA.

Crooks, K.R. 2002. Relative sensitivities of mammalian carnivores to habitat fragmentation. Conservation Biology 16(2):488-502.

Darr, L.J., D.K. Dawson, and C.S. Robbins. 1998. Land-use planning to conserve habitat for breeding forest birds in a fragmented landscape. Urban Ecosystems 2:75-84.

Dawson, D.K., L.J. Darr, C.S. Robbins. 1993. Predicting the distribution of breeding forest birds in a fragmented landscape. Trans. 58th North American Wildlife and Natural Resource Conference. Pgs.35-43.

Dawson, D.K., C.S. Robbins, and L.J. Darr. 1998. Effects of urbanization on the distribution of area-sensitive forest birds in Prince George's County, Maryland. Pages 207-213 in G. D. Therres (ed.), Conservation of Biological Diversity: A Key to the Restoration of the Chesapeake Bay Ecosystem and Beyond. Maryland Department of Natural Resources, Annapolis, MD.

DeCalesta, D.S. 1994. Effect of white-tailed deer on songbirds within managed forests in Pennsylvania. Journal. Wildlife Management 58(4):711-718.

Dechant, J.A., M.L. Sondreal, D.H. Johnson, L. D. Igl, C. M. Goldade, B. D. Parkin, and B. R. Euliss. 2001. Effects of management practices on grassland birds: Field sparrow. Northern Prairie Wildlife Research Center, Jamestown, ND. Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/literatr/grasbird/fisp/fisp.htm (Version 17FEB2000).

Deeble, B., M. Koenen, and D.W. Mehlman. 2000. Species management abstract for black-billed cuckoo. The Nature Conservancy, Arlington, VA.

Desrochers, A. and S. Hannon. 1997. Gap crossing decisions by forest songbirds during the post-fledgling period. Conservation Biology 11(5):1204-1210.

Dinkins, M.F., A.L. Zimmerman, J.A. Dechant, B.D. Parkin, D.H. Johnson, L.D. Igl, C.M. Goldade, and B.R. Euliss. 2001. Effects of management practices on grassland birds: Horned lark. Northern Prairie Wildlife Research Center, Jamestown, ND. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/literatr/grasbird/hola/hola.htm (Version 16JUN2000).

Donovan, T.M., F.R. Thompson, J. Faaborg, and J.R. Probst. 1995. Reproductive success of migratory birds in habitat sources and sinks. Conservation Biology 9(6):1380-1395.

Donovan, T.M., R.H. Lamberson, A. Kimber, F. R. Thompson, and J. Faaborg. 1995. Modeling the effects of habitat fragmentation on source and sink demography of neotropical migrant birds. Conservation Biology 9(6):1396-1407.

Eckerle, K. and C. Thompson. 2001. Yellow-breasted chat. No. 575 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Faaborg, J., M. Brittingham, T. Donovan, et al. 1995. Habitat fragmentation in the temperate zone. Pages 357-380 in Martin, T. E. and D. M. Finch (eds.) Ecology and management of Neotropical migratory birds: A synthesis and review of critical issues. Oxford University Press, New York.

Fahrig, L. 1998. When does fragmentation of breeding habitat affect population survival? Ecological Modelling 105:273-292.

Fahrig, L. and, G. Merriam. 1985. Habitat patch connectivity and population survival. Ecology 66(6):1762-1768.

Fahrig, L. and, G. Merriam. 1994. Conservation of fragmented populations. Conservation Biology 8:50-59.

Forman, R.T. 1995. Land mosaics: The ecology of landscape and regions. Cambridge University Press, Cambridge.

Forman, R.T., A. Galli and C. Leck. 1976. Forest size and avian diversity in New Jersey woodlots with some land use implications. Oecologia 26:1-8.

Forman, R.T., and M. Godron. 1981. Patches and structural components for a landscape ecology. Bioscience 31:733-740.

Forman, R. and S. Collinge. 1997. Nature conserved in changing landscapes with and without spatial planning. Landscape and Urban Planning 37:129-135.

Forman, R.T. and R.D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts (USA) suburban highway. Conservation Biology 14:36-46.

Forman, R.T., B. Reinaking, and A. Hersperger. 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. Environmental Management 29(6):782-800.

Franklin, J. 1993. Preserving biodiversity: Species, ecosystems, or landscapes? Ecological Applications 3(2):202-205.

Franklin, J. and R. Forman. 1987. Creating landscape patterns by forest cutting: Ecological consequences and principles. Landscape Ecology 1:5-18.

Golden, D.M. and T.O. Crist. 2000. Experimental effects of habitat fragmentation on rove beetles and ants: Patch area or edge? Oikos 90:525-538.

Haas, C. 1995. Dispersal and use of corridors by birds in wooded patches on an agricultural landscape. Conservation Biology 9(4):845-854.

Haddad, N. 1999. Corridor use predicted from behaviors at habitat boundaries. The American Naturalist 153(2):215-227.

Haddad, N. 2000. Corridor length and patch colonization by a butterfly, Junonia coenia. Conservation Biology 14(3):738-745.

Hammerson, G., B. Robertson, and S. Cannings. 2001. Species management abstract (element stewardship abstract) for Northern Parula (Parula americana). The Nature Conservancy, Arlington, VA.

Hansen, A. J., R. Rasker, B. Maxwell, J. J. Rotella, J. D. Johnson, A. W. Parmenter, U. Langner, W. B. Cohen, R. L. Lawrence, and M. Kraska. 2002. Ecological causes and consequences of demographic change in the New West. Bioscience 52(2):151-162.

Hargis, C.D., J.A. Bissonnette, and D.L. Turner. 1999. The influence of forest fragmentation and landscape pattern on American martens. Journal of Applied Ecology 36:157-172.

Heckscher, C.M. and D.W. Mehlman. 1999. Species management abstract (element stewardship abstract) for Hooded Warbler (Wilsonia citrina). The Nature Conservancy, Arlington, VA.

Hodges, M., Jr., and D. Krementz. 1996. Neotropical migratory breeding bird communities in riparian forests of different widths along the Altamaha River, Georgia. The Wilson Bulletin 108:496-506.

Hoover, J., M. Brittingham, and L. Goodrich. 1995. Effects of forest patch size on nesting success of wood thrushes. Auk 112(1):146-155.

Howe, R. 1984. Local dynamics of bird assemblages in small forest habitat islands in Australia and North America. Ecology 65(5):1585-1601.

Hudgens, B. R. and N. M. Haddad. 2003. Predicting which species will benefit from corridors in fragmented landscapes from population growth models. American Naturalist 161(5):808-820.

Keller, C., C. Robbins, and J. Hatfield. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands 13:137-144.

Keppie, D. and R. Whiting. 1994. American woodcock. No. 100 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Kilgo, J., R. Sargent, B. Chapman, and K. Miller. 1998. Effect of stand width and adjacent habitat on breeding bird communities in bottom and hardwoods. Journal of Wildlife Management 62:72-83.

Lamberson, R., B. Noon, C. Voss, and K. McKelvey. 1994. Reserve design for territorial species: The effects of patch size and spacing on the viability of the northern spotted owl. Conservation Biology 8:185-195.

Lanyan, W. E. 1995. Eastern meadowlark No. 160 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Lehtinen, R., S. Galatowitsch, and J. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands 19(1):1-12.

