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Identifying Conservation Targets for the Lower Hudson PRISM:

Invasive Species Threats to Species of Greatest Conservation Need

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Introduction

Ecosystem services, the "free" work of nature that supports human society, include biodiversity support. Biodiversity, the variety of life in nature at all levels from genes to landscapes and regions, underlies many other ecosystem services as well as *per se* providing many material and non-material benefits to people. Although there are many approaches to managing higher levels of organization, especially "ecosystems," because each species has different requirements and tolerances it is often necessary to manage individual species to prevent their disappearance from a region – or from the biosphere. The effects of invasive species are believed to be a major cause of the declines and extinctions of native species, although there is controversy regarding how generalizable this is.

There is a multitude of "invasive species" – nonnative organisms that spread into native habitats and have adverse effects on one or more ecosystem services. People can only address a small portion of this problem through management actions, therefore it is crucial to understand where harm is occurring and target those invasive species (IS) that are most harmful and are susceptible to management. One of the major concerns about IS is their effects on rare native species, a valuable component of native biodiversity. Certain IS evidently pose threats to rare native species, whereas other IS probably do not. Furthermore, some rare species are in greater need of conservation attention than others, and both phenomena vary in space and time. As an interesting example, Ujvari et al. (2011) found that an invasive animal affected a native prey species differently in different geographic locations, and cautioned that spatial replication is needed in order to draw accurate conclusions. Many other examples of the complexity of IS effects and IS management could be cited.

Instead of trying to kill or inhibit invasive species haphazardly (or everywhere), we believe it is important to use limited financial, labor, and intellectual resources efficiently by targeting management efforts to those IS - rare species interactions that are causing the most harm to biodiversity.

The goal of this project was to identify invasive species threats to the conservation of rare species in the Lower Hudson Partnership for Regional Invasive Species Management (LH PRISM) region, as best we can with current and developing knowledge. We restricted consideration of rare species to the existing New York State list of animal Species of Greatest Conservation Need (SGCN), and of invasive species to nonnative plants and animals (fungi and microorganisms excluded). The SGCN list is based on extensive documentation and expert review. Our project constituted a survey and analysis of existing information and did not include field or laboratory work. Although we focus on identifying and prioritizing IS - rare native species interactions, we also comment briefly on management approaches and techniques that may or may not be appropriate in certain situations.

Any compendium of IS effects on rare species, or recommendations for management of IS, is necessarily a work in progress. Some of the information in this report may quickly be superceded by new research or monitoring findings, or because existing research data become more readily available. Additionally, strategies and techniques for management of IS are continually being improved. Although our project did not address IS effects on rare native plants, we are hopeful that future research will analyze those interactions analogous to what we have done here for rare native animals.

Methods

We reviewed the statewide SGCN list which contained 537 species of animals (prior to the posting of the draft revised list in September 2014). Using range maps, consultations with experts, and personal experience we narrowed this list to 149 species occurring in the LH PRISM region (Table 1; for the birds we considered only those species known to breed in the region; Figure 1). We eliminated a few species for various reasons. For example, comely shiner is considered nonnative in eastern New York and common mudpuppy is probably a canal introduction in the Hudson River although it is native in western New York. Rainbow smelt is functionally extirpated from the region. Common snapping turtle is abundant and widespread in New York and we do not consider it a high priority species for management although it is locally threatened by harvest. There is a single reported locality where golden eagle attempted to nest unsuccessfully. We replaced southern leopard frog with the newly described Atlantic Coast leopard frog, the species formerly identified as southern leopard frog in southeastern New York. We then aggregated some of the SGCN into groups of species that constitute higher taxa or guilds (i.e., species sharing ecological function and habitat) for ease of analyzing and presenting information.

Table 1. New York State Species of Greatest Conservation Need (SGCN) known to occur in the Lower Hudson PRISM region. A few scientific and common names have changed since the state list was promulgated and new names are shown with the species accounts (below). We have used the common names as published in the SGCN list with the exception that we have retained older orthography for three snake names (rat snake, green snake, ribbon snake). The SGCN species group names are taken from the published statewide SGCN list and are not necessarily relevant to our report.

Higher taxon	Common name	Scientific name	SGCN species group
Bird	American bittern	*Botaurus lentiginosus*	Freshwater marsh nesting birds
Bird	American black duck	*Anas rubripes*	Breeding waterfowl
Bird	American oystercatcher	*Haematopus palliatus*	Beach and island ground-nesting birds
Bird	American woodcock	*Scolopax minor*	Early successional forest/shrubland birds
Bird	Bald eagle	*Haliaeetus leucocephalus*	Bald eagle
Bird	Barn owl	*Tyto alba*	Barn owl
Bird	Black-billed cuckoo	*Coccyzus erythropthalmus*	Early successional forest/shrubland birds
Bird	Black-crowned night-heron	*Nycticorax nycticorax*	Colonial-nesting herons
Bird	Black-throated blue warbler	*Dendroica caerulescens*	Deciduous/mixed forest breeding birds
Bird	Blue-winged warbler	*Vermivora pinus*	Early successional forest/shrubland birds
Bird	Bobolink	*Dolichonyx oryzivorus*	Grassland birds
Bird	Brown thrasher	*Toxostoma rufum*	Early successional forest/shrubland birds

Bird	Canada warbler	*Wilsonia canadensis*	Early successional forest/shrubland birds
Bird	Cerulean warbler	*Dendroica cerulea*	Deciduous/mixed forest breeding birds
Bird	Common nighthawk	*Chordeiles minor*	Common nighthawk
Bird	Cooper's hawk	*Accipiter cooperii*	Forest breeding raptors
Bird	Eastern meadowlark	*Sturnella magna*	Grassland birds
Bird	Glossy ibis	*Plegadis falcinellus*	Colonial-nesting herons
Bird	Golden-winged warbler	*Vermivora chrysoptera*	Early successional forest/shrubland birds
Bird	Grasshopper sparrow	*Ammodramus savannarum*	Grassland birds
Bird	Great egret	*Ardea alba*	Colonial-nesting herons
Bird	Henslow's sparrow	*Ammodramus henslowii*	Grassland birds
Bird	Horned lark	*Eremophila alpestris*	Grassland birds
Bird	Kentucky warbler	*Oporornis formosus*	Deciduous/mixed forest breeding birds
Bird	King rail	*Rallus elegans*	Freshwater marsh nesting birds
Bird	Least bittern	*Ixobrychus exilis*	Freshwater marsh nesting birds
Bird	Long-eared owl	*Asio otus*	Forest breeding raptors
Bird	Louisiana waterthrush	*Seiurus motacilla*	Deciduous/mixed forest breeding birds
Bird	Northern bobwhite	*Colinus virginianus*	Early successional forest/shrubland birds
Bird	Northern goshawk	*Accipiter gentilis*	Forest breeding raptors
Bird	Northern harrier	*Circus cyaneus*	Grassland birds
Bird	Osprey	*Pandion haliaetus*	Osprey
Bird	Peregrine falcon	*Falco peregrinus*	Peregrine falcon
Bird	Pied-billed grebe	*Podilymbus podiceps*	Freshwater marsh nesting birds
Bird	Prairie warbler	*Dendroica discolor*	Early successional forest/shrubland birds
Bird	Prothonotary warbler	*Protonotaria citrea*	Deciduous/mixed forest breeding birds
Bird	Red-headed woodpecker	*Melanerpes erythrocephalus*	Deciduous/mixed forest breeding birds
Bird	Red-shouldered hawk	*Buteo lineatus*	Forest breeding raptors
Bird	Ruffed grouse	*Bonasa umbellus*	Early successional forest/shrubland birds
Bird	Saltmarsh sharp-tailed sparrow	*Ammodramus caudacutus*	Salt marsh breeding birds
Bird	Scarlet tanager	*Piranga olivacea*	Deciduous/mixed forest breeding birds
Bird	Seaside sparrow	*Ammodramus maritimus*	Salt marsh breeding birds
Bird	Sedge wren	*Cistothorus platensis*	Grassland birds
Bird	Sharp-shinned hawk	*Accipiter striatus*	Forest breeding raptors
Bird	Snowy egret	*Egretta thula*	Colonial-nesting herons
Bird	Upland sandpiper	*Bartramia longicauda*	Grassland birds
Bird	Vesper sparrow	*Pooecetes gramineus*	Grassland birds
Bird	Whip-poor-will	*Caprimulgus vociferus*	Early successional forest/shrubland birds
Bird	Willow flycatcher	*Empidonax traillii*	Early successional forest/shrubland birds
Bird	Wood thrush	*Hylocichla mustelina*	Deciduous/mixed forest breeding birds
Bird	Worm-eating warbler	*Helmitheros vermivorum*	Deciduous/mixed forest breeding birds
Bird	Yellow-breasted chat	*Icteria virens*	Early successional forest/shrubland birds

Bird	Yellow-crowned night-heron	*Nyctanassa violacea*	Colonial-nesting herons
Crustacean	Piedmont groundwater amphipod	*Stygobromus tenuis tenuis*	Freshwater crustacean
Fish	Common pipefish	*Syngnathus fuscus*	Estuarine associates of SAV
Fish	Fourspine stickleback	*Apeltes quadricus[quadracus]*	Estuarine associates of SAV
Fish	Lined seahorse	*Hippocampus erectus*	Estuarine associates of SAV
Fish	Mummichog	*Fundulus heteroclitus*	Estuarine forage species
Fish	North American ninespine stickleback	*Pungitius pungitius occidentalis*	Estuarine associates of SAV & Inland
Fish	Spotfin killifish	*Fundulus luciae*	Estuarine forage species
Fish	Threespine stickleback	*Gasterosteus aculeatus*	Estuarine associates of SAV
Fish	Brook trout, Heritage strains	*Salvelinus fontinalis*	Brook trout, Heritage strains
Herpetofauna	Black rat snake	*Elaphe obsoleta*	Woodland/grassland snakes
Herpetofauna	Blanding's turtle	*Emydoidea blandingii*	Uncommon turtles of wetlands
Herpetofauna	Blue-spotted salamander	*Ambystoma laterale*	Vernal pool salamanders
Herpetofauna	Bog turtle	*Clemmys muhlenbergii*	Uncommon turtles of wetlands
Herpetofauna	Common five-lined skink	*Eumeces fasciatus*	Lizards
Herpetofauna	Eastern box turtle	*Terrapene carolina*	Box Turtle
Herpetofauna	Eastern hognose snake	*Heterodon platirhinos*	Woodland/grassland snakes
Herpetofauna	Eastern ribbon snake	*Thamnophis sauritus sauritus*	Lake/river reptiles
Herpetofauna	Eastern spadefoot	*Scaphiopus holbrookii*	Eastern Spadefoot Toad
Herpetofauna	Fence lizard	*Sceloporus undulatus*	Lizards
Herpetofauna	Four-toed salamander	*Hemidactylium scutatum*	Freshwater wetland amphibians
Herpetofauna	Fowler’s toad	*Bufo fowleri*	Freshwater wetland amphibians
Herpetofauna	Jefferson salamander	*Ambystoma jeffersonianum*	Vernal pool salamanders
Herpetofauna	Longtail salamander	*Eurycea longicauda*	Stream salamanders
Herpetofauna	Marbled salamander	*Ambystoma opacum*	Vernal pool salamanders
Herpetofauna	Northern black racer	*Coluber constrictor*	Woodland/grassland snakes
Herpetofauna	Northern copperhead	*Agkistrodon contortrix mokasen*	Woodland/grassland snakes
Herpetofauna	Northern cricket frog	*Acris crepitans*	Freshwater wetland amphibians
Herpetofauna	Northern diamondback terrapin	*Malaclemys terrapin terrapin*	Diamondback Terrapin
Herpetofauna	Northern map turtle	*Graptemys geographica*	Lake/river reptiles
Herpetofauna	Northern red salamander	*Pseudotriton ruber*	Stream salamanders
Herpetofauna	Smooth green snake	*Opheodrys vernalis*	Woodland/grassland snakes
Herpetofauna	Southern leopard frog (actually Atlantic Coast leopard frog)	*Rana sphenocephala (*actually *Rana kauffieldi)*	Freshwater wetland amphibians
Herpetofauna	Spotted turtle	*Clemmys guttata*	Uncommon turtles of wetlands
Herpetofauna	Stinkpot (musk turtle)	*Sternotherus odoratus*	Uncommon turtles of wetlands
Herpetofauna	Timber rattlesnake	*Crotalus horridus*	Woodland/grassland snakes
Herpetofauna	Wood turtle	*Clemmys insculpta*	Lake/river reptiles

Herpetofauna	Worm snake	*Carphophis amoenus*	Woodland/grassland snakes
Insect: Beetle	A tiger beetle (Appalachian tiger beetle)	*Cicindela ancocisconensis*	Riparian tiger beetles
Insect: Beetle	Sylvan hygrotus diving beetle	*Hygrotus sylvanus*	Sylvan hygrotus diving beetle
Insect: Butterfly	Checkered white	*Pontia protodice*	Other butterflies
Insect: Butterfly	Frosted elfin	*Callophrys irus*	Other butterflies
Insect: Butterfly	Henry's elfin	*Callophrys henrici*	Other butterflies
Insect: Butterfly	Hessel's hairstreak	*Callophrys hesseli*	Other butterflies
Insect: Butterfly	Mottled duskywing	*Erynnis martialis*	Other butterflies
Insect: Butterfly	Northern metalmark	*Calephelis borealis*	Other butterflies
Insect: Butterfly	Northern oak hairstreak	*Fixsenia favonius ontario*	Other butterflies
Insect: Butterfly	Persius duskywing	*Erynnis persius persius*	Other butterflies
Insect: Butterfly	Regal fritillary	*Speyeria idalia*	Other butterflies
Insect: Butterfly	Tawny crescent	*Phyciodes batesii batesii*	Other butterflies
Insect: Moth	Regal moth	*Citheronia regalis*	Other moths
Insect: Odonate	Arrow clubtail	*Stylurus spiniceps*	Odonates of rivers/streams
Insect: Odonate	Arrowhead spiketail	*Cordulegaster obliqua*	Odonates of seeps/rivulets
Insect: Odonate	Blue-tipped dancer	*Argia tibialis*	Odonates of rivers/streams
Insect: Odonate	Brook snaketail	*Ophiogomphus aspersus*	Odonates of rivers/streams
Insect: Odonate	Cobra clubtail	*Gomphus vastus*	Odonates of rivers/streams
Insect: Odonate	Comet darner	*Anax longipes*	Odonates of lakes/ponds
Insect: Odonate	Gray petaltail	*Tachopteryx thoreyi*	Odonates of seeps/rivulets
Insect: Odonate	Midland clubtail	*Gomphus fraternus*	Odonates of rivers/streams
Insect: Odonate	Mocha emerald	*Somatochlora linearis*	Odonates of small forest streams
Insect: Odonate	Needham's skimmer	*Libellula needhami*	Odonates of brackish marshes/lakes/ponds
Insect: Odonate	New England bluet	*Enallagma laterale*	Odonates of lakes/ponds
Insect: Odonate	Rapids clubtail	*Gomphus quadricolor*	Odonates of rivers/streams
Insect: Odonate	Russet-tipped clubtail	*Stylurus plagiatus*	Odonates of rivers/streams
Insect:	Sable clubtail	*Gomphus rogersi*	Odonates of small forest streams

Odonate			
Insect: Odonate	Septima's clubtail	*Gomphus septima*	Odonates of rivers/streams
Insect: Odonate	Sparkling jewelwing	*Calopteryx dimidiata*	Odonates of rivers/streams
Insect: Odonate	Spatterdock darner	*Aeshna mutata*	Odonates of lakes/ponds
Insect: Odonate	Spine-crowned clubtail	*Gomphus abbreviatus*	Odonates of rivers/streams
Insect: Odonate	Taper-tailed darner	*Gomphaeschna antilope*	Odonates of bogs/fens/ponds
Insect: Odonate	Tiger spiketail	*Cordulegaster erronea*	Odonates of seeps/rivulets
Mammal	Allegheny woodrat	*Neotoma magister*	Allegheny Woodrat
Mammal	Eastern red bat	*Lasiurus borealis*	Tree bats
Mammal	Hoary bat	*Lasiurus cinereus*	Tree bats
Mammal	Indiana bat	*Myotis sodalis*	Indiana Bat
Mammal	Little brown bat	*Myotis lucifugus*	Little brown bat
Mammal	New England cottontail	*Sylvilagus transitionalis*	Game species of concern
Mammal	Northern bat	*Myotis septentrionalis*	Northern bat
Mammal	River otter	*Lontra canadensis*	Furbearers
Mammal	Silver-haired bat	*Lasionycteris noctivagans*	Tree bats
Mammal	Small-footed bat	*Myotis leibii*	Small-footed bat
Mollusk	Alewife floater	*Anodonta implicata*	Freshwater bivalves
Mollusk	Blue mussel	*Mytilus edulis*	Blue mussel
Mollusk	Brook floater	*Alasmidonta varicosa*	Freshwater bivalves
Mollusk	Canadian duskysnail	*Lyogyrus walkeri*	Freshwater gastropods
Mollusk	Dwarf wedgemussel	*Alasmidonta heterodon*	Freshwater bivalves
Mollusk	Eastern pearlshell	*Margaritifera margaritifera*	Freshwater bivalves
Mollusk	Eastern pondmussel	*Ligumia nasuta*	Freshwater bivalves
Mollusk	Fringed valvata	*Valvata lewisi*	Freshwater gastropods
Mollusk	Lance aplexa	*Aplexa elongata*	Freshwater gastropods
Mollusk	Mossy valvata	*Valvata sincera*	Freshwater gastropods
Mollusk	Ribbed mussel	*Geukensia demissa*	Ribbed mussel
Mollusk	Tidewater mucket	*Leptodea ochracea*	Freshwater bivalves
Mollusk	Yellow lamp mussel	*Lampsilis cariosa*	Freshwater bivalves

Then, for each species we performed literature searches using Google Scholar and the common name or scientific name with search terms as in [“wood turtle” invasive]. We reviewed the first four (sometimes more) pages of “hits” (references); after about four pages the references generally became redundant or off-target. We also consulted experts on certain species or species groups, especially biologists who had conducted research in the LH PRISM region. And we solicited information from the members of the LH PRISM and also reviewed our personal experience with many of the SGCN. In a few cases we conducted open searches on the World Wide Web. We also referred to species accounts compiled by NatureServe, the New York Natural Heritage Program, and the SGCN program of the New York State Department of Environmental Conservation (DEC).

Much of the information about the interactions between SGCN and invasive species (IS) is deficient (some species have virtually no ecological information at all that we could find). Many mentions of IS threats are vague or nonspecific, or do not cite references or data. Many assertions regarding IS threats to rare species are supported by few if any scientific data and amount to hypotheses or speculations. In other cases, assertions are based on research from geographic areas that are ecologically dissimilar to the LH PRISM region, or that has methodological weaknesses (such as space-for-time substitutions or not controlling for confounding factors). Even the best research, in most cases, is limited to one or a few study sites and one or two years of study. Ecological relationships between SGCN and IS, including competition, predation on SGCN, and changes in food base, are often variable in space and time. Most SGCN are affected (threatened) by factors other than, or in addition to, IS, particularly including the effects of human activities on habitats and landscapes that may be synergistic with IS effects or difficult to distinguish from them. In order to address the quality of information accurately, we have tried to show in the species (group) accounts the strength and quality of the information we cite. It is inevitable that errors of citation, interpretation, and omission creep into a compilation of this extent, and we take responsibility for any mistakes in citing the literature or personal communications.

Nancy Slowik prepared the odonate, butterfly, moth, bird (exceptions noted below), river otter, Allegheny woodrat, and New England cottontail accounts. Sarah Hoskinson prepared the grassland birds account and assisted with the criteria for prioritizing IS for management. Kiviat prepared all other species and species group accounts including those for American oystercatcher, bald eagle, northern bobwhite, and whip-poor-will. David Strayer provided substantial assistance to Kiviat in preparation of the accounts for freshwater snails, lance aplexa, freshwater mussels, and Piedmont groundwater amphipod. Several other biologists were very helpful in providing or reviewing information, and are listed in the Acknowledgments and cited in the accounts.

Because information on ecological interactions between SGCN and IS is scant for most SGCN, in some cases we have posed our own hypotheses based on logical reasoning or field observations. One group of such hypotheses, for example, refers to the potential for invasive plants that grow rapidly and produce large aboveground standing crops to overgrow bare soil or sparsely vegetated habitats or microhabitats required by certain rare species (e.g., nesting or basking reptiles). We clearly qualify these interactions as hypothetical or anecdotal where such is the case.

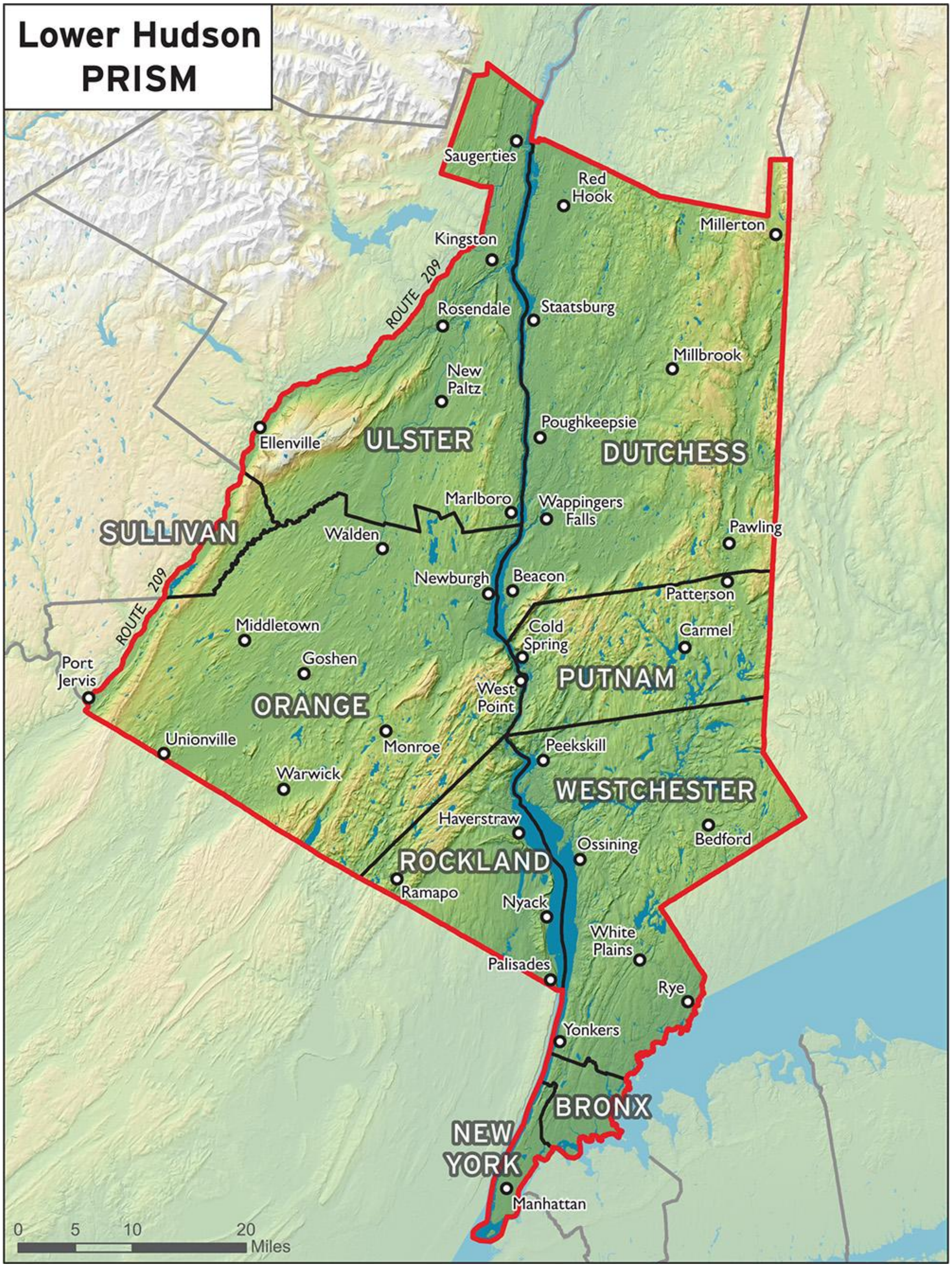

Figure 1. Map of the Lower Hudson PRISM region (from www.nynjtc.org).

Species of Greatest Conservation Need

In this section, the core of our report, we present brief accounts with selected, relevant information about SGCN by species or species group, and identify as best we can the IS threats to each species or species group. We cite the sources of our information and ideas to allow practitioners and other researchers to consult the original sources and reinterpret the data and ideas if they wish to do so. Many of the IS effects we discuss are as yet weakly supported or hypothetical. There is an appalling lack of good research data on IS effects on rare species, and more fundamentally on the basic ecology of many rare species.

The accounts, below, are approximately in the order of the SGCN list in Table 1 (alphabetical by higher taxon then by common name). These accounts focus on the information most relevant to identification and assessment of IS threats to SGCN. Of course there are life history aspects and management concerns in addition to IS, and readers may wish to consult the literature on those subjects.

Freshwater Marsh Breeding Birds

Occurrence in the Lower Hudson PRISM Region

Four freshwater marsh birds are designated SGCN and were reported in the LH PRISM region:

Common Name	**Scientific Name**
American bittern	*Botaurus lentiginosus*
King rail	*Rallus elegans*
Least bittern	*Ixobrychus exilis*
Pied-billed grebe	*Podilymbus podiceps*

Two of the freshwater marsh birds were confirmed to breed in the LH PRISM region: least bittern and pied-billed grebe while two were not confirmed but listed as probable breeders: American bittern and king rail (McGowan & Corwin 2008). American bittern and least bittern both have cryptic coloration and a secretive nature, making them difficult to find and study (Kiviat & Johnson 2013). King rail is also secretive and considered the most threatened rail in North America (Poole et al. 2005). Pied-billed grebe is the most easily observed, requiring the most open water of all four species (Muller & Storer 1999).