Lovejoy, T. and D. Oren. 1981. Forest Island Dynamics in Man-Dominated Landscapes. Pages 7- 12 in R. Burgess and D. Sharpe (eds.), Forest Island Dynamics in Man-Dominated Landscapes. Springer-Verlad New York, Inc., New York.

Marti, C.D. 1992. Barn Owl No. 1 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Marzluff, J.M. and K. Ewing. 2001. Restoration of fragmented landscapes for the conservation of birds: A general framework and specific recommendations for urbanizing landscapes. Restoration Ecology 9(3):280-292.

McCollin, D. 1998. Forest edges and habitat selection in birds: a functional approach. Ecography 21:247-260.

McIntyre, N. 1995. Effects of forest patch size on avian diversity. Landscape Ecology 10(2): 85-99.

Miller, S., R. Knight, and C. Miller. 1998. Influence of recreational trails on breeding bird communities. Ecological Applications 8(1):162-169.

Mitchell, L.R., C.R. Smith, R.A. Malecki. 2000. Ecology of grassland breeding birds in the Northeastern United States: A literature review with recommendations for management. USGS Cooperative Fish and Wildlife Research Unit, Department of Natural Resources, Cornell University, Ithaca, NY. 69 p.

Moilanen, A. and I. Hanski. 1998. Metapopulation dynamics: effects of habitat quality and landscape structure. Ecology 79(7):2503-2515.

Mönkkönen, M. and P. Reunanen. 1999. On critical thresholds in landscape connectivity: A management perspective. Oikos 84(3):302-305.

Moore, W. 1995. Northern flicker. No. 166 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Murcia, C. 1995. Edge effects in fragmented forests: Implications for conservation. Trends in Ecological Evolution 10:58-62.

Murphy, M. 1996. Eastern kingbird. No. 253 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Norris, D.R. and B. Stutchbury. 2001. Extraterritorial movements of a forest songbird in a fragmented landscape. Conservation Biology 15(3):729-736.

Noss, R. 1991. Landscape connectivity: Different functions at different scales. Landscape Linkages and Biodiversity. Pages 27-40 in W. Hudson, (ed.) Landscape Linkages and Biodiversity. Defenders of Wildlife, Washington, DC.

Paige, C., G. Hammerson, and D.W. Mehlman. 1998. Species management abstract (element stewardship abstract) for willow flycatcher (Empidonax trailii). The Nature Conservancy, Arlington, VA.

Palis, J. and S. Cannings. 2000. Species management abstract (element stewardship abstract) for Eastern towhee (Pipilo erythrophthalmus). The Nature Conservancy, Arlington, VA.

Poulin, R.G., S.D. Grindal, R.M. Brigham. 1996. Common nighthawk. No. 213 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Primack, R.B. 1998. Essentials of Conservation Biology, 2nd Edition. Sinauer Associates, Inc., Sunderland, MA.

Reijnen, R., R. Foppen, C. Ter Braak, and J. Thissen. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. Journal of Applied Ecology 32:187-202.

Rich, A.C., D.S. Dobkin, and L.J. Niles. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology 8(4): 1109-1121.

Ricketts, T.H. and W.F. Morris. 2001. The matrix matters: effective isolation in fragmented landscapes. American Naturalist 158(1):87-100.

Rising, J. and N. Flood. 1998. Baltimore Oriole. No. 384 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Robbins, C., D. Dawson, and B. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic states. Wildlife Monographs 103:1-34.

Robinson, S.K., F.R. Thompson III, T.M. Donovan., D.R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

Rodewald, A., and R. Yahner. 2001. Influence of landscape composition on avian community structure and associated mechanisms. Ecology 82(12):3493-3504.

Rodewald, P.G., K.G. Smith, G. Hammerson, F. Dirrigl, Jr., and D.W. Mehlman. 1995. Species management abstract (element stewardship abstract) for pine warbler (Dendroica pinus). The Nature Conservancy, Arlington, VA.

Rosenberg, D.K. and B.R. Noon. 1997. Biological corridors: Form, function, and efficacy. Bioscience 47(10).

Rosenburg, C., M. Koenen, and D.W. Mehlman. 1998. Species management abstract (element stewardship abstract) for Barn Owl (Tyto alba). The Nature Conservancy, Arlington, VA.

Rosenzweig, M.L. 1985. Some theoretical aspects of habitat selection. In M. L. Cody (ed.), Habitat Selection in Birds, Academic Press, Orlando.

Sallabanks, R., F.J. Dirrigl, Jr., G. Hammerson, and D.W. Mehlman. 1993. Species management abstract (element stewardship abstract) for prothonotary warbler (Protonotaria citrea). The Nature Conservancy, Arlington, VA.

Saunders, D., R. Hobbs, and C. Margules. 1991. Biological consequences of ecosystem fragmentation: A review. Conservation Biology 5(1):18-28.

Schmiegelow, F.K.A., C.S. Machtans, and S.J. Hannon. 1997. Are boreal birds resilient to forest fragmentation? An experimental study of short-term community responses. Ecology 78:1914-1932.

Simberloff, D., and J. Cox. 1987. Consequence and costs of conservation corridors. Conservation Biology 1:63-71.

Staicer, C.A., F.J. Dirrigl, Jr., C. Staicer, G. Hammerson, and D.W. Mehlman. 1995. Species management abstract (element stewardship abstract) for prairie warbler (Dendroica discolor). The Nature Conservancy, Arlington, VA.

Stauffer, D. and L. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. Journal of Wildlife Management 44(1):1-15.

Straight, C. and R. Cooper. 2000. Chuck-will's Widow. No. 499 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Summerville, K., and T. Crist. 2001. Effects of experimental habitat fragmentation on patch use by butterflies and skippers (Lepidoptera). Ecology 82:1360-1370.

Thompson, C.F., G. Hammerson, G., F. Dirrigl, Jr., and D.W. Mehlman. 1996. Species management abstract (element stewardship abstract) for Yellow-breasted Chat (Icteria virens). The Nature Conservancy, Arlington, VA.

Triquet, A., G. McPeek, and W. McComb. 1990. Songbird diversity in clearcuts with and without riparian buffer strip. Journal of Soil and Water Conservation 45:500-503.

Trombulak, S.C. and C.A. Frissel. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-20.

Vandermeer, J. and R. Carvajal. 2001. Metapopulation dynamics and the quality of the matrix. American Naturalist 158:211-220.

Vickery, P., M. Hunter, and S. Melvin. 1994. Effects of habitat area on the distribution of grassland birds in Maine. Conservation Biology 8(4):1087-1097.

Villard, M., M.K. Trzxinski, and G. Merriam. 1999. Fragmentation effects on forest birds: Relative influence of woodland cover and configuration on landscape occupancy. Conservation Biology 13(4):774-783.

Walsh, J., V. Elia, R. Kane, and T. Halliwell. 1999. Birds of New Jersey. New Jersey Audubon Society, Bernardsville, 704pp.

Whitcomb, R. F.m C.S. Robbins, J.F. Lynch, B.L Whitcomb, K. Klimkiewicz, and D. Bystak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pages 125-205 in R.L. Burgess and D.M. Sharp (eds.), Forest Island Dynamics in Man-dominated Landscapes, Springer-Verlag, New York.

Wiens, J., R. Schooley, and R. Weeks, Jr. 1997. Patchy landscapes and animal movements: Do beetles percolate? Oikos 78:257-264.

Wiens, J.A. 1996. Wildlife in patchy environments: Metapopulations, mosaics, and management. In D.R. McCullough (ed.), Metapopulations and Wildlife Conservation. Island Press, Washington, D.C.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66(4):1211-1214.

Wilcove, D.S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. Bioscience 48(8):607-622.

With, K. and T.O. Crist. 1995. Critical thresholds in species' responses to landscape structure. Ecology 46(8):2446-2459.

Woottan, J. 1996. Purple Finch. No. 208 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Wyatt, V. and C. Francis. 2002. Rose-breasted grosbeak. No. 692 in Poole and Gill (eds.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Zeller, N.S., G. Hammerson, and D.W. Mehlman. 1993. Species management abstract (element stewardship abstract) for yellow-throated vireo (Vireo flavifrons). The Nature Conservancy, Arlington, VA.

Appendix II. Additional Methods for Extracting Critical Wildlife Areas from Urban Land-use/Land-cover Classes

LU/LC class 1400

1400 TRANSPORTATION, COMMUNICATION & UTILITIES
The transportation, communication, and utilities land uses are often associated with the other Urban or Built-up categories, but are often found in other categories. However, they often do not meet the minimum size required for mapping and are considered an integral part of the land use in which they occur. The presence of major transportation routes, utilities such as sewage treatment plants and power lines, and communications facilities greatly influence both the present and potential uses of an area. These areas generally have a high percentage of impervious surface coverage.

- Select the polygons from the "1400 TRANSPORTATION / COMMUNICATIONS / UTILITIES," as coded in the NJDEP Land Use/Land Cover, that have less than or equal to 5% impervious surface.
- From this subset intersect the grassland species models. Where there is overlap, recode these polygons as "Grassland." All other polygons from the subset will be recoded as "Forest."
- Merge the recoded polygons into the existing "Grassland" and "Forest" layers respectively.
- Dissolve the resultant "Grassland" and "Forest" layers.
- Assign a unique Link ID to each of the independent "Grassland" and "Forest" polygons (patches).

LU/LC class 1700

1700 OTHER URBAN OR BUILT-UP
Included are undeveloped, open lands within urban areas. Some structures may be visible, as in the case of abandoned residential or commercial sites that have not yet been redeveloped. Other areas may be brush-covered or grassy. Large, managed, maintained lawns common to some residential areas, and those open areas of commercial/service complexes, educational installations, etc., are also included. Undeveloped, but maintained lawns in urban parks are also part of this category, if a specific recreational use is not evident. In addition, areas that have been partially developed or redeveloped but remain unfinished are included. Also included in this category are cemeteries.

- Select the polygons from the "1700 OTHER URBAN OR BUILT UP LANDS," as coded in the NJDEP Land Use/Land Cover, that have less than or equal to10% impervious surface.
- From this subset, select the polygons within 0.8 kilometers of an airport, using an airport shapefile from the 2002 National Transportation Atlas.
- Create a new grassland/airport shapefile using the selected polygons.
- From grassland/airport shapefile, recode all of the polygons in the lower 10 kilometers of Cape May as "Grassland."
- For all areas outside of the lower 10 kilometers, select the polygons that meet the minimum size requirement for grasslands (18 hectares). Add to that selected set, the polygons that intersect a grassland species model.
- Recode the selected polygons as "Grassland."
- Merge all of the recoded polygons into the existing "Grassland" layer.
- Dissolve the resultant "Grassland" layer.
- Assign a unique Link ID to each of the independent "Grassland" polygons (patches).

Appendix III. Protocol for Accepting or Rejecting Species Sighting Reports

1. When a sighting report arrives at the ENSP office it is logged in and tracked in a database, regardless of acceptability.
2. If no additional information is needed, the sighting report is sent to the appropriate ENSP biologist for review.
3. If additional information is needed, an attempt is made to obtain the required information. This can include sending a map to the observer to mark the location of the sighting, a telephone interview to clarify information, etc. After all of the required information is obtained the report is sent to the appropriate ENSP biologist for review.
4. ENSP biologist receives the sighting report and reviews it for acceptability/reliability. A species sighting is accepted or rejected based on the following criteria:

- ♦ Did the sighting occur within the known range of the species?
- ♦ Did the sighting occur in the known/recognized habitat for the species?
- ♦ Is the species easily identified, or is it often confused with another?
- ♦ Did anyone else confirm the sighting, or can someone else vouch for the observer's identification skills?
- ♦ Do we have first-hand knowledge of the observer's identification skills?
- ♦ Did the observer include a photograph?
- ♦ Is the species listed as endangered or threatened for the season in which it was reported? (Some species can have a separate status for breeding season and non breeding season.)
- ♦ If uncertainty remains about the validity of the sighting, the observer is interviewed by the ENSP biologist.

   a. If sufficient information accompanies the sighting report the record is either accepted or rejected by an ENSP biologist. The report is then returned to ENSP's GIS staff and advances to step 5 if accepted.
   b. The reviewing biologist may determine that it is necessary to gather additional information (e.g., ascertain observer experience, ask if there have been additional sightings, ask for photos, ask for verifications by second observer, etc.) before the record can be accepted. If the record is accepted, advance to step 5.
   c. If the reviewing biologist determines that the sighting must be field checked, it is initially rejected until fieldwork can be scheduled to verify the sighting.

5. ENSP GIS staff digitizes the sighting location and prepares the data in a standardized format to submit to the Natural Heritage Program (NHP).
6. NHP quality checks the documents submitted and enters the data into the Biological Conservation Database (BCD).

Appendix IV. Species Models

Common Name	*Landscape Model*
Birds	
Federal T or E	
BALD EAGLE FORAGING AREA*	Foraging Model
BALD EAGLE NEST BUFFER	1 km buffer
BALD EAGLE WINTERING SITE	Not used
PIPING PLOVER	Digitized by ENSP staff
ROSEATE TERN	BCD model
State Endangered	
AMERICAN BITTERN	BCD model
BLACK SKIMMER	BCD model/digitized by ENSP Staff
BLACK SKIMMER FORAGING AREA[1]	Based on ENSP digitized polygons
HENSLOW'S SPARROW	BCD model
LEAST TERN[1]	BCD model/digitized by ENSP Staff
LEAST TERN FORAGING HABITAT[1]	Based on ENSP digitized polygons
MIGRANT LOGGERHEAD SHRIKE	BCD model
MIGRATORY RAPTOR CONCENTRATION SITE[2]	BCD model
MIGRATORY SHOREBIRD CONCENTRATION SITE[3]	BCD model
NORTHERN GOSHAWK	BCD model, 300 m buffer
NORTHERN HARRIER	BCD model
PEREGRINE FALCON*	1 km buffer
PIED-BILLED GREBE	BCD model
RED-SHOULDERED HAWK[4]	BCD model/1.609 km buffer
SEDGE WREN	BCD model
SHORT-EARED OWL	BCD model
UPLAND SANDPIPER	BCD model
VESPER SPARROW	BCD model
State Threatened	
BARRED OWL[4]	BCD model/1.609 km buffer
BLACK RAIL	BCD model
BLACK-CROWNED NIGHT-HERON	BCD model/digitized by ENSP Staff
BLACK-CROWNED NIGHT-HERON FORAGING HABITAT[1]	Based on ENSP digitized polygons
BLACK-CROWNED NIGHT-HERON NESTING HABITAT[1]	Based on ENSP digitized polygons
BOBOLINK	BCD model
COOPER'S HAWK	BCD model, 300 m buffer
GRASSHOPPER SPARROW	BCD model
LONG-EARED OWL	BCD model
OSPREY	BCD model, 300 m buffer
RED KNOT	BCD model
RED-HEADED WOODPECKER	BCD model
SAVANNAH SPARROW	BCD model
YELLOW-CROWNED NIGHT-HERON	BCD model/digitized by ENSP Staff
YELLOW-CROWNED NIGHT-HERON FORAGING HABITAT[1]	Based on ENSP digitized polygons
YELLOW-CROWNED NIGHT-HERON NESTING HABITAT[1]	Based on ENSP digitized polygons

Appendix IV. (Cont.)