American bittern was listed as a probable breeding bird in Ulster and Dutchess counties and a possible breeding bird in Rockland and Orange counties. Least bittern was confirmed in Rockland County and listed as a probable breeding bird in Putnam and Westchester counties. King rail was not confirmed, but listed as a probable breeding bird in Westchester County. Pied-billed grebe was confirmed as a breeding bird in Westchester, Dutchess, Ulster and Orange counties (McGowan & Corwin 2008). Prior to the Breeding Bird Atlas, king rail was confirmed as breeding in Ulster County (Heinz Meng, personal communication) and was found singing in Dutchess County (DeOrsey and Butler 2006). These and other “secretive marsh birds” are notoriously difficult to detect, and males may sing but little and in some cases only at night.

Breeding Habitat

American bitterns nest in nontidal, freshwater marshes with tall emergent vegetation (Lowther et al. 2009). Evidence suggests that American bitterns prefer to nest in large wetlands of at least 10 ha; however, breeding birds have been found in wetlands as small as 1 ha (Gibbs & Melvin 1998). One year a male sang persistently through the breeding season in the freshwater tidal marsh at Tivoli North Bay (Kiviat, personal observation). Least bitterns can be found in both freshwater and brackish marshes with tall emergent vegetation (Poole et al. 2009). King rails are associated with both fresh and brackish marsh, mixed marsh - shrub swamp, and swales with extensive shallow water (Poole et al. 2005). Pied-billed grebes breed on seasonal or permanent ponds ranging from fresh water to moderately brackish (Muller & Storer 1999), or in marshes with extensive shallow open pools (Kiviat, personal observation). Although least bittern has maintained an apparently stable, low density, breeding population in the freshwater tidal marsh at Tivoli North Bay since the early 1970s, the other three species have been recorded irregularly in the suitable wetlands of the LH PRISM region and seem to breed for a year (perhaps longer) and then not return to a particular site (Erik Kiviat, personal observations).

Diet

The American bittern diet includes insects, amphibians, small fish and small mammals (Lowther et al. 2009). The least bittern diet includes frogs, tadpoles, snakes, crayfish and small mammals (Poole et al. 2009). Least bitterns in Tivoli North Bay forage for killifish (*Fundulus*) (Kiviat, personal observations). King rail feeds largely on crustaceans and aquatic insects but also fish, frogs, grasshoppers, crickets and seeds of aquatic plants (Poole et al. 2005). Pied-billed grebe is opportunistic, feeding on whatever prey is most readily available including large crustaceans, frogs, fish, insects and other invertebrates (Muller & Storer 1999).

Predators

Freshwater marsh birds are probably preyed on by the larger raptors, eagles, mink, other carnivores, and snapping turtle. Chicks are probably taken by largemouth bass, bullfrog, northern water snake, larger species of gulls, and great blue heron, in addition to the predators on adults.

Invasive Species Interactions

The continued loss of wetland habitat remains the greatest threat to these marshland species and the conservation of marsh birds is linked to the preservation of freshwater and brackish wetlands and their protection from polluted runoff, siltation, fragmentation and possibly nonnative plants (Kiviat & Johnson 2013). Common reed is often considered an invasive plant and its presence used to designate a wetland as degraded habitat. However, common reed can support a wide variety of nesting bird species, including all the species discussed here (Kane 2001; Kiviat 2013). While all four marshland birds occur in wetlands containing invasive plant species, other factors should be taken into consideration in wetland management since the habitats of breeding birds constitute more than native and nonnative plants. Wetlands with open water interspersed within areas of emergent vegetation generally support more diverse and dense marsh bird populations than those with extensive homogeneous stands of vegetation (Schummer et al. 2012). In a wetland study conducted on Lake Erie in Ontario, encroachment by hybrid cattail (*Typha* X *glauca*, there considered a weed) and common reed was often observed (Schummer et al. 2012), and wetlands with limited open water such as those dominated by cattail and common reed may be avoided by waterbirds (Poole et al. 2009). Marshland with areas of open water is particularly important for breeding pied-billed grebes which depend on wetlands with a mixture of dense, robust, emergent vegetation, submergent vegetation, and open water to breed (Muller & Storer 1999). King rail prefers nesting habitat with a hummocky topography and natural swales that contain grasses, sedges and rushes, and cattail (*Typha)* is a key plant throughout the range of king rail, especially in the north (Poole et al. 2005). American bittern typically builds platform nests on tussocks of emergent vegetation located in dense stands of cattails or common reed that are surrounded by shallow water (Lowther et al. 2009). Least bittern prefers to nest in bulrushes (*Scirpus* s.l.) and cattail, but common reed is sometimes suitable nesting habitat (Poole et al. 2009).

We found no reports of adverse interactions with nonnative prey or predators, although they may well exist. Rats probably prey on eggs and chicks on occasion, inasmuch as at least the Norway rat (*Rattus norvegicus*) often occurs in wetlands associated with estuaries, urban areas, and farmsteads.

Management Considerations

Common reed has colonized many of the remaining freshwater wetland habitats where these SGCN marsh birds breed. While extensive dense stands of common reed may lower the overall diversity of plants, some animal species use this habitat, and reed marshes with large shallow pools are suitable habitat for many other birds. Many wetland management projects are currently underway or planned to remove large stands of common reed in the LH PRISM region including Piermont Marsh and Iona Island Marsh (Rockland County). In New Jersey, threatened birds recently sighted and reported at Troy Meadows included American bittern and least bittern; there is a large scale project to remove nonnative marsh plants there (Sunchild 2014).

In an effort to improve wildlife habitat at Long Point on Lake Erie, dredging was used to increase wetland interspersion by creating irregularly shaped channels and ponds or openings within stands of common reed to improve habitat heterogeneity (Schummer et al. 2012). The relative abundance and species richness of birds in common reed habitats was previously studied at Long Point by Meyer et al. (2010) and they suggested reducing the area of common reed, increasing amount of edge and improving stand structural diversity and local habitat diversity to increase its use by marsh-nesting birds (Schummer et al. 2012). Of the 22 bird species detected at this site, 10 were marsh-nesting birds, including least bittern and pied-billed grebe. It was determined that marsh-nesting bird relative abundance was 40% greater at dredged and natural ponds than cattail-reed areas. Marsh-nesting bird species richness was 22% greater at dredged ponds than natural ponds and 14% greater at dredged ponds than cattail-reed areas (Schummer et al. 2012). We do not know how much of the increased bird diversity was a short-term (few year) response to ecological disturbance.

While efforts to control the spread of invasive species continue, long term studies on the effects of these methods are limited. Moderate and measured invasive control methods should be chosen, particularly in areas where SGCN species are known to breed, until more research has been done. Aspects of common reed habitat and its management were discussed by Kiviat (2010, 2013). Purple loosestrife (*Lythrum salicaria*) is also considered a pest in freshwater marsh bird habitat, and some marshes where loosestrife is dominant may be degraded for the birds discussed here. A classical biocontrol program for purple loosestrife has been implemented for about 25 years in our region, and it has resulted in reductions in purple loosestrife cover and biomass in some areas, and the persistence of short, bushy, or non-flowering clumps of purple loosestrife in others. Both purple loosestrife and common reed can be managed, and their dominance reduced, by many techniques, including raising water levels, frequent cutting, prescribed grazing, and prescribed fire; all techniques must be designed for a specific site and applied at the correct season, frequency, intensity, and number of years. All such management of wetland vegetation in freshwater wetlands of 5 ha (12.4 acres) or larger, or those smaller wetlands that support an endangered or threatened species, require a New York State permit, and some management activities in wetlands connected to a stream system require a federal permit.

American Black Duck (*Anas rubripes)*

Occurrence in the Lower Hudson PRISM

Black duck was confirmed to breed in Westchester, Dutchess, Rockland, Orange and Ulster counties (McGowan & Corwin 2008).

Breeding Habitat

Black ducks breed in diverse habitats, including beaver (*Castor canadensis*) flowages, shrubby brooks, lakes, ponds, bogs, and salt marshes (Longcore et al. 2000). Breeding habitats in the LH PRISM region include tidal wetlands, shrub-dominated swamps, and nontidal marshes (Erik Kiviat, personal observations). The most important habitats may be deeply flooded, shady, tree or shrub dominated swamps that are less attractive to mallards than to black ducks (the two species compete as well as hybridize), and which may be less susceptible to dominance by potentially weedy native and nonnative plants such as cattails, purple loosestrife, and common reed. Remaining black ducks in the LH PRISM region breed in a dispersed pattern with usually no more than one pair in a location (Erik Kiviat, personal observations). Numbers of breeders has apparently declined substantially in Dutchess County during the past40 years (Kiviat, personal observation).

Diet

Black ducks consume a wide variety of foods, including seeds, roots, tubers, stems, and leaves of moist soil and aquatic plants. They also eat corn (*Zea mays*) andother grains. Animal food includes aquatic insects, crustaceans, mollusks, and fish, especially in marine habitats (Longcore et al. 2000).

Predators

Predators of adults include various eagles, hawks, and owls, as well as several species of carnivores (Longcore et al. 2000). Additional predators on ducklings include snapping turtle, and probably larger predatory fishes, northern water snake, and the bullfrog.

Invasive Species Interactions

Nest sites are extremely variable and often near edges or breaks in cover. A Maryland study found 257 nests in Japanese honeysuckle (*Lonicera japonica*) (Stotts & Davis 1960, reviewed Longcore et al. 2000).

Nonnative weeds, especially common reed (*Phragmites*), are a concern in marshes and there has been much debate about the habitat functions of reed and its management (see, e.g., Kiviat 2010, 2013). We think that reed *per se* is not a problem for the black duck and other waterfowl. Extensive dense stands of reed (or cattail [*Typha*] or purple loosetrife [*Lythrum salicaria*] where there are few creeks and pools interspersed with emergent vegetation are generally lower quality habitat. In some cases reedbeds may provide a screen from visual disturbance and a microclimatic buffer for black ducks.

Management Considerations

Wetlands that are confirmed as breeding habitats for black duck can be monitored and if necessary managed to maintain shallow creeks and pools, or other openings, for foraging areas. Because several SGCN birds and other species of conservation concern are likely to use the same wetlands used by black ducks, management decisions may need to consider the whole suite of species.

American Oystercatcher (*Haematopus palliatus*)

Habitat

American oystercatcher was confirmed breeding on the Long Island Sound shore of Westchester County (McGowan & Corwin 2008). Oystercatchers nest on marsh islands, dunes, beaches, or dredge spoil, usually with sandy soil, and grass-forb vegetation that varies from very sparse to dense (Nol & Humphrey 1994). Nests may be just above Mean High Water (average high tide level), or a few meters higher if on dunes.

Diet

Mollusks (mostly bivalves) and polychaete worms, also crabs, sea urchins, starfish, and jellyfish, from the intertidal zone (Nol & Humphrey 1994).

Predators

Mammals and birds, including herring gull, greater black-backed gull, and black-crowned night-heron (Nol & Humphrey 1994). House cat was reported to kill oystercatcher in Florida (in Hatley 2003).

Invasive Species Interactions

Common reed (*Phragmites*) potentially overgrows nesting habitats. Nonnative vines and trees, including Oriental bittersweet (*Celastrus orbiculatus*), are abundant on some of the New York City islands where oystercatchers nest (Craig 2010). Although these woody species support heron nests, it is not known if they overgrow oystercatcher nest habitat.

Management Considerations

Known oystercatcher nesting habitats (and perhaps the best potential habitats) should be kept cleared of invasive nonnative plants that overgrow bare or sparsely vegetated sandy soil. Ideally this should be done by non-chemical means. Vegetation management should balance the maintenance of nesting habitat with the role that plants play in erosion control inasmuch as estuarine shores are vulnerable to erosive forces including sea level rise, waves, and strong winds.

American Woodcock (*Scolopax minor)*

Occurrence in Lower Hudson PRISM

American woodcock was confirmed to breed in Westchester, Dutchess, Orange, and Ulster Counties and listed as a probable breeder in Rockland and Putnam County according to the Second Atlas of Breeding Birds in New York State (McGowan & Corwin 2008). The woodcock is a fairly common breeder in the greenspaces of the New Jersey Meadowlands (outside our region; Erik Kiviat, personal observations), including in shrub thickets and tree groves on inactive garbage landfills, and may well breed in parks in the Bronx and Manhattan.

Breeding Habitat

Woodcocks breed in young forest, abandoned farmland mixed with forest, forest openings, old fields, and thickets in urban greenspaces. Shrub cover is generally high (75-87%) (Morgenweck 1977 as reviewed in McAuley et al. 2013) and nests and young broods are found in young to mid-age forest interspersed with openings (McAuley et al. 2013). The adjacent fields provide display grounds in spring (McAuley et al. 2013) and this is the best time to find breeding populations. A field in Tallman Mountain State Park was used as a display site by breeding American woodcock. The field was maintained as a practice driving range for a nearby golf course and was adjacent to a wet meadow with a border of native plants comprising sedges (*Carex* spp.), grasses, silky dogwood (*Cornus amomum*), catbriar (*Smilax rotundifolia*), and black haw (*Viburnum prunifolium*). The field was also contiguous to a young forest dominated by sweet gum (*Liquidambar styraciflua*) and gray birch (*Betula populifolia*). The woodcock displayed there and sometimes on a nearby lawn, with the numbers of males declining from 15 to

2 through the 1990s and 2000s (Nancy Slowik, personal observations). A similar habitat in New Jersey, 2 miles south of the New York line, was a wet meadow with grasses, sedges, willows (*Salix*), and abundant multiflora rose (Slowik, personal observations).

Diet

Woodcocks primarily consume invertebrates, especially earthworms (Oligochaeta), with plant foods in relatively small amounts (McAuley et al. 2013). Their feeding activity was influenced indirectly by vegetation (leaf litter that earthworms use as food; Reynolds et al. 1977), and soil moisture and texture (McAuley et al. 2013). Their long bills are specialized for probing and extracting earthworms (McAuley 2013). Earthworms predominate as food in the northern range (79% of 479 birds), and the earthworms used in the north are *Dendrobaena octaedra*, *Aporrectodea tuberculata*, *Lumbricus rubellus*, and *Dendrodrilus rubidus (*Reynolds 1977). *A. tuberculata* and *D. octaedra* are often most abundant in the northern range, and *A tuberculata* is the most significant species (McAuley 2013). Spiders (Araneae), snipe flies (Rhagionidae), and click beetles (Elateridae) were eaten more in the north (McAuley 2013). Plant foods are relatively minor but similar in north and south except for sedges which are only used in the north (McAuley 2013).

Invasive Species Interactions

We can assume that woodcock in the LH PRISM are feeding on "invasive" earthworms since north of the glacial boundary most earthworms are nonnative species. These invasive animals are apparently beneficial to American woodcock since earthworms constitute the majority of their diet.

Habitat loss is thought to be a cause of woodcock population declines; however, little is known about the impact of invasive plants on woodcock nest site selection and nesting success. Results from southeastern Pennsylvania indicated that woodcock avoided nonnative vegetation when selecting nest sites and that nest success and habitat decreased significantly with an increase in percentage of nonnative plant cover (Miller & Jordan 2011). Woodcock nest success was greater in plots containing a lower percentage of nonnative stems and nesting woodcocks appeared to avoid invasive shrubs, particularly multiflora rose and Tartarian honeysuckle (Miller & Jordan 2011). Multiflora rose can form nearly impenetrable thickets which exclude most native plants (Kaufman & Kaufman 2007 as reviewed in Miller & Jordan 2011) and both Tartarian honeysuckle and multiflora rose leaf out earlier than native shrubs and may interfere with detection of approaching predators (Miller & Jordan 2011).

A wetland field in northern New Jersey was identified as a singing site for American woodcock while collecting data for the New Jersey Breeding Bird Atlas (Walsh et al. 1999). The population numbers were monitored from 1994 to 2009 as multiflora rose spread through the field (Slowik, personal observations). In 1998, about 75-80% of the multflora rose was removed and chipped onsite. American woodcock numbers increased slightly from 2-3 males to 4-5 males displaying (Slowik, personal observations).

Management Considerations

Woodcock habitat management should address nonnative shrubs (Miller & Jordan 2011), especially multiflora rose, Tartarian honeysuckle (or Bell's honeysuckle, *Lonicera* X *bella*), and autumn-olive (*Elaeagnus umbellata*). Timing of control methods is critical and repeated growing season fire treatments to reduce plant vigor were recommended (Richburg 2005 as reviewed in Miller & Jordan 2011).

Bald Eagle (*Haliaeetus leucocephalus*)

The bald eagle was extremely rare in our region in the 1970s during the low point of the regional population (Erik Kiviat, personal observations). Wintering congregations and nesting eagles have increased steadily in recent years through an intensive DEC reintroduction program, protection of nests and winter roosts from human intrusion, and the larger scale recovery of this species from pesticide and other impacts. Eagles are still affected by human-caused mortality (shooting, collisions with power lines, passenger train strikes, etc.; Buehler 2000). Statistics on New York eagles are in Nye (2010).

Habitat

Nesting bald eagles select forested areas near large bodies of water, often the Hudson River in our region. Nests are typically in tall, live, "emergent" trees (taller than surrounding trees), and built above the tree canopy (Stalmaster 1987). Cliffs and other substrates are used elsewhere and are potential nest sites here. Bald eagles in our region use eastern cottonwood (*Populus deltoides*) and white pine (*Pinus strobus*) most often; tuliptree (*Liriodendron tulipifera*) is also used, and occasionally sycamore (*Platanus occidentalis*) and oak (*Quercus*; Tom Lake, personal communication).

In areas with more human activity, nests are typically situated farther away from shorelines (Buehler 2000). One Dutchess County nest, however, is in a large tree in the midst of a low density residential subdivision a short distance from estuarine waters (Tom Lake, personal communication). In general, Hudson River bald eagles avoided shoreline development (i.e., built structures) and areas of transitory human activity (Thompson & McGarigal 2002).

Diet

Bald eagles are opportunistic foragers that eat mostly live and dead fish along with many other kinds of animals (diverse water birds, turtles, large crustaceans, mammals). Twenty diet studies across the North American range constituted on average 56% fish, 28% birds, and 14% mammals (Buehler 2000).

Predators

Egg predators include gulls, common raven, crows, raccoon, and black bear (Buehler 2000). Predators on nestlings reportedly include black bear, raccoon, hawks, owls, crows, common raven, and bobcat (Buehler 2000). Predation on healthy juveniles and adults probably very rare.

Invasive Species Interactions

Prey. The commonest prey of Hudson River bald eagles was the nonnative gizzard shad (*Dorosoma cepedianum*; Thompson et al. 2005). This fish arrived and became common recently in the Hudson River (Daniels et al. 2005).

"Mudflats" (probably unvegetated intertidal flats) were the habitat where the largest amount of foraging took place. There was concern about this habitat being degraded by invasive plants (?water-chestnut, *Trapa natans*) but no details were stated (Thompson et al. 2005).

Ellis et al. (2011) analyzed the decline of bald eagle prey at a large western lake due to introduction of a mysid shrimp and resultant rearrangement of the fish assemblage. The Hudson River estuary, which principally supports the bald eagle population in our region, has been so pervasively altered by acquisition and loss of species during the time when bald eagles were absent that it is unlikely we will understand the web of interactions and be able to predict future outcomes.

The nonnative mitten crab (*Eriocheir sinensis*) is a potential prey, inasmuch as bald eagles sometimes eat blue crabs.

Trees. Nest trees and perch or roost trees are typically tall trees of certain species. We do not expect trees such as eastern cottonwood, white pine, and tuliptree, which are commonly used for nesting, to be replaced in the near future by nonnative trees that might have different values to eagles. However, certain native trees may be more or less vulnerable to nonnative insect pests, which could eventually affect the availability of tall, sturdy nest trees.

Hydrilla. In 2014, hydrilla (*Hydrilla verticillata*) was documented as extensive in the Croton River between the New Croton Reservoir and Croton Point (Hudson River). Hydrilla spreads via fragments created by physical damage to the plant (as well as by rhizomes, turions, "tubers," and seeds; Langeland 1996, Owens et al. 2006). It is likely that this nonnative, submergent, invasive plant will become more widespread in the Hudson River and other nearby water bodies. Hydrilla is the substrate for a newly described species of cyanobacterium (blue-green "alga") associated with a fatal disease of bald eagles, American coots, waterfowl, and other birds of prey in the southeastern states (Wiley et al. 2007). The disease, avian vacuolar myelinopathy (AVM), is thought to be caused by a natural cyanobacterial toxin. It is not clear if there is an obligate relationship between the cyanobacterium and hydrilla, or how far northward this disease might spread.

Management Considerations

The DEC and the US Fish and Wildlife Service manage the bald eagle. Active nests in New York are monitored by DEC biologists through the breeding season.

Biologists and naturalists should watch for hydrilla outside the lower Croton River and tidal marsh area where the species was well documented in 2014 (suspected hydrilla should be collected for verification by an expert). We have no other specific recommendations.

New or increased mortality of eastern cottonwood, white pine, or tuliptree should be reported to the DEC.

Barn Owl (*Tyto alba*)

The barn owl is very widespread around the world. It is versatile in the use of nest sites and prey selection, and often breeds near human habitation (Marti et al. 2005).

Occurrence in Lower Hudson PRISM

The barn owl reaches its northeastern range limit in New York (Marti et al. 2005). Barn owls were confirmed to breed in Ulster County, and listed as possible in the Bronx (McGowan & Corwin 2008). Breeding in our region has been very spotty (e.g., a nest in the City of Beacon in the 1970s [Erik Kiviat, personal observation]); considering that barn owls are doing well in northeastern New Jersey, and the warming climate, we may have a regular breeding population in the near future.

Breeding Habitat

Primarily found breeding in open habitats including grasslands, marshes, and agricultural fields (Cramp 1985, reviewed Marti et al. 2005), but also found in and around metropolitan areas (e.g., nesting in Yankee Stadium, Bronx, in 1984 (Rising & Rosenberg 1998). Hollow trees, cavities in cliffs and riverbanks, nest boxes, and many human structures including barns and church steeples are used for nesting and roosting (Marti et al. 2005).

Diet

The diet is principally small mammals, with voles (*Microtus*, probably mostly *Microtus pennsylvanicus*) the primary prey. Barn owls also consume mice (*Peromyscus*), rats, shrews, and other mammals, small numbers of birds, and rarely reptiles, amphibians, fish, and arthropods (Marti et al. 2005).

Predators

There appears to be little predation on barn owls. In the U.S. snake predation on nestlings has been recorded, and in Europe stoat (weasel) predation (Marti et al. 2005). There is limited evidence for predation by other raptors in the U.S.

Invasive Species Interactions

Rats (Norway rat [*Rattus norvegicus*], and probably black rat [*Rattus rattus*] where it occurs) are probably important prey in urban and urban fringe areas as well as around garbage landfills, farms, and estuarine shores. Barn owls are highly susceptible to secondary poisoning from rodenticides used to control pests such as the Norway rat (Mendenhall & Pank 1980). Thus a nonnative mammal is a benefit and a threat to this native bird.

No other information was found about invasive species impact on barn owl.

Management Considerations

Rodenticides are widely used outdoors in urban areas and on farms; we have seen many rodenticide (brodifacoum?) bait stations, for example, at motels and restaurants in northeastern New Jersey where barn owls and other predators potentially forage. Rats, voles, songbirds, and insects feed at rodenticide bait stations and represent pathways of exposure for predators including barn owls (Elliott et al. 2014). Certain widely-used anticoagulant rodenticides, such as brodifacoum, may be banned in the near future because of secondary poisoning to wild predators and domestic animals. Rodenticides such as cholecalciferol (vitamin D) should be used in place of anticoagulants to reduce the frequency of secondary poisoning to barn owls (Mendenhall & Pank 1980), or rodent pests controlled non-chemically where that is feasible.

Birds of Shrubland and “Young” Woodland

These seven SGCN species breed in “early successional forest/shrubland”:

Common Name	Scientific Name
Black-billed cuckoo	*Coccyzus erythropthalmus*
Blue-winged warbler	*Vermivora cyanoptera [Vermivora pinus]*
Brown thrasher	*Toxostoma rufum*
Golden-winged warbler	*Vermivora chrysoptera*
Prairie warbler	*Setophaga [Dendroica] discolor*
Willow flycatcher	*Empidonax traillii*
Yellow-breasted chat	*Icteria virens*

Although the SGCN list and many other sources use the term “early successional,” we avoid this term because “successional” implies a stage in an orderly process of vegetation development that may not pertain (see Egler 1954, Drury & Nisbet 1973). For example, some shrubland vegetation may never develop to forest because of barrens conditions (frequent fires, excessively well-drained, infertile soils, etc.), and in other situations trees may colonize an old field without an intervening shrub stage. Even the term "young forest" is troublesome because commonly tree size is known but age is not, and trees growing in harsh conditions may be small for their age. What is important for the birds discussed here is the physical structure of the shrub and tree vegetation, not the age of the individuals. We also avoid the term "brush" because it often has the negative connotation of undesirable vegetation in the Hudson Valley.

Shrubland and young forest habitats are often short-lived and require frequent disturbance that suppresses tree growth and prevents forest development (Wallace & Tarr 2012). With current patterns of land use and urbanization in our region, it will be difficult to maintain extensive shrublands for breeding birds, New England cottontail (see below), and other shrubland species because of sprawling development patterns unrelated to habitat distributions.

Occurrence in Lower Hudson PRISM

Brown thrasher and willow flycatcher were confirmed to breed in all counties in the LH PRISM region except Manhattan. Blue-winged warbler, prairie warbler and black-billed cuckoo were confirmed to breed in all counties except Manhattan and Bronx. Golden-winged warbler was confirmed to breed only in Rockland and Orange counties. Yellow-breasted chat was not confirmed to breed in the LH PRISM REGION but had probable breeding status in Westchester and Orange (McGowan & Corwin 2008).

Breeding Habitat

All seven shrubland birds occur in a variety of situations that include powerline corridors, road verges, abandoned farmland, shrubby hillsides, and fencerows (Hughes 2001) as well as shrub swamp. Yellow-breasted chat selects sites with an open overstorey and shrubby understorey (especially dense blackberry [*Rubus*]; Eckerle & Thompson 2001). Prairie warblers breed in similar habitats where woody plants have colonized cleared areas such as along powerline corridors (Nolan et al. 2014). Both black-billed cuckoo and willow flycatcher breed in riparian woodlands, with black-billed cuckoo preferring to nest in densely wooded areas along the edge of young deciduous woodland (Hughes 2001) and willow flycatchers nesting in shrubby habitats with standing or running water, especially willow thickets (Sedgewick 2000). Golden-winged warbler breeds in a wide variety of habitats, all with dense herbaceous cover and patches of shrubs near forest edges. When occurring with blue-winged warbler, golden-winged warbler prefers a wetter habitat with denser shrubby vegetation (Confer et al. 2011). Blue-winged warbler selects habitats with dense herbaceous growth, shrubs, and often sapling-size trees (Gill 2001). Brown thrashers breed in forest clearings, edges, thickets, and scrubby fields (Cavitt & Haas 2000), sometimes close to occupied buildings where there are ornamental and wild shrubs and woods edges (Erik Kiviat, personal observations). Observations in the New Jersey Meadowlands indicate that some of these species (e.g., brown thrasher) may also nest in urban scrub patches in our region.

Diet

All seven birds are chiefly insectivorous. Yellow-breasted chat, brown thrasher, willow flycatcher, and prairie warbler also consume fruits seasonally. Yellow-breasted chat eats blackberries, blueberries (*Vaccinium*) and elderberries (*Sambucus*) in addition to small invertebrates (Eckerle & Thompson 2001). Willow flycatcher also eats some fruits including blackberries, raspberries (*Rubus*) and dogwood (*Cornus*) (Sedgewick 2000). There are native as well as nonnative species of blackberry and raspberry, but they were not identified in these references. Brown thrasher is primarily insectivorous but also eats fruits in late summer (Cavitt & Haas 2000). Black-billed cuckoo primarily feeds on large insects, including large, hairy lepidopteran larvae, especially during moth outbreaks (Hughes 2001). Prairie warblers feed on a wide variety of insects and spiders as well as mollusks and occasionally fruit (Nolan et al. 2014). Blue-winged warblers primarily consume lepidopteran larvae, crickets, grasshoppers and spiders (Gill 2001). Golden-winged warbler primarily feeds on torticids (leaf rolling moths) and their larvae by prying open curled leaves. They also forage for other moths and spiders (Confer et al. 2011).

Predators

Adult shrubland birds, in general, are vulnerable to hawk and owl predation, although dense thickets have some protective value. Eggs and nestlings of shrubland birds, often in nests within 2 m of the ground, are vulnerable to snakes, birds, white-footed mice (*Peromyscus leucopus*), and other predators. Askins et al. (2012) found significant predation on shrubland birds nesting in powerline corridors through forest.

Invasive species interactions

Physical disturbance to soils and vegetation increases availability of resources (space, light, nutrients), and may greatly increase invasibility (Funk 2013). As a result, abandoned cropfields and pastures, and other disturbed sites, are commonly colonized by nonnative as well as native weeds. Old fields or pastures that are developing woody cover are the most common habitat for birds of shrubland and young forest, and these habitats often support nonnative woody plants such as multiflora rose, Bell's honeysuckle (*Lonicera* X *bella*), autumn-olive (*Elaeagnus umbellata*), common buckthorn (*Rhamnus cathartica*), and black locust (*Robinia pseudoacacia*).

Birds that consume the fleshy fruits of nonnative invasive plants, such as multiflora rose and Japanese honeysuckle, potentially disperse the seeds short and long distances (e.g., White & Stiles 1992; Reichard et al. 2001). Some bird species benefit from feeding on the fruits of nonnative woody plants (Reichard et al. 2001), whereas other birds may not due to lower nutritional quality for those birds than the native fruits replaced. Avian dietary selection of, and nutritional effects of, native compared to nonnative shrub fruits are complex (e.g., Drummond 2005), and it is not possible to generalize across all species of plants and birds. In Illinois chats ate multifora rose (*Rosa multiflora)* and in Delaware Japanese honeysuckle (*Lonicera japonica)* fruits (Aslan & Rejmanek 2010). The nutritional qualities of these fruits for yellow-breasted chat are unknown. We expect that all the shrubland SGCN eat nonnative fruits, insects, or both.

Black-billed cuckoos eat larvae of the nonnative brown-tailed moth (*Euproctis chrysorrhoea*) and gypsy moth (*Lymantria dispar*; Hughes 2001). The former is potentially toxic. The nutritional and toxicological implications of cuckoos feeding on nonnative moths are unknown.

A substantial population of golden-winged warblers nests in shrubby wetlands in Harriman State Park and Sterling Forest (Orange County) where they escape adverse interactions with blue-winged warblers. However, shrubby wetlands invaded by common reed (*Phragmites*) are not suitable for golden-winged warbler nesting (Confer et al. 2011 and personal communication; Ed McGowan, personal communication).

With the exception of house cats, we are not aware of nonnative predators affecting shrubland birds. There is a potential for predation on nests by Norway rats (*Rattus norvegicus*) and possibly black rats (*Rattus rattus*), especially in urban, agricultural, and estuarine shoreline areas.

Management Considerations

The interactions of nonnative plants and birds remain largely unexplored (Aslan & Rejmanek 2010). Nonnative plants can affect bird habitat affinities, diets, nest success, and survival. However, nonnative plants, especially the woody species most likely to affect habitat quality for shrubland birds, may be beneficial to certain bird species and harmful to others, as well as providing other ecosystem services including vegetating derelict lands and urban greenspaces where many native plants do not thrive. Moreover, nonnative woody plants provide resources to nonbreeding (e.g., migrant and wintering) birds and other wildlife.

In Southbury, Connecticut, nest success rates for shrubland specialists was found to be similar or higher for actively managed shrubland when compared to unmanaged sites. Rotational mowing, selective tree removal and invasive plant control were listed as the most effective management practices for shrubland bird species listed as conservation targets which included blue-winged warbler and prairie warbler (Slayi & Smith 2012). Invasive plant species were listed in the study but no correlations were made between invasive plants and shrubland specialist bird species.

In the absence of critical, species-specific information, we are unable to recommend which IS should be managed for particular shrubland bird species. An exception appears to be common reed invasion of the shrub swamp breeding habitats of the golden-winged warbler. The Palisades Interstate Park Commission is experimenting with reed management to benefit the warbler (Ed McGowan, personal communication). The challenge, of course, is to inhibit or remove common reed without harming native plants or rare wildlife. Other than this specific example, we recommend that managers focus on creating and maintaining large blocks of upland shrubland, irrespective of its species composition, until better information and techniques are available for managing IS.

Willow flycatcher, golden-winged warbler, and sometimes the other shrubland SGCN nest in shrub swamp as well as upland shrubland. Beaver cutting of trees in tree-dominated swamp is releasing the shrub layer in some places, and mortality of ashes (*Fraxinus* spp.) due to emerald ash borer may increase this trend.

Colonial-Nesting "Herons"

Five colonial-nesting long-legged waders (herons and an ibis) designated as SGCN include:

Common Name	**Scientific Name**
Black-crowned night-heron	*Nycticorax nycticorax*
Glossy ibis	*Plegadis falcinellus*
Great egret	*Ardea alba*
Snowy egret	*Egretta thula*
Yellow-crowned night-heron	*Nyctanassa violacea*

We will refer to all five species as "herons" although glossy ibis is in a different family in the same order as the herons.

Occurrence in Lower Hudson PRISM

The 2010 nesting survey conducted by Audubon's Harbor Herons Project reported all five SGCN colonial-heron species nesting on South Brother Island in the East River (Bronx) located within the Lower Hudson PRISM (Craig 2010). Colonial behavior can aid in the detection of heron rookeries in coastal bays or uninhabited islands when nests are found in trees and shrubs as compared to birds that nest singly on the ground (Walsh et al. 1999). Additional rookeries reported in the LH PRISM REGION included three SGCN species on Mill Rock (Manhattan), three SGCN species on Goose Island in Long Island Sound (Westchester) and one SGCN species on Huckleberry Island (Westchester) (Craig 2010). South Brother Island, with the largest colony of nesting colonial herons in previous years, continued to support a large portion of this assemblage in 2010 with 456 nests (Craig 2010). By 2013, breeding bird surveys indicated the overall number of heron nests decreased by 26%. This more recent decline included four of the SGCN species; black-crowned night-herons (-27%), great egret (-15%), snowy egret (-24%) and glossy ibis (-45%) (Elbin 2013). Black-crowned night-herons were also confirmed breeding in Rockland and Orange counties and yellow-crowned night-heron was found breeding along the Hudson River in Rockland County (McGowan & Corwin 2008).

Breeding Habitat

All five herons bred in mixed-species colonies, especially when rookeries were on uninhabited islands. Nests were primarily located in trees and shrubs in our region (Craig 2010) with glossy ibis and black-crowned night-heron occasionally nesting in common reeds on the ground and snowy egret in common reeds near the water in New Jersey (Walsh et al. 1999). Great egrets preferred to nest at the highest point of woody vegetation (McCrimmon et al. 2011). Snowy egrets preferred estuarine sites with their nests situated in the densest part of the tree or shrub (Parsons & Master 2000). Black-crowned night-heron and yellow-crowned night-heron preferred to nest in mixed hardwoods, especially oaks (Hothem et al. 2010) whereas yellow-crowned night-heron could also be found nesting in wooded neighborhoods and park-like settings with an open canopy (Watts 2011). In 2008 five yellow-crowned night-heron nests were observed in Harmon Cove, a gated suburban community located in northern New Jersey. Nests were located along the drive and constructed in honey locusts (*Gleditsia triacanthos*), a nonnative street tree planted near the townhouses (Nancy Slowik, personal observation 2008).

Foraging Habitat and Diet

All five colonial herons were found to forage in a wide variety of habitats including freshwater wetlands, estuaries, tidal pools, mudflats and shallow marshes. Water depth was important for snowy egrets (less than 20 cm) and glossy ibis (less than 15 cm), with both species feeding in mixed groups and glossy ibis acting as "beaters," stirring up prey for snowy egrets (Davis & Kricher 2000). Snowy egrets consumed a wide variety of prey that included aquatic and terrestrial worms, insects, crustaceans and fish (Parsons & Master 2000). Glossy ibis foraged in freshwater inland wetlands, consuming insects and crustaceans and traveling greater distances from their breeding grounds (Davis and Kricher 2000). Great egrets were classified as opportunistic feeders but fed mainly on freshwater fish foraged in upland freshwater habitats (McCrimmon et al. 2011). Black-crowned night-herons are also opportunistic feeders, foraging in mudflats and salt marshes at dawn, dusk, and during the night (Hothem et al. 2010). Yellow-crowned night-herons are crustacean specialists consuming a wide variety of crabs and foraging in habitats that include tidal marshes, tidal pools, shallow creeks, rivers, and artificial habitats (Watts 2011).

Invasive Species Interactions

The Harbor Herons Project and the New York City Parks Department have been studying the impact of habitat degradation and causes for abandonment of colonial nesting herons on Prall's Island between New York and New Jersey outside the LH PRISM region. As one of the first heron rookeries reported in the 1950's it was abandoned in 2006 (Bounds 2014). Increased dredging for commercial boat traffic caused erosion and degradation of the salt marshes surrounding the upland allowing invasive plants to invade and degrade the breeding habitat. Invasive species include Phragmites (*Phragmites australis*), Glossy buckthorn (*Frangula alnus*), Oriental bittersweet (*Celastrus orbiculatus*), Callery pear (*Pyrus calleryana)* and (*Ailanthus altissima*) (Bounds 2014).

The loss of colonial-nesting herons has been attributed to a variety of factors that include (Bounds 2014):

-degradation of landscape caused by dredging

-loss of salt marsh habitat from subsequent erosion

-increased boat traffic as a result of dredging

-invasive plant species overwhelming native vegetation used for nesting (especially shrubs and small trees)

-establishment of tree-of-heaven (*Ailanthus altissima),* a taller invasive tree that offers perches for raptors

-Asian long-horned beetle (*Anoplophora glabripennis*; ALB) invasion, quarantine, and eradication disturbed the native and allowed invasive species like mile-a-minute (*Persicaria perfoliata)* to dominate.

-loss of shade trees which were removed to control Asian long-horned beetles, encouraged sun-loving invasive species, especially mile-a-minute, that shaded remaining native vegetation

-increasing numbers of nesting double-crested cormorants (a native species) are known to damage and eventually kill nesting trees and shrubs used by herons (Dahler 2010) with potentially negative impacts on colonial nesting herons.

-glossy buckthorn (*Frangula alnus)* was reported to be "exploding" on Prall's Island, overwhelming native vegetation used for nesting. This shrub leafs out earlier than most native species, forming dense, shady thickets, thus preventing germination of other

Common reed (*Phragmites australis)* was utilized as nesting material in New Jersey coastal wetlands for three SGCN species (snowy egret, glossy ibis and black-crowned night-heron) when found nesting on the ground and or near water (Walsh et al. 1999). Reedbeds have also been reported as nesting habitat, nest substrate, and nest material for most North American herons and ibises in diverse situations (e.g., Kiviat 2013).

Management Considerations

The control of invasive plant species and the restoration of nesting structures in the Harbor Heron Project are considered critical steps to the recovery of islands as nesting locations (Bounds 2014). Clearcutting and chipping of all shade trees on Prall's Island in 2007 to control ALB created significant disturbances to the site, increasing the colonization of invasive plant species (Elbin 2013). Careful selection of plant materials and a measured restoration approach may limit extreme changes in the landscape, minimizing colonization of invasive species.

The use of common reed for nesting is well known and should be carefully evaluated before any removal is recommended.

Destruction of nesting trees by native double-crested cormorants continues to impact heron breeding sites (Dahler 2010). Camera traps confirmed the presence of native mammal nest predators (raccoons) and egg predators (fox and skunk) on Prall's Island and demonstrated the need for predator-proof flashing to be installed on nesting trees, since removing predators is not feasible (Elbin 2013).

Songbirds of Deciduous Forests

These seven SGCN species breed in mixed-species deciduous forest habitats:

Common Name	Scientific Name
Black-throated blue warbler	*Setophaga [Dendroica] caerulescens*
Cerulean warbler	*Setophaga [Dendroica] cerulea*
Kentucky warbler	*Geothlypis [Oporornis] formosa*
Louisiana waterthrush	*Seiurus motacilla*
Scarlet tanager	*Piranga olivacea*
Wood thrush	*Hylocichla mustelina*
Worm-eating warbler	*Helmitheros vermivorum*

Occurrence in Lower Hudson PRISM

Wood thrush was confirmed to breed in all LH PRISM counties. Scarlet tanager, Louisiana waterthrush and worm-eating warbler were confirmed to breed in all counties except Manhattan and Bronx. Black-throated blue warbler was confirmed to breed in Rockland, Orange and Dutchess counties while cerulean warbler was confirmed to breed in Westchester, Rockland and Ulster counties (cerulean warbler almost certainly breeds in Putnam and Dutchess counties as well, to judge from historic records). Kentucky warbler was confirmed to breed only in Westchester County (McGowan & Corwin 2008).

Breeding Habitat

All seven SGCN species breed in closed canopy, deciduous forest habitat. Both black-throated blue warbler and worm-eating warbler are almost restricted to large tracts of mature forest. Black-throated blue warblers are considered interior forest birds that usually need forest tracts greater than 100 hectares (Holmes et al. 2005). Worm-eating warbler breeds on steep slopes in large forest tracts with a dense understorey (Vitz et al. 2013). Cerulean warbler and scarlet tanager prefer forest tracts with mature, tall trees and both species nest high in the canopy (Mowbray 1999; Buehler et al. 2013). Despite a well-known affinity for bottomland forests with large trees, cerulean warblers also breed in oak-hickory woodlands on dry slopes and ridgetops in areas such as the Hudson Highlands and Taconic Mountains (Rosenberg et al. 2000; Hamel et al. 2004; Erik Kiviat, personal observation). Kentucky warbler prefers mature deciduous forest with a dense understorey (McDonald 2013). Louisiana waterthrush breeds in deciduous-mixed forests along swift streams (Mattsson & Cooper 2006) and occasionally in tree swamps. Wood thrushes select a closed-canopy forest habitat with a diverse understorey and deep leaf litter (Evans et al. 2011).

Diet

All seven deciduous forest songbirds are primarily insectivorous, especially during the breeding season. Wood thrush, scarlet tanager and black-throated blue warbler also consume fruits and berries seasonally. Wood thrushes supplemented their diet with fruits high in lipids including elderberry (*Sambucus*), blueberry (*Vaccinium*), blackberry (*Rubus*), cherry (*Prunus*) and grape

(*Vitis*; Evans et al. 2011). Scarlet tanager ate a wide variety of shrub and tree fruits (Mowbray 1999). Black-throated blue warblers are primarily insectivorous during breeding season, consuming larval and adult Lepidoptera as well as craneflies (Tipulidae), adult Diptera, and spiders (Holmes et al. 2005). During migration they were observed feeding on the fruits of angelica tree (*Aralia elata)*, an invasive species in our region (Nancy Slowik, personal observation). Worm-eating warbler, cerulean warbler, Kentucky warbler and Louisiana waterthrush are all exclusively insectivorous. Worm-eating and cerulean warblers feed primarily on larvae of Lepidoptera found in the tree canopy. Kentucky warblers eat Hemiptera, Coleoptera, and Hymenoptera from the leaf litter (McDonald 2013). Louisiana waterthrushes feed primarily on aquatic invertebrates found in shallow streams, mossy streambanks, and woodland leaf litter (Mattsson et al. 2009).

Invasive Species Interactions

Contrasting results indicate that responses of birds to nonnative plants are species-specific for both birds and plants (Conover 2011). One of the most important factors predicting the presence of wood thrush in suburban forest fragments of Delaware and Maryland was the proportion of native shrubs and small trees in the understorey (Conover 2011). However, in northeastern Illinois woodlands, scarlet tanager increased in woodlands managed to control invasive species but wood thrush declined (Forest Preserve District of DuPage County 2014).
Some examples of invasive woody plant interactions with SGCN forest songbirds follow.

Treefall Gaps

Cerulean warbler and Kentucky warbler selected breeding sites near treefall gaps that provided openings within a closed canopy (Buehler et al. 2013; McDonald 2013). Kentucky warbler selected breeding sites near forest openings that more species in the understorey (Magee & Van Clef, no date). Cerulean warbler preferred forests with natural disturbances from storm damage, breeding where there was increased understorey cover (Buehler et al. 2013). Light gaps also provide greater opportunity for invasive plant species to invade and should be monitored following severe storm damage. Because cerulean warbler stays mostly in the tree canopy, invasive herbs or shrubs might not affect that species but might affect Kentucky warbler.

All of the SGCN forest songbirds are insectivorous during the breeding season, with four of the species exclusively feeding on insects. In general, native woody plants supported more species of invertebrates than introduced plants (Tallamy 2009; Burghardt et al. 2010). Thus, invasions by nonnative woody plants might reduce the food base for insectivorous birds. Although hundreds of nonnative plant species have been naturalized in the United States, only a small percentage of these have been studied in their new biotic communities and their interactions with resident bird species remain largely unexplored (Aslan & Rejmanek 2010). Not all nonnative species are necessarily unfavorable for the food supply or other needs of forest songbirds.

Amur honeysuckle (*Lonicera maackii*)

The decline of forest birds has been linked to an increase in nonnative plants, with songbird nest predation linked to nonnative honeysuckle species (*Lonicera*) and buckthorns *(Rhamnus* *cathartica).* American robins experienced higher nest predation in nonnative Amur honeysuckle (*Lonicera maackii)* and nesting wood thrush experienced apparent competition for nest sites with American robin when using honeysuckle (Schmidt & Whelan 1999).

Autumn-olive (*Elaeagnus umbellata*)

Kentucky warblers nested at a Mercer County, New Jersey, site with an understorey of mixed saplings interspersed with nonnative autumn-olive. Despite the large size of the site, fewer Kentucky warblers were found breeding there and most were first-year birds, suggesting poor habitat quality (Magee & Van Clef, no date).

Multiflora rose (Rosa multiflora)

Multiflora rose in some of the prime breeding territories of Kentucky warbler in Mercer County, New Jersey, was overgrown by spicebush (*Lindera benzoin*) shrubs. In these situations the multiflora rose was in poor health. The study reported 39 of 42 nest sites were predominantly or entirely in spicebush cover and concluded Kentucky warbler required a dense understorey to breed and tolerated invasive plants when native plants dominated the understorey (Magee & Van Clef, no date).

Stiltgrass (*Microstegium vimineum*) and garlic-mustard (*Alliaria petiolata*)

Nonnative stiltgrass reduced biodiversity by suppressing tree regeneration (Aronson & Handel 2011). However, stiltgrass differentially affected tree species (Marshall et al. 2009), and the combined effects of understorey shade and leaf litter suppressed stiltgrass (Schramm & Ehrenfeld 2010). Nonnative garlic-mustard suppressed forest herbs and trees (Stinson et al. 2006; Moser et al. 2009). Stiltgrass and garlic-mustard may have the potential to affect habitat integrity for some of the SGCN forest songbirds. It is unclear, however, how long populations of these plants dense enough to affect native flora persist.

Japanese knotweed and relatives (*Polygonum cuspidatum, Polygonum sacchalinense,* and hybrids)

Japanese knotweed occurs on the banks of fresh or brackish waterways, in the drier edges of wetlands, in grassland, forest, shrubland, and floodplains, as well as roadsides and urban habitats (Richards et al. 2008; Erik Kiviat, personal observations). It spreads quickly and forms shrub-like thickets that can exclude most native plants. Invasion of streambanks in deciduous forest might impede nesting by Louisiana waterthrush. Several common bird species nest in Japanese knotweed (Kiviat, personal observations). Nesting of rare birds may have been overlooked due to relatively little study of biotic associations with knotweed.

No invasive animal interactions with SGCN forest songbirds were found. Undoubtedly these birds eat some nonnative insects, snails, and other invertebrates. The birds are also surely preyed on by feral and free-ranging house cats, although such predation may or may not have a population-level effect.

Management Considerations

We are reluctant to recommend specific practices inasmuch as the interactions between nonnative plants and forest songbirds are so complex. We do not think that across-the-board removal of all nonnative plants is necessarily a good practice for managing rare forest songbirds even if it is feasible and sustainable.

All forest managers should survey the birds, vascular plants, and other biota of their preserves. Early detection and removal of nonnative weeds that are just becoming established should be practiced in a preserve unless it can be proven that a species will not be harmful (invasive). Japanese knotweed is a good target for EDRR because once well-established it is difficult to control. In addition, observations of the ecology rare native species of concern may allow management decisions for the conservation of those species.

Grassland Birds

Common Name	**Scientific Name**
Bobolink	*Dolichonyx oryzivorus*
Eastern meadowlark	*Sturnella magna*
Grasshopper sparrow	*Ammodramus savannarum*
Henslow’s sparrow	*Ammodramus henslowii*
Horned lark	*Eremophila alpestris*
Northern harrier	*Circus cyaneus*
Sedge wren	*Cistothorus platensis*
Upland sandpiper	*Bartramia longicauda*
Vesper sparrow	*Pooecetes gramineus*

Habitat needs

Breeding

Most of the SGCN require grasslands that are at least 5 ha in extent, and a least 100 ha are needed to support a diverse bird assemblage (Vickery et al. 1994; Jones & Vickery 1997; Rothbart & Capel 2006; Weidman & Litvaitis 2011). The ideal grassland structure (e.g. percent bare ground, vegetation height, forb vs. grass percent cover) varies by bird species. Horned lark, grasshopper sparrow, vesper sparrow, and upland sandpiper prefer relatively short, patchy vegetation cover interspersed with bare soil for dirt bathing (Vickery et al. 1994, Delisle & Savidge 1997, reviewed in Rothbart & Capel 2006). In contrast, Henslow’s sparrow, sedge wren, bobolink, and eastern meadowlark prefer more productive, dense vegetation to conceal nests, with northern harriers preferring grasslands with interspersed shrubs (Vickery et al. 1994; Delisle & Savidge 1997, reviewed in Rothbart & Capel 2006). In addition to breeding in upland meadows, sedge wren and northern harrier may also breed in wet meadows (both species) or marshes (harrier). Sedge wren nesting habitats may have a shrubby component (Erik Kiviat, personal observation). Northern harrier may nest in a variety of herbaceous, shrubby, or possibly even sapling-dominated habitats as long as the habitat is extensive and remote from direct human disturbance.

Foraging

Northern harriers primarily hunt for small mammals in large forest openings that are within 11 miles of their nests (Simmons & Smith 1985). The other SGCN forage for grassland insects and seeds. Grasslands with a diverse plant species assemblage that includes a forb component may support more insect biomass. In fact, Jonas et al. (2002), and McIntyre and Thompson (2003), Hickman et al. (2006), found that forb cover was positively correlated with insect biomass in western grasslands (but see Hull et al. 1996). Plant species mixtures composed of only a few species tend to provide less forage, but the relative importance of grassland structure vs. species composition is not clear (Flanders et al. 2006, George et al. 2013).

Invasive Species Interactions

Studies that focus on the interaction between grassland birds - invasive species in the Northeast are limited, but there are a few studies from elsewhere that have focused on invasive species that are found in the LH PRISM region:

-Spotted knapweed (*Centaurea stoebe*)- In Montana, pine savanna sites dominated by spotted knapweed harbored fewer insects, and the reduction in food availability reduced chipping sparrow (*Spizella passerina*) reproductive success (Ortega et al. 2006). However, although chipping sparrows forage for seeds and insects in savannas, their breeding behavior is unlike grassland breeding birds (Ortega et al. 2006).

-Leafy spurge (*Euphorbia esula*)- In North Dakota, sites with relatively high spurge cover (>60%) had lower grasshopper sparrow densities than sites with lower spurge cover, but bobolink and western meadowlark (*Sturnella spp.)* densities were not affected by spurge cover (Scheiman et al. 2003). Spurge cover did not affect nest site selection for these species, and western meadowlark nest success was actually positively correlated with spurge cover (although this result is based on a small sample size). The dense vegetation on sites dominated by spurge may have been what limited grasshopper sparrow use, whereas the bobolink and western meadowlark tend to use areas with dense vegetation (Scheiman et al. 2003).

- Chinese silvergrass (*Miscanthus sinensis*)- Grassland birds breed in *M. sinensis* stands in its native Japan (Stewart et al. 2009), but if *M. sinensis* develops into dense stands they could become impenetrable to birds (Bellamy et al. 2009). In Europe, Bellamy et al. (2009), Bright et al. (2009), and Sage et al. (2010) found that birds nest in *M.* X *giganteus* (hybrid of *M. sinensis* and *M. sacchariflorus*) stands when the stands are first establishing and patchy, and suspect that established, dense stands will no longer support birds. *Miscanthus* (probably *M.* X *giganteus*) is being planted for bioenergy in a few places in eastern New York and cultivated *Miscanthus* may be relevant to grassland bird issues.