Common Name	*Landscape Model*
Priority Species	
BIRD SPECIES OF PRIORITY	BCD model
COLONIAL WATERBIRD FORAGING HABITAT[1]	Based on ENSP digitized polygons
COLONIAL WATERBIRD NESTING HABITAT[1]	Based on ENSP digitized polygons
Herptiles	
Federal T or E	
ATLANTIC GREEN TURTLE	Not used
ATLANTIC HAWKSBILL	Not used
ATLANTIC LEATHERBACK	Not used
ATLANTIC LOGGERHEAD	Not used
ATLANTIC RIDLEY	Not used
BOG TURTLE[5]	DEP FWW selected that represent habitat
State Endangered	
BLUE-SPOTTED SALAMANDER	300 m buffer
COPE'S GRAY TREEFROG	300 m buffer
CORN SNAKE	BCD model
EASTERN TIGER SALAMANDER	300 m buffer
TIMBER RATTLESNAKE[6]	BCD/southern forested wetland model
State Threatened	
EASTERN MUD SALAMANDER	BCD model
LONGTAIL SALAMANDER	300 m buffer
NORTHERN PINE SNAKE	500 m buffer
PINE BARRENS TREEFROG	300 m buffer
WOOD TURTLE*	Wood turtle model
Priority Species	
HERPTILE SPECIES OF PRIORITY	1/6 USGS Quadrangle
Invertebrates	
Federal T or E	
AMERICAN BURYING BEETLE	BCD model
DWARF WEDGEMUSSEL	Not used
MITCHELL'S SATYR	BCD model
NORTHEASTERN BEACH TIGER BEETLE	BCD model
State Endangered	
APPALACHIAN GRIZZLED SKIPPER	BCD model
AROGOS SKIPPER	BCD model
BRONZE COPPER	BCD model
BROOK FLOATER	Not used
GREEN FLOATER	Not used
State Threatened	
CHECKERED WHITE	BCD model
EASTERN LAMPMUSSEL	Not used
EASTERN PONDMUSSEL	Not used

Appendix IV. (Cont.)

Common Name	Landscape Model
State Threatened	
FROSTED ELFIN	BCD model
SILVER-BORDERED FRITILLARY	BCD model
TIDEWATER MUCKET	BCD model
TRIANGLE FLOATER	Not used
YELLOW LAMPMUSSEL	Not used
Priority Species	
INVERTEBRATE SPECIES OF PRIORITY	BCD model
Mammals	
Federal T or E	
BLACK RIGHT WHALE	Not used
BLUE WHALE	Not used
FIN WHALE	Not used
HUMPBACK WHALE	Not used
INDIANA BAT	2 km buffer
SEI WHALE	Not used
SPERM WHALE	Not used
State Endangered	
ALLEGHENY WOODRAT	BCD model
BOBCAT[4]	BCD model

**For explanation of model see "Detailed Methodology for Delineating Critical Areas by Special Habitat Requirements."*

1. Colonial Nesting Waterbirds

Terns and Skimmers: Nesting area critical habitat includes all open water, beaches, mudflats and emergent wetlands within the foraging radius from a known nesting colony.

Foraging radii:

black skimmer	10.46 kilometers	forsters tern	12.07 kilometers
least tern	4.82 kilometers	common tern	12.07 kilometers

Herons and Egrets: Critical nesting habitat includes all undeveloped habitat within 90 meters (3 pixels) of a known nesting colony, 180 meters for great blue heron. Critical foraging habitat includes all emergent wetlands, all tidal creeks and ditches, and all open waters within 90 meters of the shoreline within the foraging radius of a known nesting colony.

Foraging radii:

great egret	11.42 kilometers	tricolored heron	10.46 kilometers
snowy egret	13.84 kilometers	black-crowned night heron	9.65 kilometers
cattle egret	11.26 kilometers	yellow-crowned night heron	2.73 kilometers
great blue heron	12.07 kilometers	glossy ibis	14.64 kilometers
little blue hereon	13.19 kilometers		

2. Migratory Raptor Concentration Site: All non developed habitat (1995 CRSSA LC) in the lower 10 kilometers of the Cape May peninsula.

3. **Migratory Shorebird Concentration Site:** ENSP staff hand-digitized polygons that represent sites where migratory shorebirds congregate for feeding or staging during migration.

4. **Barred Owl, Red-shouldered Hawk and Bobcat:** Since these species require large, unfragmented patches of forest they only value those patches that meet the core area requirements as defined in the "Detailed Methodology for Delineating Critical Areas by Habitat Type" section of this document.

5. **Bog Turtle:** Critical areas for bog turtles are mapped by hand-selecting emergent, scrub/shrub, modified agricultural and forested wetland polygons from the DEP Freshwater Wetlands maps. The selected wetland habitats correspond to core bog turtle habitat (i.e. where turtles are concentrated), contiguous dispersal corridors between extant colonies within 1.6 kilometers of each other, and groundwater discharge areas, where possible. Only extant populations were mapped. Suitable bog turtle habitat that is not connected to an extant site is not incorporated into the mapping.

6. **Timber Rattlesnake**

   Skylands Landscape: Hand-digitized polygons that represent timber rattlesnake den locations and their associated foraging areas. This is adequate in protecting the majority of female gestating and birthing areas, transient habitat and foraging habitat. Most gestating and birthing areas in this part of the state occur within a few to several hundred meters of the den location.

   Pinelands and Delaware Bay Landscapes: Any portion of a stream (including intermittent) within 2.5 kilometers of a timber rattlesnake occurrence (seconds precision only) is considered "potential hibernacula." The identified stream segments are buffered 1 kilometer.

Appendix V. NJDEP 1995/97 Land-use/Land-cover Classes and Corresponding Landscape Habitats