-Common reed (*Phragmites australis*, Old World form)- Extensive dense reedbeds would not be favorable for grassland birds. Sedge wrens may be able to breed in sedge or short grass-dominated openings within reedbeds, and northern harriers sometimes breed in extensive dense reedbeds (neither has yet been documented in the LH PRISM region although known not far away).

-Eurasian boar ("feral swine" *Sus scrofa*)- Boars have been documented in Ulster, Sullivan, and Greene counties. Boars will opportunistically eat ground nesting bird eggs and nests, but the impacts of nest predation on grassland bird population numbers are unclear (reviewed in Mayer & Brisbin 2009).

Invasive species that are found in theLH PRISM region may be expected to affect grassland birds by changing grassland structure for nesting and foraging:

-Woody shrub and tree encroachment is a well- documented threat to grassland specialist birds because the vegetation structure becomes unsuitable for nesting and foraging (e.g. Coffman et al. 2014, but see Hill & Diefenbach 2013). Thus, shrubs that can invade Lower Hudson grasslands (e.g**., multiflora rose [*Rosa multiflora*], Japanese barberry [*Berberis thunbergii*], wineberry [*Rubus phoenicolasius*], autumn-olive [*Elaeagnus umbellata*], nonnative honeysuckles [*Lonicera* spp.], Bradford pear [*Pyrus calleryana*]**) that are persistent and difficult to remove once established are a threat. However, while invasive shrubs may pose a threat to species that prefer sparse vegetation (e.g. horned lark, grasshopper sparrow, vesper sparrow, and upland sandpiper), species that use interspersed shrubs (e.g. northern harriers, Henslow's sparrow) may not be affected until the shrubs become abundant.

-Grassland specialist birds tend to have difficulty foraging in very dense vegetation. Exotic vines in the Lower Hudson that can smother grasslands (i.e., **mile-a-minute [*Persicaria perfoliata*], black swallowwort [*Cynanchum louiseae*], Japanese honeysuckle [*Lonicera japonica*], porcelainberry [*Ampelopsis brevipedunculata*]**) likely pose the greatest threat to grassland birds because of their architecture. In fact, birds may be unable to nest in grasslands where **swallowwort** is the majority of the ground cover because birds are unable to penetrate the dense vegetation (Marcelo del Puerto, personal communication). However, even in dense infestations, when **swallowwort** is erect birds can perch and call from it (Marcelo del Puerto, personal communication).

-Studies in western grasslands have found that arthropod biomass tends to decrease in monocultures or homogeneous grasslands (e.g. Flanders et al. 2006; George et al. 2013), so if left unchecked, invasive forbs (i.e. **Canada thistle [*Cirsium arvense*], wild parsnip [*Pastinaca sativa*], mugwort [*Artemisia vulgaris*], cypress spurge [*Euphorbia cyparissias*], spotted knapweed**) might threaten grassland birds through a decline in the availability of arthropod prey. The displacement of grass species will likely also result in a decline in forage from seed (Flanders et al. 2006). The higher density of vegetation in forb-invaded grasslands may be expected to especially hinder bird species that require sparse vegetation with bare patches (e.g. horned lark, grasshopper sparrow, vesper sparrow, and upland sandpiper). The species that can tolerate more productive grasslands (e.g. Henslow's sparrow, sedge wren, bobolink, eastern meadowlark, northern harrier) may not be as affected by the change in structure.

-Like the invasive forbs, **Japanese stiltgrass (*Microstegium vimineum)*** will likely have the greatest impact on grassland birds that require patchy vegetation with bare soil (e.g. horned lark, grasshopper sparrow, vesper sparrow, and upland sandpiper) because it is a dense annual grass with thick litter. Henslow's sparrows, which use dense grasslands with thick litter, may not be affected by the change in structure, but the impacts of stiltgrass on forage quantity and quality are less clear. There are few documented cases of stiltgrass impacts on arthropod biomass in grassland systems, and the few studies in forest systems are mixed; in some cases, areas dominated by stiltgrass have no effect on arthropod abundance or diversity (Marshall & Buckley 2009), but Simao et al. (2010) found that stiltgrass-dominated stands reduced richness and abundance, and Tang et al. (2012) found that stiltgrass dominance was associated with enhanced richness and abundance, but decreased evenness. It is unclear if birds consume stiltgrass seed.

Prioritizing Grasslands for Invasive Species Management

-Prioritize areas that are likely to be managed to remain in grassland (not allowed to afforest). For example, grasslands owned by airports or military training sites, or managed by preserves are likely to remain in field, as are agricultural fields on good quality soils.

-If possible, prioritize grasslands that are at least 5 ha in extent because smaller grasslands usually do not support breeding birds. Many grassland bird species avoid field edges, so it is best to prioritize grasslands with a low perimeter to area ratio (e.g., Helzer & Jelinski 1999).

-If possible, choose a variety of grassland types in the LH PRISM region (i.e., wet with dense vegetation vs. dry with more sparse vegetation) because these vegetation types tend to support different assemblages of bird species.

Invasive Species Management Considerations

-Timed mowing is a common invasive species control method in grasslands, but it is important to avoid mowing during bird breeding season (spring- early summer). Sedge wrens may breed from late spring- early fall, so mowing is not a viable control method for many invasive species when sedge wrens are present. However, because sedge wrens often do not breed in the same meadow in successive years, it may be possible to monitor singing sedge wrens and mow in years when the wrens are not breeding. And if nonnative woody plants are the primary concern, mowing may be done after September.

-Birds use grasslands for foraging, breeding, and cover at various time points, so it is best to avoid disturbing the entire grassland area at one time. Additionally, in order to potentially support a variety of grassland birds, it is ideal to maintain heterogeneity in vegetation structure within the field (e.g., areas with short, sparse vegetation vs. tall, dense vegetation). When mitigating invasive species, this can be accomplished by spot treating invasive species or establishing sections within the grassland and staggering when each is mowed (e.g., see Walk & Warner 2000).

-While vine invasion will likely be detrimental to all grassland bird SGCN, forb and shrub encroachment at low densities is likely not as threatening, especially to SGCN that use grasslands with relatively dense vegetation. From this perspective, forb and shrub species that are the most persistent and spread most rapidly in grasslands should be prioritized for management.

Canada Warbler (*Cardellina canadensis [Wilsonia canadensis])*

Occurrence in Lower Hudson PRISM

Canada warbler was confirmed to breed in Putnam and Dutchess counties and was a probable breeder in Rockland and Orange counties (McGowan & Corwin 2008).

Breeding Habitat

During breeding season Canada warblers inhabit diverse forests, but the species is most abundant in cool, moist forests with a mixture of coniferous and deciduous trees, a dense understorey, and complex ground cover, often with standing water and trees that emerge from the subcanopy. They prefer the shrubby understorey of moist woodlands, and nest in dense vegetation, often with mosses and ferns, on or near the ground (Reitsma et al. 2010).

Diet

This warbler eats a variety of insects including flies, moths, beetles and small spiders using varied foraging techniques that include foliage gleaning, ground foraging, and flycatching (Reitsma et al. 2010).

Predators

We found no information.

Invasive Species Interactions

Canada warbler is negatively affected by any action that decreases shrub cover including overbrowsing by deer (Matteson et al. 2009). The invasion of nonnative buckthorns (presumably *Rhamnus cathartica* and *Frangula alnus)* and other nonnative shrubs may threaten Canada warbler populations in Wisconsin because these species can replace native species and interfere with tree reproduction. Forest management practices that reduce overall conifer cover may decrease site suitability for Canada warbler (WDNR 2005). Absence of regeneration techniques for important canopy species such as northern white cedar, eastern hemlock and eastern white pine is a concern (WDNR 2005).

Eastern hemlock (*Tsuga canadensis*) loss due to woolly adelgid (*Adelges tsugae*) infestations, with resulting structural changes in forest habitats, has caused changes in bird populations in Connecticut and Massachusetts (Tingley et al. 2002). However, effects on breeding Canada warblers are not known. Other nonnative forest pests and pathogens, such as emerald ash borer, might alter the habitat of this species.

Management Considerations

Populations of this warbler have declined steadily over the past 30 years, likely in response to forest maturation and loss of forested wetlands, making Canada warbler a high priority for management and monitoring (Reitsma et al. 2010). Although the effects of nonnative woody plants are poorly understood, Canada warbler breeding sites should be monitored for colonization by shrubs such as smooth buckthorn (*Frangula alnus*), Bell's honeysuckle (*Lonicera* X *bella*), privets (*Ligustrum* spp.), winged euonymus (*Euonymus alata*), and nonnative viburnums (*Viburnum* spp.). Ideally, species such as these may be controlled on an EDRR basis.

Common Nighthawk (*Chordeiles minor)*

The Common Nighthawk remains poorly understood since most studies of this species have been short-term and anecdotal in nature and specific data about much of its life history remain scarce (Brigham et al. 2011).

Occurrence in the Lower Hudson PRISM

The common nighthawk was not confirmed as a breeding bird in the LH PRISM region, but was listed as a probable breeding bird in Kings (Bronx), Westchester, Rockland and Orange counties (McGowan & Corwin 2008). Nighthawks bred historically in Dutchess County (DeOrsey and Butler 2006) and probably throughout our region.

Breeding Habitat

Common nighthawk often nests on unvegetated or sparsely vegetated ground such as gravel beaches, rock outcrops, cultivated fields, sparse native grassland, and burned-over woodlands, as well as atop fence posts (Brigham et al. 2011). This species was also well known for nesting on flat gravel roofs, especially in cities. Roof-nesting behavior is declining due to changes in roof design. Whether nesting on roofs or natural sites, nighthawks lay eggs directly on the ground (Brigham et al. 2011). Viel (2014) found nighthawk nesting in an urban area associated with night lighting.

Diet

Common nighthawk feeds on the wing at dawn and dusk, capturing more than 50 insect species as prey (Gross 1940; Terres 1980, reviewed Brigham et al. 2011). Most prey are flying ants, beetles, caddisflies, moths, and true bugs (Brigham et al. 2011).

Predators

House cat is a predator on adult nighthawks (Brigham et al. 2011). Nesting on the ground makes nighthawks susceptible to predation and many predators are suspected including birds, dogs and native carnivores, and snakes (Brigham et al. 2011).

Invasive Species Interactions

The house cat, and possibly domestic dog, is a predator (Brigham et al. 2011).

Undoubtedly certain prey species are nonnative but we found no comments on interactions.
As a species that requires bare or sparsely vegetated soil for nesting, it is likely that nonnative (as well as native) plants colonize nesting habitats eventually to the detriment of the birds. This is analogous to the dilemma of turtle nest sites (Dowling et al. 2010). Episodic soil disturbance is presumably required to create and maintain nesting habitats.

Management Considerations

Management of non-roof nesting habitats may be needed at intervals to prevent overgrowth by nonnative or native plants (NCWRC 2015). It is possible that tilling would be effective much as for Blanding's turtle nesting habitat (Dowling et al. 2010) but on larger areas.

Predation on nests might be reduced by proper control of domestic cats and dogs, and reduction of artificial food sources that attract raccoons and other potential predators.

Forest Breeding Raptors

All five raptors are designated SGCN species and were found breeding in forest habitat in the LH PRISM REGION:

Common Name	**Scientific Name**
Cooper's hawk	*Accipiter cooperii*
Long-eared owl	*Asio otus*
Northern goshawk	*Accipiter gentilis*
Red-shouldered hawk	*Buteo lineatus*
Sharp-shinned hawk	*Accipiter striatus*

Occurrence in Lower Hudson PRISM Region

Cooper's hawk was confirmed breeding in all regional counties except Manhattan. Red-shouldered hawk was confirmed breeding in Westchester, Putnam, Dutchess, Orange and Ulster counties. Sharp-shinned hawk was confirmed breeding in Rockland, Dutchess, Orange and Ulster counties. Northern goshawk was confirmed to breed in Putnam, Orange and Ulster counties. Long-eared owl was not confirmed, but listed as a possible breeding bird in Dutchess County (McGowan & Corwin 2008) where it was documented nesting historically (DeOrsey and Butler 2006).

Breeding Habitat

All five raptors prefer to breed in mixed coniferous-deciduous forests with some variations depending on the species (Walsh et al. 1999). Sharp-shinned hawk and northern goshawk prefer to nest in conifers found in large forested tracts with goshawk nesting in mature to old growth forests with high canopy closure of 60-90% (Squires & Reynolds 1997). Cooper's hawks breed in similar habitats but are often found nesting near water and will tolerate human development unlike previous two species (Walsh et al. 1999). In New Jersey/New York region, Cooper's hawk nests were generally located on flatter terrain situated closer to roads, forest openings and human habitation (Curtis et al. 2006). Cooper's hawks have been found nesting in young deciduous forest and pine plantation (Erik Kiviat, personal observations). Red-shouldered hawks typically nest in fairly extensive hardwood swamps and nest in deciduous trees that are substantially larger than those available in the surrounding area (Dykstra et al. 2008); they may also nest in extensive mature upland forest near wetlands (Kiviat, personal observations). Long-eared owls prefer to breed in coniferous or mixed coniferous-deciduous forest, but also demonstrate a preference for red cedar groves and pine groves (or plantations), using old hawk and crow nests (Marks et al. 1994).

Diet

Cooper's and sharp-shinned hawks feed primarily on small to medium-sized birds in the Northeast (Curtis et al. 2006). Red-shouldered hawks feed primarily on small mammals, reptiles, amphibians and occasionally birds, but the commonest prey in the Northeast is meadow vole and eastern chipmunk (Dykstra et al. 2008). Northern goshawks are opportunistic hunters, but primarily feed on tree squirrels, rabbits, large passerine birds, game birds, woodpeckers, and corvids (Squires & Reynolds 1997). Long-eared owls feed on small mammals, especially meadow voles and mice (*Peromyscus*) (Marks et al. 1994).

Invasive Species Interactions

Since raptors can be threatened by species population changes at lower trophic levels, it is important to monitor the effects of introduced alien and invasive species on these top predators (Speziale & Lambertucci 2013). Despite these concerns, few studies have been conducted on the interactions of invasive species and raptors. In the Great Basin Desert in Utah, investigators found when nonnative cheatgrass (*Bromus tectorum)* invaded plant communities, small mammal populations decreased in number and diversity (Freeman et al. 2014). Since many raptors depend on small mammals as their primary food source, changes in mammal populations may cause changes in raptor population size (Freeman et al. 2014).

Native raptors can become dependent on introduced prey species as a potential new food supply thereby increasing native rodent prey (Speziale & Lambertucci 2013). Cooper's hawks adapted to preying on European hares, thereby reducing the predator pressure on native rodents. Alien species can exert a negative impact on native raptors as evidenced by elevated levels of lead concentration in the blood of sharp-shinned hawks from consuming nonnative house sparrows (*Passer domesticus*) at bird feeders ((Speziale & Lambertucci 2013). Negative effects exerted by nonnative species ranged from poisoning and pathogen susceptibility to habitat loss and diminished native prey. Introduced consumers (prey) and pathogens were found to directly affect raptors whereas introduced predators did so indirectly by competing for the same prey (Speziale & Lambertucci 2013).

Management Considerations

As introduced prey become abundant, the probability of native predators using introduced prey increases (Rodriguez 2006, reviewed in Speziale & Lambertucci 2013). Some raptor species gain an advantage over other species that do not adapt to utilizing introduced prey (Carlsson et al. 2009, reviewed in Speziale & Lambertucci 2013). Native raptors can become dependent on introduced species and any proposed control of nonnative species merits careful consideration (Speziale & Lambertucci 2013).

As Cooper's hawk populations continue to recover from significant declines in the mid-1900s they may benefit from additional breeding habitat found in urban and suburban sites in the East. Some have expressed concern about the quality of urban habitats compared to rural forest tracts and suggest urban areas may be ecological traps for the species (Boal & Mannan 2000, reviewed in Curtis et al. 2006).

Northern Bobwhite (*Colinus virginianus*)

Habitat

This quail is widely but spottily distributed around much of New York, absent from the Adirondack region and frequent on Long Island; breeding has been confirmed in Orange and Dutchess counties, and it was a possible breeder in the LH PRISM portion of Sullivan County (McGowan & Corwin 2008). It may be unclear whether individual bobwhites in our region are stocked or native. The species is near its northeastern range limit and it is possible that the population will increase if the climate continues to warm and if grassland and shrubland habitats expand.

The bobwhite is essentially a grassland and shrubland species in the Northeast; agricultural fields are among the habitats used although insecticides are adverse to insect prey (Brennan 1999). Shrubs and other dense vegetation cover that keeps patches of ground more-or-less snow free are important to allow winter foraging on the ground (Brennan 1999). In New Jersey, nest microhabitats had greater visual obstruction and more litter (Collins et al. 2009).

Diet

This species is principally a seed eater; leaves are also eaten, and arthropods are important food for chicks and breeding females, less so for males (Brennan 1999). Cultivated grains, acorns, pine seeds, and diverse other wild grass, forb, and woody plant seeds are eaten.

Predators

Predation is an important cause of mortality during the breeding season and in winter (Brennan 1999). Many mammal, bird, and snake predator species are involved. Females are vulnerable on their ground nests, and males while displaying (Brennan 1999).

Invasive Species Interactions

Only genera of plant foods were listed by Brennan (1999), and it is likely that some of the species of, e.g., *Setaria*, were nonnative. Larson et al. (2012), in an experiment with captive birds, found that Texas bobwhites preferred the seeds of a nonnative grass to those of three native grasses. The nonnative species was highest in protein but not in gross energy content. Also in Texas, however, bobwhite tended to avoid areas with a high level of infestation by nonnative grasses (Sands 2007).

Feral swine were reported to prey on bobwhites in Texas (Tolleson et al. 1995 and references cited therein). If feral swine become established in our region they may be a threat to bobwhites. It is likely that house cats and possibly domestic dogs are predators on bobwhites.

Management Considerations

The DEC is mounting a control program for feral swine. Due to the scarcity of bobwhite in our region, and the lack of information on other potential IS threats, we are unable to make recommendations. Domestic cats and dogs, of course, should be kept under control to prevent depredation of bobwhite and many other species.

Osprey (*Pandion haliaetus)*

Ospreys colonize a broad array of habitats and are one of the best studied birds of prey in North America (Poole et al. 2002).

Occurrence in the Lower Hudson PRISM

Osprey was confirmed to breed in Westchester and Rockland counties (McGowan & Corwin 2008). There are a very few old records of breeding in Dutchess County (e.g., Tivoli South Bay on the Hudson River ca. 1958; Maggie Bowman, personal communication). The osprey has recovered substantially from the mid-1900s crash, and we may expect more nesting in the LH PRISM region.

Breeding Habitat

Breeding habitat varies widely, but all sites must provide an adequate supply of fish within a reasonable hunting distance and contain nest sites that are free from predators (Poole et al. 2002). Trees, large rocks over water, predator-free islands, various kinds of towers, and especially artificial nest platforms, are the sites of nests (Poole et al. 2002).

Diet

Osprey are the only raptors in North America that almost exclusively feed on live fish with a wide variety of species taken. Saltwater feeders concentrated on fewer species than those found in freshwater habitats (Poole et al. 2002). Osprey were found foraging along rivers, estuaries, marshes, reservoirs and natural ponds and lakes and preferred foraging in shallow water near shore where they found benthic-feeding fish easiest to catch (Poole et al. 2002).

Predators

There are few predators on ospreys. Bald eagles and great horned owls kill some adults and young; raccoons are a suspected nest predator (Poole et al. 2002).

Invasive Species Interactions

Foraging was less efficient and successful in water with dense emergent and submergent vegetation (Postupalsky & Stackpole 1974, reviewed Poole et al. 2002). This observation suggests that dense beds of nonnative plants might be adverse (native aquatic plants can also form dense beds). Connor (1978) reported the rescue of a live osprey tangled in water-chestnut (*Trapa natans*), presumably while diving for a fish, in Tivoli South Bay, Dutchess County.

Spring migrant ospreys at Tivoli Bays on the Hudson River in the 1970s caught bright-colored wild goldfish (*Carassius auratus*; nonnative) which presumably were conspicuous in turbid waters, as well as native alewife herring (*Alosa pseudoharengus*; Erik Kiviat, personal observations). Since then the Hudson River goldfish population has crashed.
It is possible that nonnative trees provide potential nest substrate different in quality from that of native trees, or that invasive lianas alter potential nest substrate.

Management Considerations

No recommendations.

Peregrine Falcon (*Falco peregrinus)*

The peregrine falcon is one of the most widely distributed, warm-blooded, terrestrial vertebrates and long-distance migratory species in North America (White et al. 2002).

Occurrence in the Lower Hudson PRISM

Peregrine falcons were confirmed to breed in Manhattan, Kings (Bronx), Westchester, Dutchess, Rockland, Orange and Ulster counties (McGowan & Corwin 2008).

Breeding Habitat

Historically peregrines nested almost exclusively on cliffs, but now most LH PRISM peregrines use structures such as large bridges and large buildings (White et al. 2002). Peregrines in the Northeast do not nest on the ground, as some do in the Arctic (White et al. 2002).

Diet

The peregrine diet includes hundreds of species of birds, some bats, and a few rodents (White et al. 2002).

Predators

Larger raptors prey on adult, juvenile, and nestling peregrines; great horned owl is one of the most serious predators (White et al. 2002). Peregrines nesting on buildings and bridges escape some predators.

Invasive Species Interactions

Two-thirds of the prey of peregrines at a Manhattan nest were rock pigeons (*Columba livia*), and this nonnative species (formerly “rock dove”) was previously reported to constitute a large portion of the diet of urban peregrines (Nadareski & Meng 1991). Rock pigeons contain fairly low levels of environmental contaminants (Nadareski & Meng 1991). Thus the rock pigeon appears to be a beneficial IS in this context.

No nonnative predators have been reported in the northeastern US. We are not aware of other interactions with IS.

Management Considerations

No recommendations concerning management of IS.

Erection of nest boxes, human disturbance to nesting birds, flooding of nests (Nancy Slowik, personal observation), and regulated removal of birds for falconry are all management issues.

Prothonotary Warbler (*Protonotaria citrea)*

This SGCN warbler inhabits wet forests throughout its range and has the distinction of being the only eastern wood warbler that nests in tree cavities (Petit 1999).

Occurrence in the Lower Hudson PRISM Region

Prothonotary warbler was confirmed to breed in Orange County (McGowan & Corwin 2008). It is near its northern range limit and quite rare in New York State.

Breeding Habitat

Prothonotary warbler habitat includes surface water in or near forest with suitable nest cavities (Petit 1999). In breeding areas, primarily in the southeastern United States, it is a bird of bottomland hardwood forests and other forested wetlands. It often uses holes excavated by downy woodpeckers (*Picoides pubescens*), as well as a variety of other cavities (Petit 1999). Other important habitat features include low elevation, flat terrain, and shaded forest habitats with sparse understorey (Petit 1999).

Diet

The prothonotary warbler is primarily insectivorous throughout the annual cycle. Prothonotaries eat butterflies and moths (Lepidoptera), flies (Diptera), beetles (Coleoptera), mayflies (Ephemeroptera), and spiders (Araneae), but also take mollusks (Mollusca) and isopods (Isopoda). In the nonbreeding season the prothonotary can be more opportunistic, feeding on some seeds, fruit, and even nectar in addition to insects and spiders (Petit 1999).

Predators

Many animals have been reported to prey on prothonotary warblers (Petit 1999). Predators on adults and recently fledged young include accipiters, southern flying squirrel (*Glaucomys volans*), blue jay, and eastern rat snake (*Pantherophis alleghaniensis* [black rate snake, *Elaphe obsoleta*]). Eggs and nestlings are taken by snakes, house wren, mice (*Peromyscus*), red squirrel, southern flying squirrel, and raccoon. Nests over water are less susceptible to predation (Petit 1999).

Invasive Species Interactions

Invasive forest insects such as emerald ash borer (EAB; *Agrilus planipennis)* have the potential to destroy habitats of the prothonotary warbler. While initially creating more cavities for nesting, ultimately EAB would open the tree canopy and damage habitat (COSEWIC 2007). Asian long-horned beetle (*Anoplophora glabripennis)* has an affinity for red maple and silver maple, the dominant trees found in some prothonotary warbler swamp habitats (COSEWIC 2007). Two invasive plants, common reed *(Phragmites)* and European alder (*Alnus glutinosa)* can fill in the open pools of water and render the habitat unsuitable for prothonotary warbler (COSEWIC 2007).

It is possible that replacement of native trees by nonnative trees (e.g., tree-of-heaven (*Ailanthus altissima*), which sometimes grows in flood-prone soils (Kiviat 2004), could be adverse to prothonotaries.

We did not find reports, but consider it possible that house sparrows or European starlings compete with prothonotaries for nest cavities as is the case with many other cavity-nesting birds.

Management Considerations

The protection of existing lowland, wet, or flooded forests from development, logging, hydrological alterations, and other adverse changes is crucial for this and many other swamp species. Swamps or forests where prothonotary warbler occurs during the breeding season should be monitored for common reed and European alder, on an EDRR basis if possible. Forest insects potentially causing mortality of dominant trees are also a concern.

Red-headed Woodpecker (*Melanerpes erythrocephalus)*

This species is known for its erratic occurrence, undergoing periods of abundance, then appearing to be on the verge of extinction (Smith et al. 2000).

Occurrence in Lower Hudson PRISM

Red-headed woodpecker was confirmed breeding in Putnam, Dutchess, Orange and Ulster counties (McGowan & Corwin 2008).

Breeding Habitat

Found in deciduous woodlands, especially with beech or oak (Reller 1972, reviewed Smith et al. 2000), lowland and upland habitats, river bottoms, open woods, groves of dead and dying trees, orchards, parks, open agricultural country, upland meadows, pastures, savanna-like grasslands with scattered trees, golf courses, and forest edges or roadsides (Bull 1974; DeGraff et al. 1980). Prefers drier woodlands and areas that have tall trees of large diameter (Bond 1957; reviewed Smith et al. 2000). Occasionally this species is seen in nontidal or tidal swamps (Erik Kiviat, personal observations), but not known if it breeds there.

Diet

Considered the most omnivorous North American woodpecker, red-headed woodpeckers consume a wide variety of foods including seeds, nuts, crops such as corn, berries, cultivated fruits; and insects, bird eggs, nestlings, occasionally adult birds and mice (Smith et al. 2000). They capture insects on warm days and are considered expert flycatchers among woodpeckers (Smith et al. 2000). Seasonal movements are influenced by the availability of nut crops and possibly large-scale variations in abundance of acorns (Smith et al. 2000).

Predators

Adults taken by Cooper's hawk (*Accipiter cooperii*) and other birds of prey; snakes, raccoon, and flying squirrels prey on nestlings or eggs (Smith et al. 2000).

Invasive Species Interactions

Competition for nesting sites with European starlings (*Sturnus vulgaris*) was widely reported as causing the decline of red-headed woodpecker populations, but recent investigations suggest otherwise (Smith et al. 2000). The nonnative European starling is often said to compete with many cavity-nesting native birds (Koenig 2003). Evidence from breeding bird surveys and Christmas Bird Counts proved this not to be true for most species including the red-headed woodpecker and native nesting birds held their own against the starling invasion (Koenig 2003). Starlings sometimes usurp cavities from red-headed woodpeckers but it is difficult to discern effects on woodpecker populations (Smith et al. 2000).

Red-headed woodpeckers are declining in urban areas due to removal of dead trees and branches (Pulich 1988, reviewed in Smith et al. 2000), and in rural areas due to loss of nesting habitat to firewood cutting, clearcutting, agricultural development, and channelizing rivers (Ehrlich et al. 1992, reviewed in Smith et al. 2000). Reforestation, loss of orchards, loss of American chestnut (*Castanea dentata*), decline of oak-savanna habitat, fire suppression during the 1900s, and a switch to "cleaner" farming practices (e.g., removal of hedgerows, odd corners of fields, larger monoculture fields) probably have all contributed to the decline (Smith et al. 2000).

The potential effects on red-headed woodpeckers of nonnative tree replacement of native trees, or of the depredations on native trees by introduced insects such as emerald ash borer and Asian long-horned beetle, are unknown.

Management Considerations

Management programs that create and maintain dead snags should benefit red-headed woodpeckers (Smith et al. 2000). It is recommended that snags be retained in groups for roosting and foraging (Conner 1976, reviewed in Smith et al. 2000). Managing woodland, savanna, or shrubland with prescribed fire was considered beneficial for threatened and endangered species that included red-headed woodpecker (Lamb et al. 2008).

Federal and state agencies are studying, and developing controls for, the more serious forest pest insects.

Ruffed Grouse (*Bonasa umbellus)*

Ruffed grouse has undergone a large scale decline, including the LH PRISM population, during the past three decades.

Occurrence in the Lower Hudson PRISM Region

This game bird was confirmed to breed in Westchester, Putnam, Dutchess, Rockland, Orange and Ulster counties (McGowan & Corwin 2008). Despite its wide distribution in our region, it is rare to see or hear grouse in areas where they were once resident and conspicuous (Erik Kiviat, personal observations).

Habitat

Ruffed grouse is widely distributed in many forest types of the northern US and southern Canada, and does best in "early-successional" aspen (*Populus* spp.) forests (Rusch et al. 2000). In the Northeast the species occurs in young mixed deciduous-coniferous forest (Bump et al. 1947). Dense understorey cover combined with a tree canopy is favorable, but dense shrubs and saplings devoid of overstorey apparently are not (Rusch & Keith 1971 as reviewed in Rusch et al. 2000). Too much forest canopy cover (> 60%) may be unfavorable (Rusch et al. 2000). Some grouse live in forests where aspens are rare and the shrub layer is sparse (Erik Kiviat, personal observation). In Pennsylvania, hemlock swamp forest is especially good habitat (NatureServe 2009). Patches of mature forest interspersed with patches of young forest are considered favorable (Rusch et al. 2000).

Nests are on the ground at the base of a tree, stump or boulder, or in brushpiles, under fallen trees, in hollow stumps, or among shrub stems (Rusch et al. 2000).

Diet

Leaves, buds, and fruits of deciduous forest plants constitute most of the diet (Rusch et al. 2000). Grouse feed primarily on herb leaves in spring; in summer acorns and berries including greenbrier (*Smilax*), grape (*Vitis*), viburnums (*Viburnum*), dogwoods (*Cornus*) and rose (*Rosa*); and aspen and willow (*Salix*) buds and twigs from late October through winter. Buds of quaking aspen (*Populus tremuloides)* are preferred to those of bigtooth aspen (*Populus grandidentata*; Rusch et al. 2000).

Predators

Many species of mammals, birds, and snakes prey on ruffed grouse eggs, chicks, juveniles, or adults (Rusch et al. 2000). In a New York study, 94% of deaths of adults and juveniles were due to predation (Bump et al. 1947).

Invasive Species Interactions

Habitats have undergone significant changes because of invasion of nonnative species, wildfires, land use development, and management practices that reduced the availability of food for grouse (Forbey et al. 2013). Loss of young forests is believed the most important factor in ruffed grouse decline (Rusch et al. 2000). Hemlock communities, which are an important component of the landscape for ruffed grouse, are threatened by hemlock woolly adelgid (*Adelges tsugae*) infestations. As tree mortality occurs, light availability increases due to the widening of canopy gaps and provides opportunities for the colonization of invasive plant species within the understorey (Orwig & Foster 1998). The general effects of hemlock death and resulting vegetation change on grouse in the LH PRISM region are unknown.

There was a population of ruffed grouse in Greenbrook Nature Sanctuary, Alpine, New Jersey, from 1946 until 1993 (unpublished breeding bird surveys). Drumming (the male advertisement display) occurred in an area of old hemlocks. Ruffed grouse disappeared with the decline of hemlocks from woolly adelgid infestation in the mid-1980s, although a causal relationship was not proven. With increased sunlight, mile-a-minute (*Persicaria perfoliata)* invaded an extensive portion of this area in 2003 (Nancy Slowik, personal observations 1989-2010).

Feral swine, which would likely prey on grouse nests, would be a concern, as would any other nonnative predator.

Aspens are vulnerable to mortality during outbreaks of the nonnative gypsy moth (Lovett et al. 2013), and are also attacked by a number of other native and nonnative insects and fungi (Fowells 1965; Canadian Forest Service 1999). Some of these pests may have affected aspens in our region or may do so in the future.

Management Considerations

The lack of forest habitat patches of variable development, degradation of existing habitat due to fire suppression, and changes to local hydrology have all been suggested to have caused the decline of ruffed grouse (Wiggins 2006). In the Midwest suppression of wildfires and reduced logging that formerly helped to regenerate aspen stands have been blamed for the ruffed grouse decline and biologists have advocated measures to increase aspen cover to enhance population viability of ruffed grouse (Wiggins 2006). Quaking aspen is a preferred beaver food, and although aspens resprout readily after cutting (Fowells 1965), it is possible that the great increases in beaver populations in our region during the past 3-4 decades may have contributed to degradation of ruffed grouse habitat.

Forest change is believed more important in ruffed grouse decline than hunting mortality (Rusch et al. 2000). Given the high levels of predation, however, we wonder if there have been increases in predator populations placing additional stress on grouse populations.
Aspen stands should be monitored for infestations by pests and pathogens.

Salt Marsh Sparrows

Two salt marsh sparrows designated as SGCN breed in the LH PRISM REGION: Both sparrows are restricted to the high salt marsh, a specialized area where few terrestrial species are resident or reproduce (Greenberg et al. 2006).

Common Name	**Scientific Name**
Saltmarsh sharp-tailed sparrow (=Saltmarsh sparrow)	*Ammodramus caudacutus*
Seaside sparrow	*Ammodramus maritimus*

Occurrence in the Lower Hudson PRISM Region

Saltmarsh sparrow was confirmed to breed in Westchester County and on the border of the Bronx. Seaside sparrow was found to breed only in Westchester County (McGowan & Corwin

2008). In the 1930s, both species were recorded in Piermont Marsh (Rockland County) during the breeding season by Joseph Hickey (personal communication and field notes).

Breeding Habitat

Saltmarsh sparrow and seaside sparrow are considered habitat specialists and both breed in the high salt marsh, the area above the mean high tide line (Kiviat & Johnson 2013). Saltmarsh sparrows are limited to breeding in the high tidal salt marsh where they nest in the upper reaches of cordgrass-dominated wet grasslands and in drier saltmeadow habitats (Greenlaw & Rising 1994). Seaside sparrow nests are found in expanses of medium-sized smooth cordgrass (*Spartina alterniflora*) with a mixture of salt meadow cordgrass *(Spartina patens*), saltgrass (*Distichlis spicata),* and black rush *(Juncus gerardii).* The nests are ideally located near creek edges or pools in which the birds can forage (Post & Greenlaw 2009).

Diet

Saltmarsh sparrow showed a preference for adult noctuid moths and larvae and pupae of tabanid flies, which were larger but less abundant than other arthropods (Post & Greenlaw 2009). Seaside sparrow fed on a limited variety of arthropods found in open mud flats or at the bases of plants. These included fly larvae, moth larvae and adults, spiders, short-horned grasshoppers and crickets. Seaside sparrow has a bill adapted to probing mud, but a common foraging behavior is walking and gleaning arthropods from plant stems and these foraging techniques are similar for saltmarsh sparrow (Post & Greenlaw 2009).

Invasive Species Interactions

The breeding habitat of both sparrows is threatened most by habitat loss from coastal development and degradation due to pollution (Kiviat & Johnson 2013). Coastal marshes are also threatened by invasive species, changes in sea level and salinity and fragmentation at the landscape level that is likely to increase the impact of IS, predators, competitors and diseases. Tidal marshes are particularly prone to common reed (*Phragmites*) which can have a major impact on the structure and function of marsh ecosystems (Greenberg et al. 2006). At the upper edge of the marshes along the Atlantic coast of North America, the nonnative Old World genotype of common reed (*Phragmites australis*) is spreading into areas once dominated by black rush, cordgrasses (*Spartina* spp.), and marsh-elder (*Iva frutescens*). The effect of such invasions is poorly documented, but recent research has shown that common reed invasion favors certain generalist species over tidal marsh specialists (Benoit & Askins 1999). The invasive common reed supports a local increase in marsh wren populations, which may further affect endemic sparrows because marsh wrens often puncture the eggs of other songbirds. At low densities, common reed may create habitat heterogeneity, but when it spreads to form extensive, highly-dominant stands, resources for some marsh nesting species disappear (Greenberg et al. 2006; Kiviat 2013). Dominance of the high salt marsh by the nonnative common reed was considered a threat to both species on the Connecticut coast (Benoit & Askins 1999), although in Rhode Island DiQuinzio et al. (2002) found saltmarsh sparrow nesting in short common reed. Under favorable conditions, common reed can densely colonize the high salt marsh, changing a short graminoid habitat with several vascular plants to a tall graminoid habitat that may be strongly dominated by a single plant (Erik Kiviat, personal communication).

Management Considerations

Common reed stands in high salt marshes are often managed by application of herbicide, especially glyphosate or a formulation of glyphosate. This can cause adverse nontarget impacts to plants other than common reed, and is potentially toxic to animals as well (Kiviat 2009). In some situations it is possible to increase salinity above levels favorable to common reed; this can be done by diverting fresh water flowing into a high salt marsh, or opening a berm that restricts flushing of the marsh by saline tidal waters. It may be possible to use prescribed livestock grazing (Silliman et al. 2014) or frequent mowing in some situations. Any management of tidal marshes requires federal and state permits. Because seaside sparrow, saltmarsh sparrow, several vascular plant species, and certain other organisms are restricted to the high salt marsh habitat in the northeastern U.S., management of this habitat for native biodiversity and rare species is important but it is also a challenge with currently available methods.

Whip-Poor-Will (*Antrostomus vociferus [Caprimulgus vociferus]*)

Habitat

Whip-poor-will was found in all the LH PRISM counties except Westchester, Bronx, and Manhattan during the Breeding Bird Atlas (McGowan & Corwin 2008) but breeding was not confirmed, presumably because the nests of this species are notoriously cryptic (Cink 2002). Dry deciduous or mixed deciduous-coniferous woodland with sparse understorey and open canopy is the usual habitat in the Northeast (Cink 2002). Protection from episodic vegetation fires, and fertilization by atmospheric nitrogen deposition, might be reducing the extent of suitable habitat. Wilson and Watts (2008) found whip-poor-wills most common where regenerating forests and mature forests adjoined.

Food

Strictly insects, mostly night-flying taxa taken on the wing (Cink 2002). The single quantitative data set included moths 57% and scarabaeid beetles 32% by volume (Cink 2002). Some hypothesize the whip-poor-will specializes in giant silk moths (Saturniidae), the decline of which may have contributed to the whip-poor-will decline (Cink 2002).

Predators

Ground nests vulnerable to predation; a Kansas study found striped skunk, raccoon, coyote, red fox, and snakes depredating nests. Cats and dogs also implicated (Cink 2002 and references cited therein).

Invasive Species Threats

Undoubtedly nonnative insects are among prey species, but we have seen no evidence that these may be harmful. It is possible that the toxic, nonnative brown-tailed moth (*Euproctis chrysorrhoea*) is a threat.

Nonnative plants that can thrive in dry rocky woodland, such as angelica tree (*Aralia elata*) and possibly Japanese barberry (*Berberis thunbergii*), could fill in the understorey and degrade whip-poor-will habitat.

Management of Threats

The whip-poor-will song is loud and distinctive, thus this is a good species for a citizen science survey effort. Dry woodland habitats where whip-poor-wills have been heard, or are likely to live, should be monitored for invasive shrubs and understorey trees on an EDRR basis. Control, if needed, should be accomplished by non-chemical means or by cut-stem herbicide treatments which are less risky for other plants.

Piedmont groundwater amphipod (*Stygobromus tenuis tenuis*)

David Strayer collaborated in preparing this account.

Stygobromus is a speciose genus of mostly groundwater or cave-associated amphipod crustaceans, many of which have been described very recently. Important references on the genus are Holsinger (1978, 1986). The literature on these organisms is essentially all systematic and zoogeographic in nature (e.g., D. Smith 1985), and virtually nothing is known about relationships with other organisms. Groundwater organisms in general are diverse and ecological study is well deserved.

Habitat

The Piedmont groundwater amphipod lives in subterranean waters in shallow wells, seeps, springs, springhouses, caverns, and other geological features, probably mostly in carbonate (limestone, dolostone, marble) terrains. It is sometimes found at the surface in springs and seeps. In our region there are many old “spring houses” (small shelters covering springs and sometimes small excavated spring pools formerly used for water supply) that might support this species. An extensive karstic area between Rosendale and Kingston (Ulster County), which has many abandoned dolostone mines, caves, crevices, and springs, would be a good place to look for this species, as would the weak marble bedrock of the Harlem Valley in eastern Dutchess and Putnam counties. Two other species of this genus, *Stygobromus allegheniensis* and *Stygobromus* cf. *borealis*, have been collected in our region where they appear to be rare (Strayer 1988 and personal communication), but they are not currently listed as SGCN.

Food

Not reported?

Predators

Not reported?

Invasive Species Threats

None known. The Piedmont groundwater amphipod is presumably sensitive to changes in temperature, chemistry, and organic matter content of groundwaters, and water pollution is probably an important threat. It is possible that nonnative surface-living predators or competitors interact with this species in springs.

Five Fishes (Estuarine Associates of SAV)

Five SGCN fishes are known as "estuarine associates of SAV." (SAV refers to "submerged aquatic vegetation." This guild includes the native plants wild-celery [*Vallisneria americana*], clasping pondweed [*Potamogeton perfoliatus*], sago pondweed [*Stuckenia pectinata {Potamogeton pectinatus}]*, eelgrass [*Zostera marina]*, and widgeon-grass [*Ruppia maritima*], and the nonnative plant Eurasian watermilfoil [*Myriophyllum spicatum*]. Inasmuch as SAV often trails at the surface at low tide or even grows in the intertidal zone on mudflats, we prefer the term "submergent plants" which is parallel to the commonly used "emergent plants.") For this account, we call these five fishes EAS (estuarine associates of SAV).

With the exception of the fourspine stickleback which ranges from marine waters into tidal fresh waters, and the ninespine stickleback which is double-listed as a freshwater fish SGCN, EAS are essentially marine species, hence are uncommon to rare in the LH PRISM region (Robert E. Schmidt, personal communication). In other words, their rarity may be a function of habitat rather than conservation issues.

Common Name	**Scientific Name**
Common pipefish	*Syngnathus fuscus*
Fourspine stickleback	*Apeltes quadracus* (1)
Lined seahorse	*Hippocampus erectus*
North American ninespine stickleback	*Pungitius pungitius occidentalis*
Threespine stickleback	*Gasterosteus aculeatus*

(1) Sometimes misspelled "quadricus."

Habitats

As the SGCN classification implies, EAS are closely associated with dense submergent vegetation (and the rooted, floating-leaved, water-chestnut, *Trapa natans*, in the case of fourspine stickleback). This vegetation mostly occurs in shallow (less than 2 m deep at low tide), low-energy, waters on silty or sandy sediments in bays, coves, stream mouths, and other sheltered environments. Salinity varies from polyhaline (essentially marine) to freshwater tidal, although three of the five species occur exclusively or almost so in brackish (mesohaline to polyhaline) waters. Threespine stickleback may also occur in freshwater (Thomson et al. 1971) but it is unclear whether it does in the LH PRISM region. Ninespine stickleback spawns in freshwater (C. Smith 1985).

Food

Fourspine stickleback eats plankton, especially microcrustacea (Thomson et al. 1971; C. Smith 1985). Threespine stickleback eats small invertebrates, fish eggs, and fry (Thomson et al. 1971). Common pipefish eats crustacea, fish eggs, and fry (Thomson et al. 1971). Ninespine stickleback eats immature insects, crustaceans, and its own early life stages (C. Smith 1985).

Predators

Predators are presumably mostly larger fishes. Other predatory vertebrates (e.g., turtles, birds) and probably large estuarine invertebrates such as crabs must also eat EAS but how much is unknown.

Invasive Species Threats

Given the association of EAS with aquatic vegetation, we might expect nonnative aquatic weeds to affect this relationship. Water-chestnut, which has extensively occupied low-energy freshwater tidal shallows in the Hudson River, apparently provides good habitat for fourspine stickleback (e.g., in Tivoli South Bay [Dutchess County]) (Robert E. Schmidt, personal communication; E. Kiviat, personal observations). Water-chestnut tolerates only a little salinity and forms dense beds only as far down the Hudson River as South Cove at Constitution Island Marsh, thus it is not a factor for the principal habitats of the other four EAS. The potential influence of Eurasian watermilfoil, which is or was a prominent submergent species as far downriver as Bowline Pond (Rockland County; Menzie 1980), has not been studied.

Kimball & Able (2007), in a study of fishes differentially present in common reed (*Phragmites*) vs. smooth cordgrass (*Spartina alterniflora*) tidal marsh in New Jersey, found that common pipefish was present in small numbers in *Spartina* and absent from common reed. It is unclear if this finding is generalizable to the Hudson River where smooth cordgrass is very limited in distribution. C. Smith (1985) described pipefish as fairly common in the Hudson River from Indian Point southward, but did not state if the species occurred in the tidal marshes. Pipefish was not taken in many samples collected by means of multiple gear types in Iona Island Marsh or Piermont Marsh and it might require a sandy bottom (Rockland County; David Yozzo, personal communication).

Haught and von Hipel (2011) believed that introduced northern pike (*Esox lucius*) caused declines or extirpations of native threespine stickleback in certain Alaska lakes. It is possible that nonnative piscivorous fishes (e.g., northern snakehead [*Channa argus*], if it becomes established in the Hudson River) would prey on EAS, but given the dense vegetation habitat typical of EAS we are reluctant to consider this a threat. It is unlikely that invasive invertebrates replacing native prey species would threaten EAS given the broad diet niches of these fishes.

The weatherfish (*Misgurnus anguillicaudatus*), established in a Hudson River tidal marsh and tributary at Staatsburg in Dutchess County (Schmidt & Schmidt 2014), could compete for small invertebrate food with EAS.

Management Considerations

Until there is more information we are reluctant to make recommendations. Moreover, management of estuarine habitats is mostly controlled by federal and state agencies in New York.

Mummichog (*Fundulus heteroclitus*)

The mummichog is a killifish in the family Fundulidae. It is evidently the most abundant fish in tidal marshes in the LH PRISM region, and one of the most abundant fishes in our estuaries overall. The mummichog is sufficiently abundant that it should not be a SGCN. We profile this species, however, because of an interesting interaction with an IS.

Habitat

The mummichog is typically a brackish tidal marsh species. It also thrives in freshwater tidal marshes in the Hudson River and is abundant in the marshes at least as far upriver as Tivoli North Bay at the extreme northern end of the LH PRISM region (and much farther upriver at Schodack Island; David Yozzo, personal communication). Mummichog populations also occur in a few nontidal habitats such as the nontidal Bronx River (Samaritan and Schmidt 1982), and Springfield Gardens Lake in Queens (just outside our region) where storm surges have evidently allowed estuarine nekton to colonize (David Yozzo, personal communication).

Young mummichogs remained in small pools in the intertidal zone at low tide but adults moved down into subtidal habitats (Kneib 1986). In Tivoli North Bay, mummichogs often follow the tideline (the margin of water advancing or receding across mudflats; Erik Kiviat, personal observation).

Food

Mummichogs in a North Carolina tidal marsh ate mostly small crustaceans and polychaetes as well as living plant material (Kneib & Stiven 1978). Mummichogs apparently feed both on benthos and organisms associated with the surface film (Erik Kiviat, personal observations).

Predators

Mummichogs in Hudson River tidal marshes are eaten by most fish-eating vertebrates. Although the behavior of skipping across the water surface when disturbed, and the predilection for very shallow water, probably help mummichogs escape predation by larger fishes, it may make them vulnerable to predation by birds. Birds eating mummichogs in Tivoli North Bay include mallard, greater yellowlegs, and least bittern (Kiviat, personal observations). Snapping turtles in Tivoli North Bay also eat mummichogs (Kiviat 1980), and other predators presumably include snakes and mammals. Kneib (1986) thought the blue crab to be the most important predator on adult mummichogs, along with many fishes and wading birds. Adult mummichogs and xanthid crabs were major predators on young mummichogs (Kneib 1986).

Invasive Species Interactions

There is now a number of studies indicating that fewer larval and small juvenile mummichogs are found in common reed (*Phragmites*) stands compared to smooth cordgrass (*Spartina alterniflora*) stands, and that common reed is adverse to immature mummichogs. Although the type of reed is not identified in the literature, in our we reasonably assume it to be nonnative (Old World) *Phragmites* because all reed samples analyzed from New York City and the Hudson Valley to date have been this form (Kristin Saltonstall, personal communication; Laura Meyerson, personal communication).

Although adult mummichogs are about equally abundant in tidal marshes dominated by reed compared to those dominated by cordgrass or cattail (*Typha*), and mummichogs spawn in reedbeds as well as the alternate habitats, several research teams have found lower abundances of larval and small juvenile mummichogs in reedbeds. These studies have been performed at several East Coast locations including Piermont Marsh (Hudson River) in our region (see Dibble et al. [2013] for references).

Weinstein et al. (2009) found biochemical indicators of better habitat quality for mummichog in a smooth cordgrass marsh compared to a common reed marsh. Hagan et al. (2003) found young-of-the-year mummichogs most abundant in restored (reed to cordgrass) marshes, moderately abundant in reference smooth cordgrass marshes, and least abundant in reed marshes. In addition to the probably higher habitat quality of cordgrass marshes for juvenile mummichogs, we think there might have been a disturbance effect explaining the greatest abundance in restored marshes. Dibble et al. (2013) conducted a meta-analysis of common reed effects on tidal marsh fauna and found greater effects on immature compared to adult fishes, as well as regional and taxon differences.

The mechanism by which *Phragmites* negatively affects mummichogs is not well understood. The microtopographic smoothing and loss of intertidal pools providing low tide habitat for immature mummichogs has often been cited (e.g., by Weinstein & Balletto [1999] who posed this hypothetically). Lower abundance of food (prey) for immature mummichogs is another hypothesis. Raichel et al. (2003) found support for both hypotheses in a study in the New Jersey Meadowlands. A third possible explanation as yet unpublished is heavy metal contamination inasmuch as reed takes up metals and retains them such that they go into reed detritus and soils (except for mercury), whereas smooth cordgrass takes up metals and excretes them via salt glands into the water column (Burke et al. 2000; Windham et al. 2003). This could account for higher levels of certain metals in the food of young mummichogs eating detritivorous invertebrates. However, Weis et al. (2002) found no difference in survival of invertebrates in the laboratory fed reed or cordgrass diets.

Despite the repeated findings of adverse impacts of common reed on the mummichog, it has not been shown that common reed abundance affects the mummichog population at a larger scale. This is still one of the most abundant fishes in the Hudson River estuary and presumably the estuaries of the Westchester County shore.

Management Considerations

There have been many projects that aimed to return tidal marshes from reed dominance to cordgrass or cattail dominance (depending on salinity). Except for a few small exceptions, these projects have sprayed glyphosate to kill reed, in some cases an upper layer of sediment was removed with much of the belowground reed biomass, and generally the alternate (native) marsh dominant was planted (spray-dredge-plant or SDP technique). In the case of diked or flow-restricted tidal marshes dominated by reed, there are many examples of successful restoration to smooth cordgrass by reopening marshes to saline tides.

SDP projects have generally reverted to reed dominance, or are in the process of doing so, unless there is frequent maintenance to kill resprouting or recolonizing reeds. In a few cases, it has been shown that restored cordgrass marshes are better than reed marshes for immature mummichogs or other fishes (e.g., Able et al. 2003; also see Dibble et al. 2013).

As far as we know, there has been no field investigation of glyphosate toxicity to nontarget organisms (potentially including mummichogs) in these projects. Nor is it understood whether reed spread is harming mummichog populations on a whole-estuary or regional scale, although this seems unlikely given the broad habitat affinities and high abundances of mummichogs in general fish sampling studies. We therefore do not recommend reed control for the sake of the mummichog unless there are data supporting a strong local (marsh-specific) rationale. Common reed provides many non-habitat services, and has many varied negative and positive habitat functions that should be taken into account in management decisions (Kiviat 2013).