Level 1 Class	Level 3 Modified Class	Habitat
BARREN LAND	BEACHES	Beach
WETLANDS	AGRICULTURAL WETLANDS (MODIFIED)	Emergent Wetland
WETLANDS	FORMER AGRICULTURAL WETLAND (BECOMING SHRUBBY)	Emergent Wetland
WETLANDS	FRESHWATER TIDAL MARSHES	Emergent Wetland
WETLANDS	HERBACEOUS WETLANDS	Emergent Wetland
WETLANDS	SALINE MARSHES	Emergent Wetland
WETLANDS	SEVERE BURNED WETLANDS	Emergent Wetland
WETLANDS	VEGETATED DUNE COMMUNITIES	Emergent Wetland
WETLANDS	WETLAND RIGHTS-OF-WAY (MODIFIED)	Emergent Wetland
FOREST	CONIFEROUS BRUSH/SHRUBLAND	Forest
FOREST	CONIFEROUS FOREST (>50% CROWN CLOSURE)	Forest
FOREST	CONIFEROUS FOREST (10-50% CROWN CLOSURE)	Forest
FOREST	DECIDUOUS BRUSH/SHRUBLAND	Forest
FOREST	DECIDUOUS FOREST (>50% CROWN CLOSURE)	Forest
FOREST	DECIDUOUS FOREST (10-50% CROWN CLOSURE)	Forest
FOREST	MIXED DECIDUOUS/CONIFEROUS BRUSH/SHRUBLAND	Forest
FOREST	MIXED FOREST (>50% CONIFEROUS WITH >50% CROWN CLOSURE)	Forest
FOREST	MIXED FOREST (>50% CONIFEROUS WITH 10%-50% CROWN CLOSURE)	Forest
FOREST	MIXED FOREST (>50% DECIDUOUS WITH >50% CROWN CLOSURE)	Forest
FOREST	MIXED FOREST (>50% DECIDUOUS WITH 10-50% CROWN CLOSURE)	Forest
FOREST	OLD FIELD (< 25% BRUSH COVERED)	Forest
FOREST	PLANTATION	Forest
FOREST	SEVERE BURNED UPLAND VEGETATION	Forest
AGRICULTURE	CONFINED FEEDING OPERATIONS	Grassland
AGRICULTURE	CROPLAND AND PASTURELAND	Grassland
AGRICULTURE	ORCHARDS/VINEYARDS/NURSERIES/ HORTICULTURAL AREAS	Grassland
AGRICULTURE	OTHER AGRICULTURE	Grassland
URBAN*	OTHER URBAN OR BUILT-UP LAND	Grassland
URBAN*	TRANSPORTATION/COMMUNICATIONS/UTILITIES	Grassland/Forest
WETLANDS	ATLANTIC WHITE CEDAR SWAMP	Forested Wetland/Forest
WETLANDS	CONIFEROUS SCRUB/SHRUB WETLANDS	Forested Wetland/Forest
WETLANDS	CONIFEROUS WOODED WETLANDS	Forested Wetland/Forest
WETLANDS	DECIDUOUS SCRUB/SHRUB WETLANDS	Forested Wetland/Forest
WETLANDS	DECIDUOUS WOODED WETLANDS	Forested Wetland/Forest
WETLANDS	MIXED FORESTED WETLANDS (CONIFEROUS DOM.)	Forested Wetland/Forest
WETLANDS	MIXED FORESTED WETLANDS (DECIDUOUS DOM.)	Forested Wetland/Forest
WETLANDS	MIXED SCRUB/SHRUB WETLANDS (CONIFEROUS DOM.)	Forested Wetland/Forest
WETLANDS	MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS DOM.)	Forested Wetland/Forest

A method using impervious service and species models was developed to select out rights-of-way that contained critical areas from this classification (Appendix II**).*

Appendix VI. Species and the Habitat Types they Value

Common Name	***Emergent Wetland***	***Forested Wetland***	***Forest***	***Grassland***	***Beach***
Birds					
Federal T or E					
BALD EAGLE FORAGING AREA					
BALD EAGLE NEST BUFFER	X	X	X	X	
PIPING PLOVER					X
ROSEATE TERN	X				X
State Endangered					
AMERICAN BITTERN	X				
BLACK SKIMMER	X				X
BLACK SKIMMER FORAGING AREA	X				
HENSLOW'S SPARROW	X			X	
LEAST TERN	X				X
LEAST TERN FORAGING HABITAT	X				
MIGRANT LOGGERHEAD SHRIKE				X	
MIGRATORY RAPTOR CONCENTRATION SITE	X	X	X	X	
MIGRATORY SHOREBIRD CONCENTRATION SITE					X
NORTHERN GOSHAWK		X	X		
NORTHERN HARRIER	X			X	
PEREGRINE FALCON	X				
PIED-BILLED GREBE	X				
RED-SHOULDERED HAWK		X	X*		
SEDGE WREN	X			X	
SHORT-EARED OWL	X			X	
UPLAND SANDPIPER				X	
VESPER SPARROW				X	
State Threatened					
BARRED OWL		X	X*		
BLACK RAIL	X				
BLACK-CROWNED NIGHT-HERON	X				
BLACK-CROWNED NIGHT-HERON FORAGING HABITAT	X				
BLACK-CROWNED NIGHT-HERON NESTING HABITAT	X		X		
BOBOLINK				X	
COOPER'S HAWK		X	X		
GRASSHOPPER SPARROW				X	
LONG-EARED OWL			X	X	
OSPREY	X				X
RED KNOT	X				X
RED-HEADED WOODPECKER			X		
SAVANNAH SPARROW				X	
YELLOW-CROWNED NIGHT-HERON	X				
YELLOW-CROWNED NIGHT-HERON FORAGING HABITAT	X				

Appendix VI. (Cont.)

Common Name	Emergent Wetland	Forested Wetland	Forest	Grassland	Beach
State Threatened					
YELLOW-CROWNED NIGHT-HERON NESTING HABITAT	X		X		
Priority Species					
ACADIAN FLYCATCHER		X	X		
AMERICAN BLACK DUCK	X	X			
AMERICAN KESTREL				X	
AMERICAN OYSTERCATCHER	X				X
AMERICAN WOODCOCK		X	X		
ARCTIC TERN	X				X
BALTIMORE ORIOLE			X		
BARN OWL				X	
BLACK TERN					X
BLACK-AND-WHITE WARBLER		X	X		
BLACK-BILLED CUCKOO		X	X		
BLACKBURNIAN WARBLER		X	X		
BLACK-THROATED BLUE WARBLER		X	X		
BLACK-THROATED GREEN WARBLER		X	X		
BLUE-WINGED WARBLER	X	X	X		
BROAD-WINGED HAWK			X		
BROWN CREEPER		X	X		
BROWN THRASHER		X	X		
CANADA WARBLER		X	X		
CAROLINA CHICKADEE		X	X		
CASPIAN TERN	X				X
CATTLE EGRET	X				
CERULEAN WARBLER		X	X		
CHIMNEY SWIFT					
CHUCK-WILL'S-WIDOW		X	X		
CLAPPER RAIL	X				
CLIFF SWALLOW	X			X	
COLONIAL WATERBIRD FORAGING HABITAT	X				
COLONIAL WATERBIRD NESTING HABITAT	X		X		
COMMON MOORHEN	X				
COMMON NIGHTHAWK			X	X	X
COMMON TERN	X				X
DICKCISSEL				X	
EASTERN BLUEBIRD				X	
EASTERN KINGBIRD				X	
EASTERN MEADOWLARK				X	
EASTERN TOWHEE		X	X		
EASTERN WOOD-PEWEE			X		
FIELD SPARROW				X	
FORSTER'S TERN	X				X
GLOSSY IBIS	X				
GOLDEN-WINGED WARBLER			X		
GRAY CATBIRD		X	X		
GRAY-CHEEKED THRUSH		X	X		

Appendix VI. (Cont.)