Spotfin killifish (*Fundulus luciae*)

Habitat

Spotfin killifish is known from two sites in the LH PRISM region. Yozzo and Ottman (2003) found this species uncommon in the upper intertidal zone of Piermont Marsh (Hudson River in Rockland County), and also reported a historic record from estuarine habitat in Larchmont (Westchester County). They believed that, given the upper intertidal zone habitat, which is rarely sampled for fish, spotfin killifish might be more common than is known. C.L. Smith (1985) pointed out the similarity of spotfin killifish to the abundant mummichog, indicating that spotfin killifish might be overlooked. Byrne (1978) found spotfin killifish in upper intertidal zone habitats in Virginia marshes; however, Kneib (1987) found young in the upper intertidal zone and adults in subtidal creeks in Georgia.

Food

Byrne (1978), in Virginia smooth cordgrass marshes, found detritus, diatoms, ostracods, copepods, and dipterans in the stomachs of spotfin killifish.

Predators

Predators of spotfin killifish are presumed to be larger fish, crabs, and birds.

Invasive Species Threats

It is possible that common reed (*Phragmites*) is a threat to the spotfin killifish much as to the congeneric mummichog (see above). However, in a tidal marsh in southwestern Connecticut (near Westchester County), spotfin killifish was sampled almost exclusively in common reed rather than smooth cordgrass (*Spartina alterniflora*); this was probably due to hydrology and abiotic habitat rather than plant species *per se* (Osgood et al. 2003).

Management of Threats

No recommendations.

Brook Trout (*Salvelinus fontinalis*), Heritage Strains

Most brook trout populations in New York, whether they reproduce on their own or are supported by stocking, are of hatchery genotypes. “Heritage” brook trout are genetic strains that are truly native, i.e., they exist in the habitats where they evolved prior to European colonization. A single Heritage population was known from a stream in Harriman State Park (Orange County; John Homa, personal communication) but we do not know if this has been confirmed recently. There may be other populations that we are not aware of.

Habitats

Brook trout live in coolwater streams, often in lower-order reaches, and in cold lakes or ponds. Many habitats are small. The relatively low summer temperatures are maintained by groundwater discharge and shade from woody vegetation. Brook trout also require high dissolved oxygen levels (C.L. Smith 1985). Individual trout may be capable of dispersing downstream through the Hudson River and into other tributaries during cool months. Brook trout spawn in the fall in gravelly stream reaches, often near springs. Sediment deposition, removal of woody vegetation, and pollution are adverse to brook trout populations.

Food

Brook trout eat diverse aquatic and terrestrial macroinvertebrates as well as fishes, salamanders, and other vertebrates.

Predators

As is true of other stream fishes, brook trout are depredated by various fish-eating mammals, birds, reptiles, and fishes.

Invasive Species Interactions

In Michigan, Fausch & White (1981) found that brown trout (*Salmo trutta*) displaced brook trout from resting microhabitats and also preyed on juvenile brook trout. The brown trout is an introduced European species that is common in the LH PRISM region; it is not usually considered invasive due to its recreational value. Rose (1986) reported that early life stages of rainbow trout (*Salmo gairdneri*) and brook trout competed for food and space with unfavorable effects on brook trout. Larson & Moore (1985) believed rainbow trout were displacing brook trout from streams in the southern Appalachians following stresses caused by logging and overfishing. Rainbow trout also occurs as an introduced species in the LH PRISM region (C.L. Smith 1985) but it is unclear whether populations there are self-supporting.

There may be other IS that are competitors, predators, food, or habitat elements of the brook trout that we are not aware of.

Management Considerations

Stocking of nonnative fishes should be avoided in stream systems occupied by Heritage brook trout.

Non-venomous Snakes

Six non-venomous snakes on the SGCN list occur in our region:

Common name	Scientific name
Black rat snake (eastern rat snake)	*Pantherophis alleghaniensis* (*Elaphe obsoleta*)
Eastern hognose snake	*Heterodon platirhinos*
Eastern ribbon snake	*Thamnophis sauritus sauritus*
Northern black racer (eastern racer)	*Coluber constrictor*
Smooth green snake	*Opheodrys vernalis*
Worm snake	*Carphophis amoenus*

Habitats (from Gibbs et al. 2007)

Black rat snake occurs in woodlands, field edges, around rock outcrops, and in rural buildings. This species is rather arboreal. It overwinters in rocky habitats, as well as basements and other locations safe from freezing.

Eastern hognose snake is typically associated with well-drained, sand or sandy loam soils, in woodlands, old fields, and beaches.

Eastern ribbon snake frequents moist or wet habitats close to water edges or wetlands. (In Dutchess County, usually in calcareous woodlands, at fens, edges of circumneutral bog lakes, or other moist-to-wet calcareous habitats; Erik Kiviat, personal observations).

Northern black racer frequents open woodland, shrubland, grassland, dunes, and marsh edges. It often overwinters in rocky slopes.

Smooth green snake is found in grassland, shrubland, woodland, and wetland.

Worm snake lives in moist or dry forest, often near streams.

Diets (from Gibbs et al. 2007)

Black rat snake: small mammals, birds (especially nestlings and eggs), and herpetofauna.

Eastern hognose snake: principally toads (*Bufo*), also other amphibians, snakes, reptile eggs, and invertebrates.

Eastern ribbon snake: principally frogs, and also salamanders, fish, leeches, arthropods.

Northern black racer: wide variety of vertebrates and invertebrates.

Smooth green snake: diverse arthropods, but mostly soft-bodied insects such as caterpillars.

Worm snake: principally earthworms and soft-bodied insects.

Predators

Predators of snakes include farm animals (swine, turkeys, chickens, ducks, geese), many wild mammals, herons and other aquatic birds, owls, hawks, eagles, certain songbirds, turtles, larger snakes, large frogs, predaceous fishes, and a few large spiders (Wright & Wright 1957).

Invasive Species Interactions

Snakes that eat earthworms (common garter snake [not an SGCN], worm snake) presumably benefit from the abundance of these mostly nonnative (in our region) invertebrates.

Feral swine would definitely be a threat to snakes (see, e.g., Seward et al. 2004; Jolley et al. 2010). House cats kill a few small snakes and could prey on worm snakes, green snakes, and the young of the other SGCN species.

Nonnative vines and other nonnative plants in some cases may overgrow basking habitats or other habitats important to snakes, as might native plants.

Management Considerations

The DEC is mounting a feral swine control program statewide.

If snakes are a target of conservation efforts, a mixture of wooded, shrubby, and open (grassy or sparsely vegetated sandy) habitats would generally be favorable.

Northern Copperhead (*Agkistrodon contortrix mokasen*)

Habitat

At their northern range margin, copperheads occur discontinuously in the rugged, rocky, extensively forested areas of the Taconic Mountains, Hudson Highlands, Northern Shawangunk Mountains, and some other portions of our region. Copperheads also occur in sandy or rocky lowlands, notably in the Town of Hyde Park, and possibly the towns of Rhinebeck and Red Hook (all Dutchess County). There is a historic sight record from the vicinity of the Rhinebeck-Clinton town line (A. Scott Warthin, personal communication). Undoubtedly there are other such areas in the LH PRISM region, but within our region we expect copperheads to be progressively less common southward because of increasing urbanization.

Copperheads may be found in woodlands, fields, and wetlands during the active season (Gibbs et al. 2007). Tennant (2003) reported occurrence in debris-strewn urban lots; Wright and Wright (1957) also mentioned quarries as habitat and that copperheads may persist in developed areas. Forest leaf litter, in which copperheads hide, is an important habitat component (Gibbs et al. 2007).

Copperheads may share winter dens with the timber rattlesnake (see below), or may den in talus slopes supporting open canopy woodland with a good sun exposure. In Connecticut, copperheads den near wetlands, streams, and lakes (Petersen & Fritsch 1986). Copperheads in lowlands of Dutchess County might den as was found in a natural enclosure in Tennessee: in rodent burrows or runways beneath 60-90 cm of leaf litter (Sanders & Jacob 1981).

Food

Small mammals, birds, small herpetofauna, and insects constitute the copperhead diet (Petersen & Fritsch 1986; Hulse et al. 2001, Gibbs et al. 2007).

Predators

Little information. Copperheads are occasionally eaten by other snakes, and probably birds and mammals (Klemens 1993).

Invasive Species Interactions

In two state properties in Indiana, radio-tracked copperheads avoided nonnative shrubs, probably because they limited thermoregulation (Carter 2012). Presumably dense stands of nonnatives prevented solar heat from reaching the ground layer. Removal of vegetation from experimental plots attracted copperhead activity (Carter et al. 2014).

Undoubtedly copperheads eat some nonnative prey such as house mouse (*Mus musculus*), Norway rat (*Rattus norvegicus*), and nonnative insects.

As for many other terrestrial SGCN, feral swine might prey on neonates or juvenile copperheads.

Management Considerations

In known copperhead areas, creating openings in any dense stands of nonnative shrubs (or other shrubs or vines) in denning habitats or foraging habitats might be favorable to the snakes. However, Carter (2012) found radio-tracked copperheads that had been killed or injured as a result of vegetation management. Such management should therefore be conducted during the overwintering season when the snakes are deep below litter or rocks.

Timber Rattlesnake (*Crotalus horridus*)

This species is listed as Threatened in New York.

Habitat

Timber rattlesnakes most often frequent deciduous forests in rugged areas, and also use other types of forests, fields, and wetland edges (Gibbs et al. 2007). The most critical feature of the rattlesnake environment is the winter den, commonly on a steep rocky slope with aspect from eastern through southern to western (Erik Kiviat, personal observations). Den entrances may be inconspicuous, but the nearby "basking rocks" are usually prominent, unvegetated or sparsely vegetated, and exposed to strong sun. Bedrock and rock debris around dens in the LH PRISM region may be "quartz" (probably quartzite) or "limestone" (marble?; Petersen 1970), conglomerate, and probably schist, gneiss, and granite. Gravid females remain around sunny, rocky habitats, whereas males and nongravid females may range much more widely.

Rattlesnakes in our region occur in the Northern Shawangunk Mountains (Ulster County), Hudson Highlands (e.g., southwestern Dutchess County, Putnam County, Orange County, Rockland County), Taconic Mountains (eastern Dutchess), and a few other areas (Gibbs et al.

2007, Lyons-Swift & Howard 2010; Kiviat, personal observations). There are older records from northern Westchester County (Lyons-Swift & Howard 2010).

Food

Timber rattlesnakes eat principally warm-blooded prey, and specialize on rodents; herpetofauna are also taken (Petersen 1970; Gibbs et al. 2007).

Predators

Adults have few predators; other snakes, birds, and mammals prey on young rattlesnakes (Gibbs et al. 2007).

Invasive Species Threats

No threats have been specifically reported. Feral swine would probably consume young rattlesnakes.

We are concerned about the potential for certain nonnative plants to overgrow rattlesnake basking rocks. Although these habitats, which have little soil and are fire prone, xeric, infertile, and weather-beaten, are inhospitable to many nonnative weeds, angelica tree (*Aralia elata*) can do well in such areas, and certain vines could probably creep out from deeper soil around the edges. Japanese knotweed (*Polygonum cuspidatum* and hybrids) can grow from small crevices in ledges, albeit stunted (e.g., on Laurel Hill in the Meadowlands), and could contribute to weed problems. Nonetheless, we have not seen such invasions.

It may be relevant that Carter (2012), in Indiana, found northern copperheads (*Agkistrodon contortrix*) in dry woods of a state park avoiding nonnative plants. It was hypothesized that exotic shrubs, in particular, were adverse for thermoregulation.

Gypsy moth (*Lymantria dispar*) reduces acorn production, rodent populations, and timber rattlesnake reproduction (McGowan & Martin 2007)

Management Considerations

The DEC is mounting a feral swine control program.

Basking rocks at known rattlesnake dens should be monitored for overgrowth by nonnative (and native) plants. Increasing annual precipitation in our region, fire protection, and atmospheric deposition of nitrogen all potentially contribute to greater development of vegetation biomass on rocky crest habitats (Kiviat and Stevens 2001) including basking rocks.

Common Five-lined Skink (*Plestiodon [Eumeces] fasciatus*) and Eastern Fence Lizard (*Sceloporus undulatus*)

These are the only two native lizards in the region (the nonnative Italian wall lizard occurs locally in New York City). Fence lizard and skink are both southern species and inhabit sun-exposed rocky slopes and summits with warm microclimates and open vegetation. It is possible that climate warming will allow these species to expand their ranges in New York.

Habitat

The fence lizard occurs locally on hills in the Hudson Highlands close to the eastern shore of the Hudson River; these populations are disjunct from the main range of the species farther south. There is an isolated record from northeastern Westchester County (Gibbs et al. 2007). Little seems to be known of the species in New York where it is seen associated with sunny, sparsely-vegetated, west or south-facing rocks.

In southern New Jersey, female fence lizards were observed to lay their eggs in the soil in locations that were warmer than those where the females typically spent the rest of their time, and some nests were distant from the non-nesting home range of the females (Angilletta et al. 2009). Fence lizards in New York used rockpiles, tree cavities, and bark voids for refuge during the active season, and overwintered in burrows excavated by other animals, rotting stumps, and rock crevices (Gibbs et al. 2007).

The skink is more widely distributed in our region but still rather local. It occurs mainly in the Hudson Highlands and the Shawangunk Mountains; there is a possibly disjunct population in the Town of Dover (Dutchess County) on both sides of the Harlem Valley (Clyde Nichols, personal communication). Skinks are found in habitats similar to those of the fence lizard but not as restricted in geographic distribution or habitat characteristics. Gibbs et al. (2007) reported talus slopes with deciduous woods as the typical habitat for five-lined skink in New York.

Food

Both lizards are generalist feeders and eat diverse invertebrates. Five-lined skinks may also eat shrews and smaller skinks (Gibbs et al. 2007). Fence lizards eat arthropods (Gibbs et al. 2007).

Predators

Predators are not well known and presumably include many species of mammals, birds, and snakes, as well as potentially some of the larger spiders.

Invasive Species Interactions

Bateman et al. (2008), in a vegetation management experiment in a riparian area of New Mexico invaded by two nonnative trees, found that the prairie lizard (closely related to eastern fence lizard) was negatively associated with "surface litter, debris heaps, and thickets" of the nonnative plants Russian-olive (*Elaeagnus angustifolius*) and salt-cedar (*Tamarix*). Bateman and Ostoja

(2012), in salt-cedar invaded riparian areas of Arizona, found the desert spiny lizard (*Sceloporus magister*, also related to our fence lizard) associated with native trees and woody debris, perhaps because the larger native trees provided more foraging habitat on standing stems than the smaller salt-cedars. It is unclear how these studies, which were done in geographic areas and habitats very different from ours, pertain to interactions between our native lizards and nonnative plants. Nonetheless, since our lizards apparently require sunny, sparsely vegetated, rocky habitats, invasion of those habitats by nonnative shade-producing plants could degrade habitat. We would be concerned if vines such as mile-a-minute, that have the potential to spread rapidly and overgrow other surfaces, colonized fence lizard or skink habitats.

Jolley et al. (2010) found that feral swine in Texas preyed on lizards and other herpetofauna. However, the dry, rocky nature of much lizard habitat in our region, especially on talus, would be inhospitable to feral swine should swine become established here.

Arnaud et al. (1993) studied feral cat predation on an unrelated lizard on a Mexican island. Feral and free-ranging cats are fairly common in the LH PRISM region but because most areas supporting fence lizards or skinks are distant from houses and barns, we do not expect cat predation on New York lizards to be a significant problem.

The Italian wall lizard (*Podarcis sicula*) is established in the Bronx, and outside the LH PRISM region in Queens, Brooklyn, Nassau County, Suffolk County, and Greenwich, Connecticut; (Gibbs et al. 2007; Donihue et al. 2014). Gibbs et al. speculated that this so-far urban and suburban species could colonize northward up the Hudson Valley and compete with native lizards.

Management Considerations

All habitats of the eastern fence lizard, and habitats supporting high quality occurrences of five-lined skink, should be monitored for activity of invasive plants and invasive predators. If necessary, IS plant management should be conducted on a local, EDRR, basis. The DEC is managing feral swine statewide.

Turtles

Several species of turtles are listed as SGCN in New York State (see below for details on individual species). All these turtles share some documented or potential interactions with IS.

All turtles are vulnerable, as eggs and small juveniles, and potentially as adults, to predation by feral swine (Hanson & Karstad 1959, Seward et al. 2004), and domestic dogs and cats (Hamilton et al. 2002). Small juveniles are potentially susceptible to predation by larger, predatory, nonnative fishes, including largemouth bass (*Micropterus salmoides*; Gibbons et al. 1981, Britson & Gutzke 1993) and snakehead (*Channa argus*). Eggs and small juveniles are potential prey of Norway rat (*Rattus norvegicus*; Draud et al. 2004) and probably black rat (*Rattus rattus*).

Several insects, including the true flies *Eumacronychia sternalis* and *Tripanurga importuna* (Sarcophagidae) and *Megaselia scalaris* (Phoridae), and the mole cricket *Scapteriscus* have been implicated in parasitoidism or predation on turtle eggs (Iverson & Perry 1994; Maros et al. 2003; Bolton et al. 2008; Holcomb & Carr 2011). It is unclear whether these insects, and other potential insect predators of turtle eggs, are native to New York, and whether they are a threat to turtles here.

The roots of various plants have also been implicated in “preying” on turtle eggs. These include nonnative plants (see Wood Turtle, below), and a native plant (see Diamondback Terrapin, below).

Common reed (*Phragmites australis*, Old World genotype) has been documented overgrowing turtle nesting habitats on Long Point, Ontario. This phenomenon could occur in our region.

The early life stages (eggs, hatchlings) of turtles are often considered ecologically “cheap” and commonly suffer high rates of predation, much of it from native mammals. Turtles are generally adapted to high rates of mortality in the egg and probably the hatchling stage, and low rates in the adult stage. However, there are models indicating that, for example, mortality of turtle eggs can be significant in population dynamics (e.g., Mitrus 2005, Goldman 2008).

Blanding’s Turtle (*Emydoidea blandingii*)

Blanding’s turtle is listed as Threatened in New York State, and is of conservation concern throughout its global range from Nebraska to Nova Scotia. Western Dutchess County supports the only documented population in the LH PRISM region.

Habitats

Several habitat types are used by Blanding’s turtle in an extensive landscape (Kiviat 1997). The core habitat is a deep-flooding shrubby swamp, permanently or seasonally flooded. Associated wetland habitats are intermittent woodland pool, springfed pond or lake, and other wetlands in which the turtles forage and thermoregulate. The females migrate to lay their eggs in sparsely vegetated, friable, sun-exposed, well-drained soil. Nesting areas may be 800 m or farther from core habitat, and it is unclear how hatchlings get to the core habitats (if they do).

Food

Blanding’s turtles eat macroinvertebrates, crayfish, amphibian larvae, and live or dead fish (Ernst & Lovich 2009). Prey is taken entirely or largely in the water.

Predators

Nests are often excavated and eggs eaten by several mammals, most commonly raccoon or striped skunk. Little is known about predation on hatchlings although they are presumed to be vulnerable to a variety of terrestrial and aquatic predators (Ernst & Lovich 2009). Larger juveniles are likely preyed on by raccoons and other predators able to crack the shell or gnaw off appendages. Subadults and adults (carapace length greater than approximately 175 mm) may be depredated by coyotes, dogs, or other large predators. Motor vehicles, farm and construction equipment, and mowing machinery are probably the greatest "predator" of adults (Erik Kiviat, personal observation).

Invasive Species Interactions

Common reed (*Phragmites australis*, Old World genotype) in core and associated habitats. Not documented. Hypothesized to attain high stem density and prevent Blanding's turtle movement or to create too much shade (old stems in early spring) (Kiviat, unpublished).

Purple loosestrife (*Lythrum salicaria*) in core and associated habitats. Hypothesized to replace, or fill spaces in, the buttonbush or other tall shrubs that dominate core habitat. In one study (Arlington High School, Dutchess County), purple loosestrife had neutral or positive associations with adult Blanding's turtles (Hartwig & Kiviat 2007). Possibly large ungrazed clumps of purple loosestrife that have spaces between them act as a shrub substitute; heavily insect-grazed (biocontrolled) clumps, which are short and bushy, might not provide microhabitat in core habitats.

Mile-a-minute vine (*Persicaria perfoliata*), which can densely overgrow woody vegetation, might extend from wetland edge across the tall shrub habitat and create too much shade. Currently this species has not been observed in Blanding's turtle habitat in our region although it occurs nearby. Nonnative shrubs (e.g., smooth buckthorn or multiflora rose) are not likely to compete with the highly flooding-tolerant buttonbush.

Nonnative herbaceous weeds can densely overgrow nesting habitat and render habitat unsuitable. At Arlington High School, crown vetch (*Securigera varia*), sweet-clover (*Melilotus officinalis*), and spotted knapweed (*Centaurea stoebe*) overgrow nesting habitat after a few years without disturbance (Dowling et al. 2010).

We know of no evidence or hypothesis that nonnative invertebrates are deleterious to Blanding's turtle. It seems reasonable that invertebrates such as nonnative earthworms, rusty crayfish (*Orconectes rusticus*), mystery snail (*Cipangopaludina*), or zebra mussel (*Dreissena polymorpha*) would either be eaten by Blanding's turtles or ignored. It is possible that zebra mussels would colonize Blanding's turtle shells but unknown whether mussel loads would be heavy enough to be harmful. It is not possible to say whether more important native prey species would decline. A dead hatchling Blanding's turtle was found that might have choked trying to consume an unidentified earthworm (Al Breisch, personal communication); however, this seems like an isolated incident and not a menace to Blanding's turtles.

If they become established in the Blanding's turtle range, feral swine could threaten Blanding's turtle by preying on various life stages or by altering habitats.

Management Considerations

Phragmites could potentially be controlled by cutting beneath the water, or by lowering water level, cutting, and raising the water level to drown the plant. If a *Phragmites* colony extends to upland, the upland portion of colony might be able to transfer enough oxygen to the flooded portion to offset effects of flooding of cut stems, and upland culms might need to be cut frequently to deplete the rhizomes. Early detection of *Phragmites* in core habitats will allow easier control, if necessary by cut-stem herbicide treatment. Inasmuch as toxicity of herbicides to any life stage of Blanding's turtle is unknown, spraying or other techniques of herbicide application are not appropriate in Blanding's turtle habitat (Piepgras et al. 1998).

Purple loosestrife may not need management. At Arlington High School, biocontrolled (golden loosestrife beetle, *Galerucella pusilla* or *Galerucella calmariensis*) purple loosestrife and ungrazed loosestrife coexist on a small scale; there are no obvious impacts on Blanding's turtle.

Overgrown nesting habitats can be managed by tilling or ripping the soil (see Dowling et al. 2010). Possibly reverse fertilization would reduce the speed with which dense vegetation develops.

Core wetland habitats should be monitored for early detection not only of *Phragmites*, but also mile-a-minute and other vines that could alter vegetation structure and interfere with insolation.

Bog turtle (*Glyptemys [Clemmys] muhlenbergii*)

The bog turtle is listed in New York State as Endangered and federally listed as Threatened. The LH PRISM region and neighboring areas are regarded as an important population center for this species even though near its northeastern range limit. In the LH PRISM region, bog turtles occur in Putnam, Dutchess, Ulster, and Orange counties, and formerly occurred in Westchester and Rockland counties.

The U.S. Fish and Wildlife Service and the DEC, with collaboration of many private organizations and other government agencies, have an inensive program of habitat management for bog turtle. Therefore this account will only briefly summarize issues.

Habitats

In our region, bog turtles live in fens and fen-like portions of wetlands (similar to habitats described by Kiviat et al. [1993, 2011]). These are groundwater (spring or seep) fed, calcium-rich, organic or mineral soil wetland habitats with low (less than 1 m tall and ideally less than 50 cm tall), open vegetation dominated by sedges (*Carex* spp.) and shrubby cinquefoil (*Dasiphora fruticosa*). During winter, bog turtles may "hibernate" in shrubby portions of wetlands. During hot summer weather, bog turtles often spend time in shadier or denser vegetation than is suitable in spring, including red maple swamp, and common reed (*Phragmites*) or purple loosestrife patches. However, adults and juveniles in springtime, and nests and hatchlings, require low, open vegetation.

Food

Macroinvertebrates appear to constitute most of the bog turtle diet. Bog turtles are often observed feeding on slugs (and probably snails). Most slugs in the LH PRISM region are nonnative species. Seeds are eaten in small numbers (Kathleen A. Schmidt, personal communication).

Predators

Nests are excavated and eggs eaten by several mammals, probably most commonly raccoon or striped skunk. Birds, fly larvae, shrews, and plant roots are potential egg predators as well. Little is known about predation on hatchlings although they are presumed to be vulnerable to a variety of predators. Larger juveniles and adults are likely preyed on by raccoons and other mammals able to crack the shell or gnaw off appendages. Motor vehicles, farm and construction equipment, and mowing machinery are probably the greatest “predator” of adults especially those that leave wetland habitats.

Invasive Species Interactions

Publications about the bog turtle have mentioned threats from nonnative wetland weeds such as common reed (Old World genotype) and purple loosestrife (Bury 1979; Klemens 2001). Bog turtles are also found using stands of these species (Whitlock 2002; James Utter, personal communication; Erik Kiviat, personal observation). However, the overgrowth of core springtime habitat, nest sites, and nursery (hatchling) habitat by tall (greater than 50 cm or so) dense plants, whether native or nonnative, is often a problem. Common reed, purple loosestrife, reed canary grass (*Phalaris arundinacea*), certain tall native forbs, and various native and nonnative woody species are often managed in bog turtle habitats.

We know of no evidence or credible hypothesis that nonnative invertebrates are deleterious to bog turtle.

If they become established in the LH PRISM region, feral swine could threaten bog turtle by preying on various life stages or by altering habitats.

Management Considerations

Management is conducted in close consultation with USFWS and NYSDEC, hence our suggestions may be modified by those regulatory agencies.

Early detection of *Phragmites* in core habitats will allow easier control, if necessary by cut-stem herbicide treatment. USFWS (2010) specifies how vegetation management may be conducted in bog turtle habitats. However, inasmuch as toxicity of herbicides to any life stage of bog turtle (or the food supply) is essentially unknown, spraying or other techniques of herbicide application may be inappropriate.

Prescribed grazing at low stocking rates during the growing season, and manual removal of tall woody plants during the dormant season, are well established habitat management techniques. Prescribed grazing by cows, sheep, goats, and potentially horses, remove or thin tall shrubs, cattails, purple loosestrife, common reed, reed canary grass, great hairy willow herb (*Epilobium hirsutum*), and other nonnative and native plants that may tend to overgrow the low sedgy vegetation that is considered typical of good quality bog turtle habitats.