Common Name	Emergent Wetland	Forested Wetland	Forest	Grassland	Beach
Priority Species					
GREAT BLUE HERON	X	X	X		
GREAT EGRET	X				
GULL-BILLED TERN	X				X
HAIRY WOODPECKER		X	X		
HERMIT THRUSH		X	X		
HOODED WARBLER		X	X		
HORNED LARK				X	X
IPSWICH SPARROW				X	X
KENTUCKY WARBLER		X	X		
KING RAIL	X				
LEAST BITTERN	X				
LEAST FLYCATCHER		X	X		
LITTLE BLUE HERON	X				
LOUISIANA WATERTHRUSH		X	X		
MARSH WREN	X				
NORTHERN BOBWHITE				X	
NORTHERN PARULA		X	X		
NORTHERN SAW-WHET OWL			X		
PINE WARBLER		X	X		
PRAIRIE WARBLER		X	X		
PROTHONOTARY WARBLER		X	X		
PURPLE FINCH		X	X		
RED CROSSBILL		X	X		
RED-BREASTED NUTHATCH		X	X		
RED-EYED VIREO		X	X		
ROSE-BREASTED GROSBEAK		X	X		
SALTMARSH SHARP-TAILED SPARROW	X				
SANDERLING					X
SCARLET TANAGER		X	X		
SEASIDE SPARROW	X				
SHARP-SHINNED HAWK		X	X		
SNOWY EGRET	X				
SOLITARY VIREO (BLUE-HEADED VIREO)		X	X		
SPOTTED SANDPIPER	X				
TERN SPECIES FORAGING HABITAT	X				
TRICOLORED HERON	X				
VEERY		X	X		
VIRGINIA RAIL	X				
WHIMBREL	X				
WHIP-POOR-WILL		X	X		
WHITE-EYED VIREO		X	X		
WILLET	X				X
WILLOW FLYCATCHER		X	X		
WINTER WREN		X	X		
WOOD THRUSH		X	X		
WORM-EATING WARBLER		X	X		
YELLOW-BILLED CUCKOO		X	X		
YELLOW-BREASTED CHAT		X	X		
YELLOW-THROATED VIREO		X	X		

Appendix VI. (Cont.)

Common Name	Emergent Wetland	Forested Wetland	Forest	Grassland	Beach
Herptiles					
Federal T or E					
BOG TURTLE	X	X			
State Endangered					
BLUE-SPOTTED SALAMANDER	X	X	X		
COPE'S GRAY TREEFROG	X	X	X		
CORN SNAKE			X		
EASTERN TIGER SALAMANDER	X	X	X		
TIMBER RATTLESNAKE		X	X		
State Threatened					
EASTERN MUD SALAMANDER		X	X		
LONGTAIL SALAMANDER	X	X	X		
NORTHERN PINE SNAKE			X	X	
PINE BARRENS TREEFROG	X	X	X		
WOOD TURTLE					
Priority Species					
CARPENTER FROG	X	X			
COASTAL PLAIN MILK SNAKE			X	X	
EASTERN BOX TURTLE			X	X	
EASTERN KINGSNAKE		X	X		
FOWLER'S TOAD	X	X			
JEFFERSON SALAMANDER		X	X		
MARBLED SALAMANDER	X	X	X		
NORTHERN COPPERHEAD			X		
NORTHERN DIAMONDBACK TERRAPIN	X				
NORTHERN SPRING SALAMANDER		X	X		
SPOTTED TURTLE	X	X			
Invertebrates					
Federal Tor E					
AMERICAN BURYING BEETLE					X
MITCHELL'S SATYR	X	X	X	X	
NORTHEASTERN BEACH TIGER BEETLE					X
State Endangered					
APPALACHIAN GRIZZLED SKIPPER	X	X	X	X	
AROGOS SKIPPER	X	X	X	X	
BRONZE COPPER	X	X	X	X	
State Threatened					
SILVER-BORDERED FRITILLARY	X	X	X	X	
CHECKERED WHITE	X	X	X	X	
FROSTED ELFIN	X	X	X	X	

Appendix VI. (Cont.)

Common Name	***Emergent Wetland***	***Forested Wetland***	***Forest***	***Grassland***	***Beach***
Priority Species					
DOTTED SKIPPER	X	X	X	X	
GEORGIA SATYR	X	X	X	X	
HARISS CHECKERSPOT	X	X	X	X	
HESSEL'S HAIRSTREAK	X	X	X	X	
HOARY ELFIN	X	X	X	X	
NORTHERN METALMARK	X	X	X	X	
TWO-SPOTTED SKIPPER	X	X	X	X	
Mammals					
Federal T or E					
INDIANA BAT		X	X		
State Endangered					
ALLEGHENY WOODRAT			X		
BOBCAT	X	X	X*		

**Only values forest patches that meet the minimum core requirements.*

Appendix VII. Species and the Landscape Regions in which they Occur*

Common Name	***Delaware Bay***	***Coastal***	***Piedmont Plains***	***Pinelands***	***Skylands***
Birds					
Federal T or E					
BALD EAGLE FORAGING AREA	X	X	X	X	X
BALD EAGLE NEST BUFFER	X	X	X	X	X
PIPING PLOVER	X	X	X		
ROSEATE TERN		X			
State Endangered					
AMERICAN BITTERN			X	X	X
BLACK SKIMMER		X			
BLACK SKIMMER FORAGING AREA	X	X		X	
HENSLOW'S SPARROW	X	X	X		X
LEAST TERN	X	X	X	X	
LEAST TERN FORAGING HABITAT	X	X		X	
MIGRANT LOGGERHEAD SHRIKE	X	X	X		X
MIGRATORY RAPTOR CONCENTRATION SITE	X	X			
MIGRATORY SHOREBIRD CONCENTRATION SITE	X	X	X		
NORTHERN GOSHAWK				X	X
NORTHERN HARRIER	X	X	X	X	X
PEREGRINE FALCON	X	X	X	X	
PIED-BILLED GREBE	X	X	X	X	X
RED-SHOULDERED HAWK	X		X	X	X
SEDGE WREN	X		X		X
SHORT-EARED OWL	X	X			
UPLAND SANDPIPER			X	X	X
VESPER SPARROW	X		X	X	X
State Threatened					
BARRED OWL	X	X	X	X	X
BLACK RAIL	X	X			X
BLACK-CROWNED NIGHT-HERON	X	X	X	X	X
BLACK-CROWNED NIGHT-HERON FORAGING HABITAT	X	X	X	X	
BLACK-CROWNED NIGHT-HERON NESTING HABITAT		X	X		X
BOBOLINK	X		X	X	X
COOPER'S HAWK	X	X	X	X	X
GRASSHOPPER SPARROW	X		X	X	X
LONG-EARED OWL	X		X		X
OSPREY	X	X	X	X	X
RED KNOT	X	X			
RED-HEADED WOODPECKER	X		X	X	X
SAVANNAH SPARROW	X		X	X	X
YELLOW-CROWNED NIGHT-HERON		X	X	X	
YELLOW-CROWNED NIGHT-HERON FORAGING HABITAT	X	X	X	X	
YELLOW-CROWNED NIGHT-HERON NESTING HABITAT		X	X		

**Based on known species' ranges within the state.*

Appendix VII. (Cont.)