Core wetland habitats should be monitored for early detection not only of common reed, but also mile-a-minute and other vines that could alter vegetation structure and interfere with insolation.

Eastern Box Turtle (*Terrapene carolina*)

Habitat

Box turtles in the LH PRISM region use woodland, meadow, shrubland, fencerow, sparsely vegetated rocky crest, and intermittent woodland pool habitats, and probably nontidal marsh and swamp, and shallow portions of tidal wetlands (Klemens 1993; Erik Kiviat, personal observations). Box turtles move among habitats readily, probably in search of temporarily available foods, as well as for thermoregulation and mating. At a Suffolk County (New York outside the LH PRISM region) site, box turtles were often found at field-woodland edges (Erik Kiviat, personal observation).

Food

Fleshy fruits, fleshy fungi, carrion, invertebrates, small vertebrates (Kiester & Willey 2015).

Predators

Many predators on eggs (probably especially raccoon and striped skunk). Probably many predators on hatchlings and small juveniles, although the cryptic nature of these life stages may protect them to some extent. Large juveniles and adults are probably eaten by the more powerful predators such as bald eagle, raccoon, river otter, black bear, coyote, and domestic dog. Kiester and Willey (2015) cited bald eagle, hog, chipmunk, snake, and ant predators. Collecting, vehicles, and farm equipment are threats.

Invasive Species Interactions

Box turtles were not found in habitats with Amur honeysuckle (*Lonicera maackii*) and were found in alternate habitats without this nonnative shrub at a Cincinnati, Ohio, site (McEvoy & Durtsche 2003 2004). The authors suggested that the high density of the invaded vegetation, or a lack of food, might explain this avoidance. However, there could have been confounding habitat factors.

Wilson (2012) commonly found box turtles in dense cover of Japanese barberry (*Berberis thunbergii*) in Ohio, and implied that this habitat served as protective cover and possibly provided food (fruits).

The relative nutritional values of the fruits of native vs. nonnative plants may be important. We do not see justification, however, for a hypothesis that nonnatives are necessarily unfavorable.

Hypothetically, certain vines, such as mile-a-minute (*Polygonum perfoliatum*), Japanese honeysuckle (*Lonicera japonica*), or black swallowwort (*Cynanchum louiseae*), may be capable of overgrowing open areas used by box turtles for foraging or basking.

Feral swine are a potential threat to box turtle eggs, young, and perhaps adults, as are domestic dogs. Feral swine could also compete with box turtles for food.

Management Considerations

Information on threats is not specific enough to make management recommendations. Sites with significant box turtle populations should be monitored for IS threats. Further research is needed, especially on the potential positive and negative effects of densely growing nonnative shrubs with fleshy fruits. Nesting habitats should be managed to prevent overgrowth by native or nonnative plants (see Dowling et al. 2010 on Blanding's turtle). Domestic dogs should not be allowed to range free in areas where box turtles or other vulnerable SGCN occur.

Northern Diamondback Terrapin (*Malaclemys terrapin terrapin*)

Habitat

The diamondback terrapin is unique among the herpetofauna of our region in adaptation to brackish and saline tidal marshes. Terrapins spend most of their time in tidal creeks and pools in the marshes and tidal shallows nearby. They nest in, typically sandy, soil just above the level of spring tides, in the upper edge of the beach or in the shoreward edge of the dunes. In places where natural sandy soils are absent, terrapins nest in fill, road banks, or other altered habitats. Nesting habitats are sparsely vegetated and the sand must maintain an appropriate moisture level. Terrapins overwinter in the subtidal zone within or near tidal marsh. There is a small terrapin population at Piermont Marsh (Rockland County), and the species presumably occurs in the tidal marshes of the Long Island Sound shore of Westchester County as well as the Bronx.

Food

Terrapins eat a variety of large invertebrates but specialize on crabs, mollusks, and barnacles (Tucker et al. 1995; Tulipani 2013).

Predators

Eggs are depredated by several species of mammals, crows, possibly insects, and the roots of dune grass (*Ammophila*). Hatchlings on their movement from nest to water are preyed on by various birds and mammals, and once in the water presumably are eaten by predatory fishes. Hatchlings and juveniles are depredated by Norway rats (Draud et al. 2004). Nesting females may occasionally be killed by large predators but are much more likely to be killed by motor vehicles. Eggs and adult females are depredated by raccoons (Feinberg & Burke 2003). Crab pots are an important cause of mortality (drowning when caught in the trap).

Invasive Species Interactions

Dogs, Norway rats, and feral swine are a potential threat to eggs and hatchlings. Native predators, especially the raccoon, are now a greater threat.

Invasive plants that can densely colonize nesting habitats are a potential threat, as are invasive plants that may be able to form a dense barrier between marsh and nesting habitat. The latter threat has been hypothesized concerning common reed at Piermont Marsh (Rockland Co.; Simoes & Chambers 1999).

A native plant that is common in terrapin nesting habitats on the East Coast, American beachgrass (*Ammophila breviligulata*), has been implicated in "predation" on terrapin eggs (Lazell & Auger 1981). It is possible that nonnative plants also attack terrapin eggs (see Wood Turtle account).

Management Considerations

Known terrapin nesting areas should be monitored for overgrowth by common reed and other native or nonnative plants. Smaller weeds may be managed by tilling the soil (see Dowling et al. [2010] on Blanding's turtle). Common reed may require repeated hand-pulling or frequent mowing for control. Use of herbicides near turtle nests is probably ill-advised.

Northern Map Turtle (*Graptemys geographica*)

This species is ambiguously native to the Hudson River. The first published record, about map turtles at Hyde Park and Staatsburg (Dutchess County), was Kiviat and Buso (1977). In addition, two specimens collected from the freshwater tidal Hudson River during the 1936 Biological Survey fish surveys are in the Univerity of Michigan Museum of Zoology. Two pre-Columbian archaeological specimens from the Hudson Valley north of our region (Coxsackie and Little Nutten Hook) were reported by Funk (1976). Inasmuch as Native Americans traded long distances, and turtle shells sometimes had ceremonial significance, it is not certain that these shells originated locally. There are northern map turtles in Lake Champlain and Lake George, the St. Lawrence River, and the Susquehanna River (Arndt & Potter 1973; Gibbs et al. 2007). There is a population in the nontidal Delaware River (New Jersey – Pennsylvania) that also may or may not be native (Arndt & Potter 1973; Gibbs et al. 2007).

Map turtles occur in the tidal Hudson from about Papscanee Creek (Rensselaer County) south probably to Newburgh. A report from Piermont, where the river is significantly brackish, may be attributable to diamondback terrapin which occurs there. Map turtles have also been seen in the nontidal Rondout Creek above the Eddyville Dam not far from the Hudson River (Ulster County). It is possible that map turtles reached the Hudson River via the Hudson-Champlain Canal or the Delaware-Hudson Canal, or the species might have dispersed to the Hudson in connection with natural postglacial drainage changes (Ernst and Lovich [2009] believed that this species colonized much of its northern range postglacially).

Habitat

Northern map turtle is a species usually associated with larger water bodies, both lentic and lotic (Ernst & Lovich 2009). In the fresh-tidal Hudson River (LH PRISM counties of Ulster and Dutchess), map turtles frequent the subtidal shallows and intertidal zone, more often in open expanses of water rather than in confined tidal creeks and pools. These areas are typically "outside" the railroads (i.e., in the "main river") rather than in the railroad coves, although juvenile map turtles have been seen in the Tivoli Bays, and adult females in Roosevelt Cove (the latter just prior to nesting on the railroad; Don Buso, personal communication).

Map turtles in the Hudson bask above water on rocks, logs, and old timbers that are isolated from shore and away from human disturbance. Nesting occurs in the friable, coal cinder-based soil on the railroad verges, and in clayey soil on islets in the shallows (Erik Kiviat, personal observations).

Food

The northern map turtle is a mollusk and crustacean specialist that also eats fish, insects, earthworms, submergent vascular plants, duckweed (*Lemna*), and filamentous algae (Ernst & Lovich 2009). Food in the Hudson River has not been studied, and for adults presumably constitutes zebra mussel (*Dreissena polymorpha*), native freshwater mussels (Unionoida), and perhaps crayfish (e.g., *Orconectes limosus*), blue crab (*Callinectes sapidus*), and mitten crab (*Eriocheir sinensis*).

Predators

There are probably few predators on adult map turtles. Typical predators of freshwater turtles presumably take eggs (e.g., raccoon, striped skunk) and small juveniles (snapping turtle, larger fishes, mink).

Invasive Species Interactions

Besides zebra (*Dreissena polymorpha*), Ernst and Lovich (2009) reported golden clam (*Corbicula fluminea* [*Corbicula manilensis*]) and faucet snail (*Bythinia tentaculata*); probably other nonnative mollusks are eaten. Nonnative mollusks as prey are presumed to benefit the map turtle, although they could be a source of novel parasites (see Bulté et al. 2012).

It is possible that Norway rats (*Rattus norvegicus*, which are common along Hudson River shorelines) prey on map turtle eggs and hatchlings.

There are nonnative aquatic plants, such as water-chestnut (*Trapa natans*) and Eurasian watermilfoil (*Myriophyllum spicatum*) in shallows likely to be used by map turtles. The significance of these plants as a threat, if any, is unknown. The places where adult map turtles have been seen in the Hudson are often shallows with little submergent vegetation (Erik Kiviat, personal observations), and the location of the first-reported Delaware River population was essentially unvegetated (Arndt & Potter 1973).

A population of the nonnative red-eared slider (*Trachemys scripta elegans*) is established in the extensive water-chestnut bed between Denning's Point and the East Shore Railroad (Kiviat, unpublished data). Map turtles have not been reported in that area thus there may not currently be competition. This is possible in the future or at other locations where there might be sliders.

Management Considerations

Information is insufficient to make recommendations for management of IS.

Genetic analysis would be desirable to determine (as much as possible) if the species is native to the Hudson River. The zoogeographic questions are similar to those associated with the common mudpuppy (*Necturus maculatus*, SGCN but presumed nonnative in the Hudson River) and the central mudminnow (*Umbra limi*), also presumed nonnative. It is possible either that these species are canal introductions from the 1800s, or that they reached the Hudson River via postglacial drainage changes.

Spotted Turtle (*Clemmys guttata*)

Habitat

Spotted turtles may be found in almost any type of pond, lake, or wetland, including marshes, fens, wet meadows, intermittent woodland pools, flooded swamps, acidic bogs, freshwater tidal marshes, and farm ponds, as well as in nearby uplands (Gibbs et al. 2007; Erik Kiviat, personal observations). In spring, spotted turtles need open patches where they can bask. Spotted turtles in some regions visit several habitat units in the course of a year; however, a Michigan population stayed within a single wetland (Rowe et al. 2013). Estivation (summer quiescence) may take place in upland woods. Females lay eggs in sparsely vegetated upland soil, or in the tops of sedge (*Carex stricta* and possibly other *Carex* species) tussocks in a wet meadow or fen. Spotted turtles overwinter in diverse microhabitats, many of which constitute accumulations of logs, sticks, herbaceous plant material, debris, or stones built by humans, beavers, or muskrats (Gibbs et al. 2007).

Diet

Spotted turtles eat diverse macroinvertebrates including mollusks, crustaceans, and worms, as well as amphibian eggs and larvae (Gibbs et al. 2007).

Predators

Eggs are depredated by raccoon, striped skunk, and other mammals. DeGraaf and Nein (2010) reported green frog (*Lithobates clamitans*) predation on a spotted turtle hatchling. Raccoons, and probably other carnivores, kill adults. Gibbs et al. (2007) considered crows, raccoons, and coyotes important predators without stating the spotted turtle life stage depredated.

Invasive Species Interactions

Spotted turtles are sometimes found in wetlands dominated by common reed (*Phragmites*) or purple loosestrife (*Lythrum salicaria*). It is unclear whether these habitats are favorable or not. Lewis et al. (2004) assumed that honeysuckles (*Lonicera* spp.), buckthorns (*Rhamnus cathartica* and *Fangula alnus*), and cattails (*Typha* spp.) were adverse to the quality of habitat for spotted turtle in Ohio, but didn't explain the rationale for that assumption other than that those plants can grow densely and shade out native plants. In fact, Harms (2008), also working in Ohio, found that within two study sites spotted turtles favored areas with taller, denser vegetation.

The red-eared slider (*Trachemys scripta elegans*), a southern turtle widely established as a nonnative species in the northern states, is not known to compete with spotted turtle, probably due to habitat differences.

We are not aware of any threats from nonnative prey or predators. Presumably most of the slugs eaten by spotted turtles are nonnative species, as this is true of most slugs in our region.

Management Considerations

Based on current knowledge, other threats, such as road mortality, native predators, and loss or degradation of wetland habitats are probably more important than nonnative species. We have no recommendations for management of IS.

Common Musk Turtle [Stinkpot] (*Sternotherus odoratus*)

This small, cryptic, freshwater turtle is probably more inconspicuous than rare. According to Gibbs et al. (2007) it occurs in all LH PRISM counties.

Habitat

Common musk turtles live in diverse ponds, lakes, and sluggish stream segments; Ernst and Lovich (2009) stated that the species occurs in almost any water body with slow current and soft bottom (occasional musk turtles are even found in streams with predominantly stony substrate;

Erik Kiviat, personal observation). The species appears to be rare in the Hudson River estuary (rarely caught in turtle traps set for other species and probably only in freshwater rather than brackish water; Kiviat, personal observations). Because musk turtles stay close to the water, they do not often reach isolated ponds (Gibbs et al. 2007). Aquatic plant beds are important habitat elements, and removal of aquatic "weeds" is adverse to this species (Gibbs et al. 2007). Musk turtles can thrive in at least some urban environments (Wilhelm & Plummer 2012). Unlike many turtles, musk turtles often lay their eggs in muskrat lodges, beaver lodges, in or under rotting logs, in organic debris, or other non-soil substrates, in either sun or shade, and multiple females may nest communally (Ernst & Lovich 2009).

Food

Musk turtles eat algae with associated invertebrates, as well as leeches, worms, aquatic insects, crayfish, fish, carrion, and vascular plant materials (Gibbs et al. 2007; Ernst & Lovich 2009). Mollusks are very abundant in some quantitative samples cited in Ernst and Lovich (2009). Occasionally musk turtles take terrestrial slugs out of water according to Ernst and Lovich (2009).

Predators

Turtles, snakes, crows, raccoon, and other mammals prey on eggs, and adults are eaten by river otter, mink, weasels, herons, bald eagle, other birds, northern water snake, turtles, bullfrog, and largemouth bass (Gibbs et al. 2007, Ernst & Lovich 2009).

Invasive Species Threats

Control of aquatic plants in developed or recreational lakes degrades musk turtle habitat (Gibbs et al. 2007), and it must be presumed that many such weed beds are dominated by nonnative plants. This may be an unusual twist on an IS threat to an SGCN.

In a Lake Erie (Pennsylvania) population, the most common foods of musk turtles were zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis bugensis*) (Patterson & Lindeman 2009). In an urban Arkansas stream where the nonnative golden clam *Corbicula fluminea* had been present for 40 years, musk turtles at more of this mollusk than than any other prey (Wilhelm & Plummer 2012). Golden clam and zebra mussel are both abundant in the Hudson River. Bulté et al. (2012) proposed that native predators eating nonnative prey would be exposed to different assemblages of parasites that might have either negative or positive consequences for predator fitness.

Feral swine might constitute a threat to the musk turtle as swine would probably prey on turtle eggs, juveniles, and adults.

Management Considerations

The DEC is mounting a feral swine control program.

We recommend that aquatic plant control programs be limited to those weedbeds or portions thereof where control is absolutely necessary. Benefits for swimming, boating, and fishing can be gained by clearing lanes or openings in weedbeds rather than removing entire beds. Aquatic plants are important to many turtles, amphibians, fishes, invertebrates, mammals, and birds.

Wood Turtle (*Glyptemys [Clemmys] insculpta*)

The wood turtle is listed as Special Concern in New York.

Habitat

Wood turtles center their activities around slow stream reaches (Compton et al. 2002) which may be clear or turbid (Klemens 1993). Adults are sometimes found in springfed ponds, flooded swamps, beaver meadows, or fens, and hatchlings have been found in springfed wetlands (Klemens,1993; Erik Kiviat, personal observations). Overwintering occurs in the stream channel beneath snags, among roots, in mammal burrows, or beneath overhanging banks (Hulse et al. 2001). The turtles may be found in the stream (or pond) in spring, sometimes in copulating pairs. Wood turtles bask on perches above the water in spring (Gibbs et al. 2007). In late spring and summer, much or all the time is spent in riparian fields, pastures, woodlands, and other "terrestrial" habitats (Klemens 1993), probably including non-flooded wetlands. In Pennsylvania, wood turtles had an affinity for alders (*Alnus*; Kaufman 1992). Nesting areas are commonly sandy, elevated, bare, and near water (Buech et al. 1997). Hartzell & Pitt (2014) found wood turtle nests in Pennsylvania in small patches of sand around stumps and logs that appeared to have been deposited by stream flooding.

Food

Wood turtles consume various invertebrates, small vertebrates, carrion, and plant materials (Kaufmann 1992; Walde et al. 2003) and may have a preference for earthworms (Kaufmann 1986).

Predators

Wood turtles experience predation on eggs, hatchlings, juveniles, and adults, due to many species of predators (Ernst & Lovich 2009). The wood turtle is vulnerable to injury and mortality from haying equipment (Saumure et al. 2007), and some of the scars on living turtles attributed to predation attempts might be due to farm equipment.

Invasive Species Interactions

House cat has been recorded as a predator on the wood turtle (Ernst & Lovich 2009), and it is likely that the domestic dog is also a predator. Norway rat (*Rattus norvegicus*) probably preys on eggs and hatchlings. It is unknown if these nonnative predators are a threat to wood turtle populations. Feral swine would likely prey on eggs, hatchlings, and small juveniles, and could be a threat.

Wood turtle nesting areas are presumably vulnerable to overgrowth by both native and nonnative plants. Bolton and Brooks (2010) found that seasonal overgrowth of common reed (*Phragmites australis*) degraded nesting areas for freshwater turtles on Long Point, Ontario. Behler and Castellano (2005) found wood turtle eggs killed by two nonnative plants, crabgrass (*Digitaria ischaemum*) and carpetweed (*Mollugo verticillata*), along the Delaware River in New Jersey. The frequency of this phenomenon is unknown.

Management Considerations

Overgrowth of known nesting areas could be managed by tilling the soil as was done for Blanding's turtle (Dowling et al. 2010). Common reed can be inhibited and eventually eliminated by frequent cutting or pulling (see Kiviat 2010). Nonnative predators, if they are adversely affecting a wood turtle population (e.g., on a preserve), could be controlled locally.

Amphibians

Amphibians in general are declining severely in the U.S. (Adams et al. 2013).

We expect three kinds of IS threats to amphibians:

-predation due to nonnative predators,

-changes in prey due to nonnative invertebrates,

-changes in habitat due to nonnative plants or animals.

Wild pigs (feral swine) are known to prey on salamanders (Mayer & Brisbin 2009). If wild pigs become established in the LH PRISM region, as they have in certain other parts of New York, the species may become an IS threat to SGCN salamanders (and other SGCN).

There are many nonnative soil invertebrates that could be eaten by SGCN amphibians, but no information about harm caused to a particular SGCN by any nonnative invertebrate. Nonnative earthworms, which are eaten by many native animals, are probably eaten by SGCN amphibians in our region. Pinder (2013) found that earthworms constituted less than 2% of the diet of stream salamanders in the Catskills, although higher earthworm species diversity was correlated with greater salamander abundance. She also found that one species of nonnative earthworm was associated with increased rates of nitrogen cycling in riparian zones in the Catskills. Otherwise, we found no data supporting the idea that nonnative invertebrates are directly harmful to SGCN amphibians. Maerz et al. (2009) found that nonnative earthworms reduced forest litter mass thus degrading habitat for the red-backed salamander, a common species. This effect was more pronounced in maple forest compared to oak forest because oak leaves were less readily processed by earthworms. This adverse effect of earthworms on a salamander seems likely to affect other forest-floor amphibians, but effects on other species have not been demonstrated as far as we know.

We know of no introduced predator that is a threat to amphibians in our region. If feral swine become established in the LH PRISM region, they could be a threat via predation on adult salamanders or possibly eggs, or damage (by rooting for food) to the habitats of adult or larval amphibians. It is possible that an introduced stream fish, such as the northern snakehead (*Channa argus*) which already occurs in Orange County, would prey significantly on stream salamanders. Many nonnative and native freshwater organisms are likely to expand their ranges northward as climate warms (Rahel & Olden 2008). Walking catfish (*Clarias batrachus*), which in its native range is adapted to live in "stagnant" wetland waters and can wriggle overland from wetland to wetland, may become established increasingly farther north in the U.S. as water temperatures increase. Potentially this species could enter intermittent woodland pools during the season of standing water and prey on amphibian larvae or adults. Sepulveda and Lowe (2011) compared a northwestern stream salamander species in downstream segments with fish and upstream segments without fish. Although preyed on by fish, the salamander maintained populations in segments with and without fish.

The alteration of habitats by invasive plants, and especially the release of toxic secondary compounds, may be a more significant threat to SGCN amphibians. Blossey et al. (2005) noted that nonnative common reed (the Old World genotyhpe that occurs in the LH PRISM region) was toxic to spotted salamander (*Ambystoma maculatum*, a common species) larvae. Reed might also be toxic to SGCN such as other *Ambystoma* species or to four-toed salamander, but this has not been tested. Furthermore, toxicity in a laboratory or mesocosm experiment might not predict toxicity in the wild where materials in the soil or water might buffer a toxicant. Wood frog, a common breeder in intermittent woodland pools and not a SGCN, larvae were found to develop more slowly in field enclosures with reed, probably due to lower densities of planktonic food; slower development might predispose the larvae to greater risk of pool drying or predation (Perez et al. 2013). Mazerolle et al. (2014) found that there was more common reed in ponds and ponds dried faster where there was more development within 1 km, but the land cover rather than the reed *per se* influenced the ranid frogs. Nonetheless, it would be prudent to consider common reed an EDRR plant in woodland pool amphibian breeding habitats. Of course we need to know which intermittent woodland pools are used by amphibians before this can be done.

Watling et al. (2011a) found that extracts of the nonnative Amur honeysuckle (*Lonicera maackii*) adversely affected American toad larvae but not spotted salamander (*Ambystoma maculatum*) larvae; larvae of SGCN *Ambystoma* species were not tested. Watling et al. (2011b) in Missouri found larger numbers of green frog and smaller numbers of certain other (unnamed) amphibians in plots with higher densities of Amur honeysuckle. Amur honeysuckle is common in the southern portions of the LH PRISM region but should not be considered a threat to SGCN unless further research determines that it is deleterious to these particular species.

Various other studies have found chemical impacts of invasive plants on native amphibians. Sacerdote et al. (2014) found that a compound from European buckthorn was toxic to embryos of western chorus frog in the laboratory, and that levels of that compound in breeding ponds were high enough to potentially affect chorus frog eggs. Cotten et al. (2012) found that nonnative tallow tree (*Triadica sebifera*) inhibited or promoted growth of larvae of southeastern amphibians, depending on amphibian species. Brown et al. (2006) found that purple loosestrife adversely affected larvae of the American toad. We were unable to find, however, any information directly related to invasive plant impacts on any of our SGCN amphibian species. This may be an area for further research, especially regarding impacts on our SGCN amphibians of nonnative plants that have become abundant in the LH PRISM region in forested riparian areas and woodland pool habitats. There may well be native plants that are increasing in abundance, such as red maple or star-cucumber, that are potentially toxic to amphibians, and this also needs study. On the other hand, it is always possible that certain invasive plants have beneficial effects on SGCN amphibians.

Invasive insects that threaten to alter the structure of hardwood forests could adversely affect the upland or pool habitat of SGCN *Ambystoma* species or the riparian habitat of SGCN stream salamanders. Emerald ash borer appears poised to cause large scale mortality of ashes which are sometimes important in the forest vegetation in or near these habitats. Asian long-horned beetle, which can kill many species of hardwood trees, is also a potential threat. Hemlock woolly adelgid, which is killing hemlocks in the LH PRISM region, may open the canopy and expose some intermittent woodland pools to higher temperatures and possibly greater evaporation and shorter hydroperiod. Although most pools supporting SGCN mole salamanders are in hardwood forest, some pools have a hemlock-dominated hemlock-hardwood mixed overstorey. Such pools may be adversely affected by hemlock death caused by IS. These three invasive insects are the subject of intensive monitoring and management by public and private agencies, thus will not be discussed further here.

Forest tree pathogens, such as sudden oak death (the fungus *Phytophthora*), are a potential threat to SGCN salamanders in addition to, and perhaps in combination with, pest insects.

Management Concerns

State and federal programs to develop safe (i.e., least impact on nontarget organisms) biocontrols for insects and fungi that cause significant tree mortality need support. Landowners and managers can help best by reporting known tree-killing organisms or any untoward tree mortality. We do not think that control at the individual property level can address these problems, and it may even be harmful.

Until further research data are available, it seems prudent to remove common reed and common buckthorn from the breeding pools (including their margins) of the SGCN *Ambystoma* species and the four-toed salamander if this can be done non-chemically. Amphibians tend to be particularly sensitive to pesticides and other environmental contaminants.

Too little is known about the impacts of nonnative prey organisms or predators on amphibians. Of these, feral swine and predatory stream fishes would seem to be the greatest threats. State programs to control or eradicate these predators should be supported if scientifically sound and without serious nontarget impacts.

Blue-Spotted Salamander (*Ambystoma laterale*)

This mole salamander is a counterpart of the Jefferson salamander (see below), inasmuch as most blue-spotted salamander individuals are triploid female hybrids with two blue-spotted salamander chromosome sets and one Jefferson salamander chromosome set ("LLJ"). Blue-spotted salamander is listed as Special Concern in New York State.

Blue-spotted salamander life history is similar to that of the Jefferson salamander, except that blue-spotteds tend to spawn and develop as larvae in more extensive, deeply flooding swamps associated with streams, rather than in small, isolated, intermittent woodland pools (Klemens1993 & personal communication). Outside breeding season, diploid adults were found in upland forest, wet meadow, and swamp; slash, leaf litter, and soil moisture were important factors positively related to salamander presence (Ryan & Calhoun 2014).