Common Name	Delaware Bay	Coastal	Piedmont Plains	Pinelands	Skylands
Priority Species					
ACADIAN FLYCATCHER	X		X	X	X
AMERICAN BLACK DUCK	X	X	X	X	X
AMERICAN KESTREL	X		X		X
AMERICAN OYSTERCATCHER	X	X			
AMERICAN WOODCOCK	X	X	X	X	X
ARCTIC TERN		X			
BALTIMORE ORIOLE	X		X	X	X
BARN OWL	X	X	X		
BLACK TERN		X			
BLACK-AND-WHITE WARBLER	X		X	X	X
BLACK-BILLED CUCKOO	X		X	X	X
BLACKBURNIAN WARBLER					X
BLACK-THROATED BLUE WARBLER			X		X
BLACK-THROATED GREEN WARBLER			X	X	X
BLUE-WINGED WARBLER	X		X	X	X
BROAD-WINGED HAWK	X		X	X	X
BROWN CREEPER	X		X	X	X
BROWN THRASHER	X	X	X	X	X
CANADA WARBLER			X	X	X
CAROLINA CHICKADEE	X	X	X	X	
CASPIAN TERN		X			
CATTLE EGRET	X	X			X
CERULEAN WARBLER	X			X	X
CHIMNEY SWIFT	X	X	X	X	X
CHUCK-WILL'S-WIDOW	X			X	
CLAPPER RAIL	X	X			
CLIFF SWALLOW			X		X
COLONIAL WATERBIRD FORAGING HABITAT	X	X	X	X	
COLONIAL WATERBIRD NESTING HABITAT		X			
COMMON MOORHEN	X		X		X
COMMON NIGHTHAWK			X	X	X
COMMON TERN	X				X
DICKCISSEL			X		
EASTERN BLUEBIRD	X		X	X	X
EASTERN KINGBIRD	X	X	X	X	X
EASTERN MEADOWLARK	X		X	X	X
EASTERN TOWHEE	X	X	X	X	X
EASTERN WOOD-PEWEE	X		X	X	X
FIELD SPARROW	X		X	X	X
FORSTER'S TERN	X	X			
GLOSSY IBIS	X	X	X		
GOLDEN-WINGED WARBLER					X
GRAY CATBIRD	X	X	X	X	X
GRAY-CHEEKED THRUSH	X			X	X
GREAT BLUE HERON	X	X	X	X	X
GREAT EGRET	X	X	X		
GULL-BILLED TERN		X			
HAIRY WOODPECKER	X	X	X	X	X

Appendix VII. (Cont.)

Common Name	***Delaware Bay***	***Coastal***	***Piedmont Plains***	***Pinelands***	***Skylands***
Priority Species					
HERMIT THRUSH			X	X	X
HOODED WARBLER	X		X	X	X
HORNED LARK			X	X	X
KENTUCKY WARBLER	X		X	X	X
KING RAIL	X				
LEAST BITTERN	X		X	X	X
LEAST FLYCATCHER			X	X	X
LITTLE BLUE HERON	X	X	X	X	
LOUISIANA WATERTHRUSH	X		X		X
MARSH WREN	X	X	X	X	X
NORTHERN BOBWHITE	X	X	X	X	X
NORTHERN PARULA	X		X	X	X
NORTHERN SAW-WHET OWL			X	X	X
PINE WARBLER	X	X	X	X	X
PRAIRIE WARBLER	X		X	X	X
PROTHONOTARY WARBLER	X		X	X	
PURPLE FINCH			X		X
RED CROSSBILL				X	
RED-BREASTED NUTHATCH	X		X	X	X
RED-EYED VIREO	X	X	X	X	X
ROSE-BREASTED GROSBEAK	X		X	X	X
SALTMARSH SHARP-TAILED SPARROW	X	X			
SANDERLING	X	X			
SCARLET TANAGER	X		X	X	X
SEASIDE SPARROW	X	X			
SHARP-SHINNED HAWK	X	X	X	X	X
SNOWY EGRET	X	X	X	X	
BLUE-HEADED VIREO					X
SPOTTED SANDPIPER	X		X	X	X
TERN SPECIES FORAGING HABITAT	X	X	X	X	
TRICOLORED HERON	X	X			
VEERY		X	X	X	X
VIRGINIA RAIL	X	X	X	X	X
WHIMBREL	X	X			
WHIP-POOR-WILL	X		X	X	X
WHITE-EYED VIREO	X		X	X	X
WILLET	X	X			
WILLOW FLYCATCHER	X		X	X	X
WINTER WREN					X
WOOD THRUSH	X	X	X	X	X
WORM-EATING WARBLER	X		X	X	X
YELLOW-BILLED CUCKOO	X	X	X	X	X
YELLOW-BREASTED CHAT	X		X	X	X
YELLOW-THROATED VIREO	X		X	X	X
Herptiles					
Federal T or E					
BOG TURTLE		X	X	X	X

Appendix VII. (Cont.)

Common Name	Delaware Bay	Coastal	Piedmont Plains	Pinelands	Skylands
State Endangered					
BLUE-SPOTTED SALAMANDER			X		X
COPE'S GRAY TREEFROG	X			X	
CORN SNAKE	X			X	
EASTERN TIGER SALAMANDER	X	X	X	X	
TIMBER RATTLESNAKE	X			X	X
State Threatened					
EASTERN MUD SALAMANDER			X		
LONGTAIL SALAMANDER			X		X
NORTHERN PINE SNAKE	X		X	X	
PINE BARRENS TREEFROG	X		X	X	
WOOD TURTLE			X	X	X
Priority Species					
CARPENTER FROG	X	X	X	X	X
COASTAL PLAIN MILK SNAKE			X	X	
EASTERN BOX TURTLE	X	X	X	X	X
EASTERN KINGSNAKE	X	X	X	X	
FOWLER'S TOAD	X	X	X	X	X
JEFFERSON SALAMANDER			X		X
MARBLED SALAMANDER	X	X		X	X
NORTHERN COPPERHEAD			X		X
NORTHERN DIAMONDBACK TERRAPIN	X	X	X	X	X
NORTHERN SPRING SALAMANDER			X	X	X
SPOTTED TURTLE	X	X	X	X	X
Invertebrates					
Federal Tor E					
AMERICAN BURYING BEETLE			X		X
MITCHELL'S SATYR					X
NORTHEASTERN BEACH TIGER BEETLE		X			
State Endangered					
APPALACHIAN GRIZZLED SKIPPER					X
AROGOS SKIPPER				X	X
BRONZE COPPER	X		X		
State Threatened					
SILVER-BORDERED FRITILLARY	X			X	X
CHECKERED WHITE			X		
FROSTED ELFIN	X		X	X	
Priority Species					
DOTTED SKIPPER	X		X	X	
GEORGIA SATYR				X	
HARISS CHECKERSPOT			X		X
HESSEL’S HAIRSTREAK	X			X	

Appendix VII. (Cont.)

Common Name	*Delaware Bay*	*Coastal*	*Piedmont Plains*	*Pinelands*	*Skylands*
Priority Species					
HOARY ELFIN				X	
NORTHERN METALMARK					X
TWO-SPOTTED SKIPPER			X	X	
Mammals					
Federal T or E					
INDIANA BAT					X
State Endangered					
ALLEGHENY WOODRAT			X		X
BOBCAT	X		X	X	X

Appendix III. Literature Review

Ambuel, B., and S.A. Temple. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. Ecology 64:1057-1068.

Anthony, R.G. and F.B. Isaacs. 1989. Characteristics of bald eagle nest sites in Oregon. J. Wildl. Manage. 53(1):148-159.

Askins, A., J.F. Lynch, R. Greenberg. 1990. Population declines in migratory birds in eastern North America. Ch.1, pp. 1-57; In: D.M. Power, Ed., Current Ornithology Vol. 7. Plenum Press, New York.

Blake, J.G., and J.R. Karr. 1987. Breeding birds of isolated woodlots: Area and habitat relationships. Ecology 68:1724-1734.

Brittingham, M.C., and S.A. Temple. 1983. Have cowbirds caused forest songbirds to decline? BioScience 33:31-35.

Brown, W.S. 1993. Biology, status, and management of the timber rattlesnake (*Crotalus horridus*): a guide for conservation. Society for the Study of Amphibians and Reptiles. Herp. Cir. No. 22. 78pp.

Burke, D.M. and E. Nol. 1998. Influence of food abundance, nest-site habitat, and forest fragmentation on breeding ovenbirds. Auk 115(1):96-104.

Clark, K. NINJA data base. NJ Division of Fish, Game and Wildlife.

Copeyon, C.K. 1997. Endangered and threatened wildlife and plants; final rule to list the northern population of the bog turtle as threatened and the southern population as threatened due to similarity of appearance. Federal Register 62(213): 59605-59622.

Craighead, J.J. and F.C. Craighead, Jr. 1956. Hawks, owls and wildlife. Stackpole Publ. Co., Harrisburg, PA.

Crocoll, S. and J.W. Parker. 1989. The breeding biology of broad-winged and red-shouldered hawks in western New York. J. Raptor Res. 23:125-139.

Darr, L.J., D.K. Dawson, C.S. Robbins. Unpublished Manuscript. Land-use planning to conserve habitat for breeding forest birds in fragmented landscape.

Dawson, D. K., L. J. Darr, and C. S. Robbins. 1993. Predicting the distribution of breeding forest birds in a fragmented landscape. Trans. North Amer. Will. Nat. Rescuer. Con. 58:35-43.

DeCalesta, D. S. 1994. Effect of white-tailed deer on songbirds within managed forests in Pennsylvania. J. Wildl. Manage. 58(4):711-718.

Douglas, M.E., and B.L. Monroe. 1981. A comparative study of topographical orientation in *Ambystoma* (Amphibia: Caudata). Copeia 1981(2):463-466.

Elody, B.J. and N.F. Sloan. 1985. Movements and habitat use of barred owls in the Huron Mountains of Marquette County, Michigan, as determined by radiotelemetry. Jack-pine Warbler 63(1):3-8.

Ernst, C.H. 1986. Environmental temperatures and activities in the wood turtle, *Clemmys insculpta*. J. Herpetol. 20(2):222-229.

Flather, C.H., and J.R. Sauer. 1996. Using landscape ecology to test hypotheses about large-scale abundance patterns in migratory birds. Ecology 77(1):28-35.

Freda, J. and P.J. Morin. 1984. Adult home range of the Pine Barrens treefrog (*Hyla andersoni*) and the physical, chemical, and ecological characteristics of its preferred breeding ponds. Unpublished report submitted to the Endangered and Nongame Species Program. 42pp.

Frenzel, R. 1983. Nest-site spacing of bald eagles. In Anthony, R.G., F.B. Isaacs, and R.W. Frenzel, eds. *Proceedings of a workshop on habitat management for nesting and roosting bald eagles in the western United States.* Corvallis: Coop. Wildl. Res. Unit, Oregon State Univ.

Friesen, L.E., P.F.J. Eagles, and R.J. Mackay. 1995. Effects of residential development on forest-dwelling neotropical migrant songbirds. Cons. Biol. 9(6):1408-1414.

Fuller, M.R. 1979. Spatiotemporal ecology of four sympatric raptor species. Ph.D. Dissertation. University of Minnesota, St. Paul. 396 pp.

Hoover, J.P., M.C. Brittingham, and L. J. Goodrich. 1995. Effects of forest patch size on nesting success of wood thrushes. Auk 112(1):146-155.

Johnson, E. and P.J. Morin. 1985. 1985 blue-spotted salamander (*Ambystoma laterale*) project report. Unpublished report, NJDEP, DFGW, ENSP. 10pp.

Kiser, J.D. and C.L. Elliott. 1996. Foraging habitat, food habits, and roost tree characteristics of the Indiana bat (Myotis sodalis) during autumn in Jackson County, Kentucky. Final Report, Nongame Program, Kentucky Department of Fish and Wildlife Resources, Frankfort. 65pp.

Klemens, M.W. 1993. Standardized bog turtle site-quality analysis. Amer. Mus. Nat. His., New York, NY 7pp.

Martin, W.H. 1992. Phenology of the timber rattlesnake (*Crotalus horridus*) in an unglaciated section of the Appalachian Mountains. In Campbell, J.A. and E.D. Brodie, Jr. (Eds.) Biology of the Pitvipers. Selva, Tyler, Texas. pp. 259-277.

Nichols, T.H. and D.W. Warner. 1972. Barred owl habitat use as determined by radiotelemetry. J. Wildl. Manage. 36(2):213-224.

Peterson, A. 1986. Habitat suitability index models: Bald eagle (breeding season). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.126). 25 pp.

Quinn, N.W.S. and D.P. Tate. 1991. Seasonal movements and habitat of wood turtles (*Clemmys insculpta*) in Algonquin Park, Canada. J. Herpetol. 25(2):217-220.

Reap, P.A. and R.T. Zappalorti. 1983. Notes on the diploid and triploid species of the *Ambystoma jeffersonianum* complex in New Jersey. Unpublished rept. to the Endangered and Nongame Species Program: 18pp.

Reinert, H.A. and R.T. Zappalorti. 1986. Habitat utilization by the timber rattlesnake, *Crotalus horridus*, in southern New Jersey with notes on hibernation. Final Report, Endangered and Nongame Species Program, Trenton, New Jersey. 172pp.

Rich, A.C., D.S. Dobkin, and L.J. Niles. 1994. Defining forest fragmentation by corridor width: The influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology 8(4):1109-1121.

Ritke, M.E., J.G. Babb, and M.K. Ritke. 1991. Breeding-site specificity in the gray treefrog (*Hyla chrysoscelis*). J. Herpetol. 25(1):123-125.

Robbins, C.S., D.K. Dawson, and B.A. Dowell. 1989. Habitat area requirements of breeding forest birds of the Middle Atlantic States. Wildl. Monogr. No. 103:1-34.

Robinson, S.K., F.R. Thompson III, T.M. Donovan, D.R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

Semlitsch, R.D. 1981. Terrestrial activity and summer home range of the mole salamander (*Ambystoma talpoideum*). Canad. J. Zoology 59:315-322.

Semlitsch, R.D. and J.R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 17(5):1219-1228.

Stewart, R.E. 1949. Ecology of a nesting red-shouldered hawk population. Wilson Bull. 61:26-35.

Stihler, C. 1998. Indian bat radio telemetry study. West Virginia Nongame & Natural Heritage News. Summer, 1998. p. 5.

Strang, C.A. 1983. Spatial and temporal activity patterns in two terrestrial turtles. J. Herpetol. 17(1):43-47.

Whitcomb. R.F., C.S. Robbins, J.F. Lynch, B.L. Whitcomb, K. Klimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pages 125-205 in: R.L. Burgess and D.M. Sharpe, eds.,Forest Island Dynamics in Man-dominated Landscapes. Springer-Verlag, New York, NY.

Williams, P.K. 1973. Seasonal movements and population dynamics of four sympatric mole salamanders, genus Ambystoma. Ph.D. thesis, Indiana University, Bloomington, IN

Literature Cited

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper 964. 28 p.

Hasse, J, and R. Lathrop. 2001. Measuring urban growth in New Jersey. A report on recent land development patterns utilizing the 1986-1995 NJ DEP Land Use/Land Cover Dataset. Center for Remote Sensing and Spatial Analysis. Rutgers University.