We know of no specific invasive species threats to the blue-spotted salamander. However, it is possible that nonnative plant invasions of woodland breeding pools could have a detrimental effect. Because blue-spotted salamander presence was negatively related to grass cover at a small scale (Ryan & Calhoun 2014), it is possible that dense populations of the nonnative stiltgrass (*Microstegium vimineum*) could be unfavorable in nonbreeding habitat (although stiltgrass cover was favorable for common amphibian species in a Westchester County study; Nagy et al. 2011). Because spawning habitats are often connected to streams, it is possible that a predatory, nonnative fish could be a threat to blue-spotted salamander larvae (however, larvae may be distasteful to fish inasmuch as they presumably coexist with predatory native fishes).

Eastern Spadefoot (*Scaphiopus holbrookii*)

Habitat

In the LH PRISM region, this frog is known from a single site in the Town of Dover (Dutchess County) characterized by calcareous sandy soils. James DeKay, in the 1800s, reported a population in Rockland County that is considered extirpated (New York Natural Heritage Program 2013).

Spadefoots spend most of their lives quiescent in burrows in the soil. They emerge at night during or after heavy rains to forage in upland habitats, and they breed in temporary ponds; incubation and larval period are short (Gibbs et al. 2007).

Food

The adult eastern spadefoot eats terrestrial macroinvertebrates. Larvae eat varied materials (Natureserve, 2014).

Predators

A variety of animals preys on larvae, metamorphs, and adult spadefoots. In experimental pools in North Carolina, eastern newts (*Notophthalmus viridescens*) were important predators on spadefoot larvae (Morin 1983). Various snakes were considered predators of adult spadefoots (Marchisin & Anderson 1978). The bullfrog (*Lithobates catesbeianus*) is also a predator on adults (Holman 1957). Fishes and other potential predators that live in permanent waters are absent from the rain pools in which eastern spadefoots breed (see Greenberg & Tanner 2004). Perhaps most significantly, feral swine preyed on eastern spadefoot adults in Georgia (Jolley 2007).

Invasive Species Interactions

Feral swine are a potential threat to eastern spadefoot should swine colonize the LH PRISM region. We have not found mention of other invasive species threats. It is possible that certain species of nonnative weeds could colonize eastern spadefoot breeding ponds and degrade habitat by increasing evapotranspiration or changing water chemistry. It is also possible that dense colonization by deep and densely-rooting nonnative weeds could adversely alter the upland soil habitat in which eastern spadefoots spend much of their time.

Management Considerations

Breeding pools should be identified and monitored for colonization by nonnative weeds that have the potential to degrade habitat. Feral swine will (in general) be managed by the DEC and we hope not become abundant enough to affect SGCN species in the LH PRISM region.

Four-toed Salamander (*Hemidactylium scutatum*)

Habitats

Adult four-toed salamanders can be found beneath moss mats on woody plant hummocks in intermittent woodland pools, beneath rocks or logs at the edges of the same pools or within the pool when it is dry, in swamps and seeps, along streams and beneath cover objects on uplands within 100 m of a wetland (Gibbs et al. 2007). Four-toed salamander egg nests, and to a lesser extent adults, are often associated with moss and moisture (Gibbs et al. 2007; King 2012). Older literature mentions peat moss (*Sphagnum*); however, current understanding is that the moss taxon is not a determining factor. Based on an observation at the tidal Connecticut River, this species might also be found beneath cover objects (wrack or driftwood) in the supratidal zone (just above high tide line) along the freshwater tidal Hudson River. Eggs are laid out of water where newly hatched larvae will fall into water, and the larvae develop in the surface waters of wetlands.

Food

Four-toed salamanders eat small macroinvertebrates (Hulse et al. 2001).

Predators

Mammals, birds, snakes, and salamanders are predators of the four-toed salamander (Gibbs et al. 2007).

Invasive Species Interactions

We have not found any specific information regarding IS threats to four-toed salamander.

Fowler's Toad (*Bufo fowleri*)

Fowler's toad may hybridize with the much more common American toad (*Bufo americanus*). Individuals with intermediate characteristics are assumed to be hybrids (see Gibbs et al. 2007) which are presumably not listed as SGCN. Intermediate individuals were observed at the Burroughs Sanctuary in West Park (Ulster County) ca. 1980 (Erik Kiviat, personal observation).

Habitat

Quiet fresh waters at low elevations are breeding habitats. After a short larval period in late spring or summer, juvenile and adult Fowler's toads spend their life in terrestrial habitats. Adults return to ponds to chorus and lay eggs. This species is typically associated with sandy or rocky landscapes (Gibbs et al. 2007). Klemens (1993) in Connecticut always found Fowler's toads in habitats ranging from well drained to xeric, including "scarified" (cut-and-fill?), rocky, and sparsely vegetated areas. One breeding habitat in southern Dutchess County was a small ornamental pond in a residential subdivision (Erik Kiviat, personal observation). Fowler's toads do not require fish-less breeding habitats.

Food

Fowler's toads eat diverse invertebrates. Bush and Menhinick (1962) reported that beetles and ants were important prey, along with smaller numbers of other invertebrates; the beetle taxa were diverse.

Predators

Bufo toads have toxic skin secretions and are rarely eaten by mammals. However, Gibbs et al. (2007) reported that raccoon and skunks (species not stated), as well as herons, ducks, garter snakes, and hognose snakes prey on Fowler's toads. Larger amphibians, other reptiles and birds, and large fishes such as largemouth bass (a nonnative species in New York) are potential predators on adults. Metamorphs (young juveniles) are presumably eaten by a variety of vertebrates and invertebrates. Larvae are also toxic but are presumably eaten by larger invertebrates, reptiles, and birds. American toad eggs are "distasteful" (Gibbs et al. 2007) and are presumably not eaten by fish.

Invasive Species Threats

In marshes of Long Point, Ontario, Greenberg & Green (2013) found a decline of Fowler's toad coincident with low water levels and expansion of common reed (*Phragmites australis*) that eliminated the shallow open water breeding habitat.

We are not aware of other invasive species threats to Fowler's toad.

Management of Threats

Consolidation of reedbeds in Fowler's toad breeding habitat could be addressed non-chemically via creation of open pools by dredging, cutting reeds beneath the water, raising the water levels, or cutting followed by raising water levels (Kiviat 2010). Fowler's toad breeding populations in the LH PRISM region are likely to be small and may not require extensive reed-free habitat (that is, they might be able to breed in pools within reedbeds).

Jefferson Salamander (*Ambystoma jeffersonianum*)

This "species" constitutes principally triploid (three chromosome sets) hybrid females with one chromosome set from blue-spotted salamander and two sets from Jefferson salamander. (This combination is sometimes called "LJJ.") In some localities there are also pure diploid Jefferson or blue-spotted salamanders, and even tetraploid (four chromosome sets) hybrids (Bogart & Klemens 2008). The hybridization occurred 3-4 million years ago and is not a product of post-European alteration of the landscape (Bogart & Klemens 1997 2008). Jefferson salamander is listed as Special Concern in New York.

Habitats

Jefferson salamanders live in forests and spend most of their time burrowing in leaf litter and soil (Gibbs et al. 2007). Courtship, egg-laying, and larval development occur in intermittent woodland pools (Kiviat & Stevens 2001), also called "vernal pools," from late winter to early summer. Occupied nonbreeding forest habitat may extend hundred of meters from a breeding pool (Calhoun et al. 2005). Breeding pools dry up in summer and early fall, and commonly fill after late fall rains.

Food

Adults eat soil invertebrates and larvae eat aquatic invertebrates and amphibian larvae.

Predators

Predators on adults include snakes, birds of prey and other birds, shrews and other mammals. Predators on larvae include predaceous diving beetles (Dytiscidae), dragonfly larvae, larger salamander larvae, snakes, and fishes (Gibbs et al. 2007). Jefferson salamanders lay eggs in pools that dry up in a typical summer and thus usually lack fish; fishes are potential predators of eggs and larvae. Mass migrations of adults to breeding pools in late winter, especially where roads are crossed, may expose the salamanders to predation as well as road mortality.

Invasive Species Interactions

We found no reports on specific threats to the Jefferson salamander.

Longtail Salamander (*Eurycea longicauda*)

This poorly studied species is known in the LH PRISM region from the western two-thirds of Orange County, a small area of adjacent Sullivan County, and possibly extreme southern Ulster County (Gibbs et al. 2007).

Habitats

The longtail salamander is primarily found in or near cool streams or seeps that are in or at the edges of deciduous forests or mixed deciduous-coniferous forests; moist soils are selected (Gibbs et al. 2007). Longtail salamanders are sometimes found in cut-and-fill areas such as shale pits and road cuts in Pennsylvania (Hulse et al. 2001) and elsewhere outside our region at pond edges and occasionally in forests distant from streams (Petranka 1998). Adults overwinter in caves, mines, shale pits, or rock crevices (Bell 1955, cited in Gibbs et al. 2007; Hulse et al. 2001).

Food

Longtail salamanders eat a wide variety of invertebrates (Petranka 1998; Hulse et al. 2001; Gibbs et al. 2007).

Predators

Predators presumably include mammals, birds, reptiles, amphibians, fishes, and larger invertebrates. Little information is available (Petranka 1998).

Invasive Species Interactions

We found no specific information on IS threats. It is possible that nonnative plants could affect longtail salamander by altering habitat in seeps and wetland edges.

Marbled Salamander (*Ambystoma opacum*)

This is also a mole salamander but it is not a hybrid, and it spawns in the fall rather than in late winter – early spring. The marbled salamander is listed as Special Concern in New York. Interestingly, although this species is near its northeastern range limit in the LH PRISM region, it occurs at an elevation of ca 416 m at the summit of Stissing Mountain (Dutchess County; Erik

Kiviat, personal observation), and Klemens (1993) mentioned two other sites in the Hudson Valley at similar elevations.

Habitats

Marbled salamanders spawn and develop as larvae in intermittent woodland pools (vernal pools). Otherwise, the adults live in the leaf litter and soil of forests and forest edges. However, adult marbled salamanders evidently enter or cross non-wooded habitats more readily than the other two SGCN mole salamanders, and are somewhat more tolerant of dry habitats including sandy or gravelly soils and rocky slopes (Bishop 1941; Klemens 1993; Gibbs et al. 2007).

Food

Adult marbled salamanders eat a wide variety of soil invertebrates. The larvae, because they hatch when fall rains flood the breeding pools and feed during winter, are larger than other woodland pool-breeding amphibian larvae in spring. Thus marbled salamander larvae are able to feed on other amphibian larvae as well as eating invertebrates. The smaller larvae in winter eat zooplankton, and the larger larvae in spring eat mostly amphibian larvae (Gibbs et al. 2007). Hulse et al. (2001) found large larvae in Pennsylvania that had eaten principally aquatic beetles.

Predators

Predators are similar to predators of the other mole salamanders, and include snakes, birds, and mammals (Gibbs et al. 2007).

Invasive Species Interactions

We found no specific information. It is possible that dense colonization of breeding pools by common reed would be harmful. Feral swine might prey on adults.

Northern Cricket Frog (*Acris crepitans*)

This species is listed as Endangered in New York.

Habitat

Northern cricket frog is at the northeastern limit of its range in New York where it is currently known only from Orange, Ulster, and Dutchess counties (formerly on Long Island and Staten Island; Kenney & Stearns 2012). There is a puzzling historical report that seems to refer to Teatown Lake in Ossining (Westchester County).

The best core wetland habitats seem to be circumneutral bog lakes (Kiviat & Stevens 2001). These are shallow lakes or ponds with unconsolidated peat bottoms, floating peat mats, and “peat rafts” (small masses of peat that float to the surface during warm weather). Cricket frogs breed in these wetlands at low elevations. Cricket frogs may also be found chorusing in marshy pools (Jay

Westerveld, personal communication) and other water bodies that do not fit the description of circumneutral bog lakes, and spawning presumably occurs in some of those habitats. Non-calling adults may be found in almost any water body within a few hundred meters of a core breeding habitat; these other habitats may be used seasonally during migrations between breeding habitat and wintering habitat, or may be stepping stones used by cricket frogs dispersing along streams (Dickinson 1993).

A single wintering habitat has been studied in New York (Kenney et al. 2012). At that site, cricket frogs winter in crevices or burrows associated with rock outcrops in woodland. The "hibernaculum" may be as much as 140 m from the core breeding habitat. According to participants in a 27 February 2009 cricket frog workshop organized by the New York State Department of Environmental Conservation, New York cricket frogs might also overwinter in soil crevices, woody plant root channels, foundations of buildings, and other terrestrial habitats, possibly as far as 450 m from a breeding pool.

Cricket frogs formerly chorused in a number of water bodies in Harriman State Park and Sterling Forest State Park (Orange County), but now are found in but a few sites there. Cricket frog populations now breed in several lowland areas of Orange, Ulster, and Dutchess counties. Many, if not all, of the extant sites are calcareous.

Food

Cricket frogs eat small macroinvertebrates. Feeding occurs in terrestrial or aquatic habitats.

Predators

Many larger vertebrates and invertebrates have been reported to prey on cricket frogs outside our region. Predators in the LH PRISM region are poorly known.

Invasive Species Threats

Kenney and Stearns (2012) opined that largemouth bass and smallmouth bass, both nonnative but widely introduced in eastern New York, could affect northern cricket frogs via predation. Kenney and Stearns also suggested that nonnative crayfishes might affect cricket frogs by reducing the biomass of submergent vegetation. We have found no information indicating that nonnative aquatic plants have an adverse impact although this is possible.

Management Considerations

No recommendations. Management would be carried out by, or under supervision of, the DEC.

Northern Red Salamander (*Pseudotriton ruber*)

Habitats

The red salamander is usually found in and near streams and associated springs or ponds. They may also occur in bogs, meadows, ditches, or beaver ponds (Gibbs et al. 2007). Cool flowing water is a typical habitat characteristic. Occupied streams may be in forests, meadows, or pastures (Petranka 1998). Red salamander is usually associated with good environmental quality in eastern Pennsylvania, but may also occur in developed areas (Corn 2010). Large streams rarely support this species (Petranka 1998). Adults overwinter in springs or streams (Petranka 1998).

Food

Diverse invertebrates as well as other salamanders (Petranka 1998; Gibbs et al. 2007).

Predators

Snakes, and probably shrews, raccoon, skunk (species not stated), and birds (Petranka 1998).

Invasive Species Interactions

We are not aware of any reports of IS interactions. Nonnative trouts (brown trout and rainbow trout), as well as recently established nonnative predatory fishes such as the northern snakehead (*Channa argus*), could be predators on the red salamander. Feral swine could prey on red salamander adults.

Atlantic Coast Leopard Frog (*Rana [Lithobates] kauffeldi*)

This entity, formerly thought to constitute the northeasternmost populations of the southern leopard frog, was recently recognized as a distinct genetic taxon (Newman et al. 2012) and described as a unique species (Feinberg et al. 2014). This is the taxon included in the SGCN list, and discussed in Gibbs et al. (2007) and Kiviat (2011, in New Jersey) as southern leopard frog. The latter is officially listed as Special Concern in New York where it does not occur; it is unclear what listing might be accorded to the Atlantic Coast leopard frog but Special Concern or Threatened seems likely because of the small number of populations and restricted geographic range (probably much smaller than shown by Gibbs et al. 2007). This species is poorly understood and currently under intensive study by the New York Natural Heritage Program and collaborators throughout the geographic range.

Habitat

Atlantic Coast leopard frog (ACLF) is known from 1 or 2 localities in Putnam County, and several localities in Orange County (Jeremy Feinberg, personal communication; Jay Westerveld, personal communication). Some Orange County occurrences await verification. There are extant populations in Staten Island and northern New Jersey, and historic records believed to be of this species from Long Island and Connecticut.

ACLF also ranges southward near the coast to Virginia. Most known populations are essentially coastal and many are in urban areas. Some breeding pools are subject to brackish water intrusion from storm surges; in spring 2013, after Hurricane Sandy (October 2012), ACLF were chorusing in pools on Staten Island and in the New Jersey Meadowlands at salinities of 1.1-5.5 ppt (E. Kiviat & J. Feinberg, unpublished data).

Breeding pools are semi-isolated ponds, pools in common reed (*Phragmites*) marshes, flooded shrub swamps, and other wetland pools that have standing water from late winter into summer. One population in the New Jersey Meadowlands breeds in a stormwater pond (Kiviat 2011), and a Putnam County population breeds in a shrub swamp on a small stream (Erik Kiviat, personal observation). Outside the breeding season, adults probably use terrestrial and shallow wetland habitats within a few hundred meters of the breeding pools.

Food

Adults eat macroinvertebrates, especially beetles, caterpillars, and spiders (Gibbs et al. 2007; it is unclear which frog species this statement refers to). Most feeding occurs in terrestrial habitats, at times distant from breeding pools (Gibbs et al. 2007). However, two populations in the New Jersey Meadowlands had little access to uplands therefore adults might also forage in the common reed marshes where breeding occurs (Erik Kiviat, personal observations).

Predators

Presumed to be the same vertebrates that prey on other eastern leopard frogs. Gibbs et al. (2007) implied that fishes and the eastern newt prey on ACLF larvae. It is possible that nonnative fishes, such as largemouth bass or snakehead, are a threat.

Invasive Species Interactions

None yet reported. The species is apparently not adversely affected by the Old World form of common reed; two relatively large populations breed in flooded reed marshes in the Meadowlands and at least two in similar habitats on Staten Island (Kiviat 2011; E. Kiviat & J. Feinberg, unpublished data).

Management Considerations

No recommendations.

Appalachian Tiger Beetle (White Mountain Tiger Beetle; *Cicindela ancocisconensis*)

This beautiful tiger beetle appears to be widespread but may be endangered in portions of its global range (Leonard & Bell 1999). A recent New York statewide survey found Appalachian tiger beetle at only 5 of 16 historic localities and 3 of 28 "*de novo*" (i.e., no historical record) sites (Schlesinger & Novak 2011). Reported extant and historic localities of this species are not far outside the LH PRISM boundaries and one Sullivan County site may be within the boundaries (Schlesinger & Novak 2011). One historic Ulster County site is on upper Esopus Creek near Belleayre Mountain in the Catskills; Appalachian tiger beetle might occur on lower Esopus Creek in the LH PRISM region. Other rivers with potential habitat include Wappinger Creek and Fishkill Creek in Dutchess County.

Habitat

Leonard and Bell (1999) described the habitat of Appalachian tiger beetle as "shaded gravel, sandbanks, and sandbars of mountain brooks and medium-to-small rivers with large boulders..." In the Genesee River of western New York, Appalachian tiger beetles were found on cobble bars where they favored the inland edges of the bars near vegetation (Hudgins 2010). In West Virginia, the Appalachian tiger beetle lives on dry, sparsely vegetated, sandy banks and islands above the high water line of rivers (Allen & Acciavatti 2002).

Food

In general, tiger beetle larvae and adults eat any arthropods they can catch and subdue, and adults may even feed on small frog larvae stranded in drying pools, carrion, or fallen fruit (Pearson & Vogler 2001). Yet food and competition for food are believed to be limiting factors for tiger beetles. We did not find specific information about food of the Appalachian tiger beetle.

Predators

Adult tiger beetles in general are adept at escaping predation. However, they are eaten by robber flies (Asiliidae), spiders, other arthropods, lizards, certain birds, and possibly ants (Pearson & Vogler 2001). Several kinds of wasps, flies, and mites attack tiger beetle larvae (Pearson & Vogler 2001). We did not find specific information about predators of Appalachian tiger beetle.

Invasive Species Interactions

Native and nonnative plants may overgrow the bare or sparsely vegetated soils characteristic of tiger beetle habitats (Knisley 2011; Goldberg et al. 2012; Cornelisse et al. 2013). Nonnative plants adversely affected habitat of a common and a rare tiger beetle at Point Reyes, California (Cornelisse & Hafernik 2009). Omland (2002) found that false-indigo (*Amorpha fruticosa*) colonized sandy beach habitat at a potential reintroduction site of the threatened tiger beetle *Cicindela puritana* along the freshwater tidal Connecticut River, but did not specifically describe effects on the beetle. False-indigo is native south and west of New York, and is common along the Hudson River shorelines but rarely far inland (Erik Kiviat, personal observation).

Nonnative riparian weeds that might be threats to Appalachian tiger beetle in the LH PRISM region include Japanese knotweed (*Polygonum cuspidatum*). There are many nonnative and native plants that colonize and overgrow, or produce at least temporary litter layers, on the bare soil habitats known to be used by this beetle.

It is possible that nonnative predators will affect the adults or larvae of Appalachian tiger beetle; however, none has been reported as far as we know.

Management Considerations

If populations of Appalachian tiger beetle are confirmed in our region, the habitats should be analyzed to determine if they are being overgrown by invasive nonnative plants (or native plants). It is premature to make specific management recommendations.

Sylvan Hygrotus Diving Beetle (*Hygrotus sylvanus*)

This member of the diving beetle family (Dytiscidae) was collected at Peekskill (Westchester County) prior to 1900. Recently, the species has been found in the western Great Lakes states and southern Canada. The unreferenced information in this account is from Shea (2014). Literature on the genus *Hygrotis* is almost completely systematic and biogeographic; little appears to be known of ecology.

Habitat

Known habitats constitute temporary pools in fens and ponds; the habitat of the Peekskill locality was a woodland pond.

Food

Unknown.

Predators

Unknown. Wilson's phalarope was a predator on larvae of *Hygrotus* sp. in Canada (Höhn & Barron 1963).

Invasive Species Interactions

Unknown.

Butterflies

Ten SGCN butterflies occur in the LH PRISM region:

Common Name	**Scientific Name**
Checkered white	*Pontia protodice*
Frosted elfin	*Callophrys irus*
Henry’s elfin	*Callophrys henrici*
Hessel’s hairstreak	*Callophrys hesseli*
Mottled duskywing	*Erynnis martialis*
Northern metalmark	*Calephelis borealis*
Northern oak hairstreak (= Oak hairstreak)	*Fixsenia favonius ontario [= Satyrium favonius]*
Persius duskywing	*Erynnis persius persius*
Regal fritillary	*Speyeria idalia*
Tawny crescent	*Phyciodes batesii batesii*

Checkered white is described as a nomadic opportunist; frosted elfin is considered rare and local, living almost exclusively in small, widely scattered colonies; Henry’s elfin is found in a wide variety of habitats with different host plant associations; Hessel’s hairstreak is an obligate Atlantic white cedar feeder; mottled duskywing has a wide geographical range and was never common; northern metalmark has scattered locations due to specialized larval and adult food requirements; northern oak hairstreak is the rarest *Satyrium* in its range and at the center of much taxonomic uncertainty; Persius duskywing is distinguished from the wild indigo and columbine duskywings with difficulty; regal fritillary is among one of most severely imperiled, and its rapid decline in the East is poorly understood; tawny crescent in the Northeast has declined dramatically for unknown reasons since 1960 (Cech & Tudor 2005).

Occurrence in the Lower Hudson PRISM Region

Checkered white is listed for Bronx and Manhattan counties; frosted elfin in Westchester, Rockland and Putnam counties; Henry’s elfin in Westchester County; Hessel’s hairstreak in Rockland County; mottled duskywing in Westchester, Dutchess, Rockland and Orange counties; northern metalmark in Orange County (also in Dutchess County; James Utter, personal communication); northern oak hairstreak in Westchester, Rockland and Orange counties; Persius duskywing in Westchester, Dutchess and Rockland counties; regal fritillary in Westchester, Putnam, Dutchess, Rockland, Orange counties; and tawny crescent in Ulster County (BAMONA).

Habitat

Checkered white is an irruptive colonist in dry, weedy waste areas, fields, beach edges, and railroad verges. It will not enter woods even if frightened (Cech & Tudor 2005).

Frosted elfin is associated with clearings in dry oak woods, shale and pine barrens, sandhills, coastal scrub, and sometimes more mesic habitats (Cech & Tudor 2005).

Henry's elfin frequents poor, acidic-soil woodlands with a shrubby understorey (Glassberg 1993). In New York these are coastal holly forests, and dry upland clearings and edges (Cech & Tudor 2005).

Hessel's hairstreak is restricted to Atlantic white cedar swamps and nearby areas with nectar plants (Cech & Tudor 2005).

Mottled duskywing is associated with dry, open woods and barrens, including pine barrens and sometimes shrubby fields (Cech & Tudor 2005).

Northern metalmark is restricted to limestone outcrops, including old quarries, near specific host plants (Cech & Tudor 2005).

Northern oak hairstreak (oak hairstreak) is found in both coastal and upland oak forest, and pine-oak barrens with nearby nectar plants (Cech & Tudor 2005).

Persius duskywing is a specialist of patchy, pine-oak woods and pine barrens (Cech & Tudor 2005).

Regal fritillary occurs in moist, open grasslands, often with rolling topography and wet swales (Cech & Tudor 2005). It was formerly found in a variety of largely unnatural open situations such as pastures and hayfields, usually wet (Glassberg 1993).

Tawny crescent is found in low vegetation of damp or dry, often rocky sites (Cech & Tudor 2005). This species has been reported in dry open grasslands, often with little bluestem grass (*Schizachyrium scoparium)* and asters (Glassberg 1993).

Host Plants

Larvae of the SGCN butterflies feed on certain plants as follows.

Checkered white feeds on almost any wild or cultivated crucifer; often shepherd's purse (*Capsella bursa-pastoris*; nonnative*)* or Virginia peppergrass (*Lepidium virginicum*; native*)*. Larvae eat buds, flowers, fruits and sometimes leaves (Cech & Tudor 2005).

Frosted elfin feeds mainly on wild lupine (*Lupinus perennis)* and wild-indigo (*Baptisia tinctoria)*, also blue false-indigo (*Baptisia australis*; nonnative*)* and rattlebox *(Crotalaria sagittalis).* With the exception of wild indigo, these plants are rare in our region. The larvae bore into fruits (Cech & Tudor 2005).

Henry's elfin feeds on American holly (*Ilex opaca)*, blueberries (*Vaccinium)* and huckleberries (*Gaylussacia*) (Cech & Tudor 2005).

Hessel's hairstreak feeds on new branch tips of Atlantic white cedar (*Chamaecyparis thyoides*) (Cech & Tudor 2005).

Mottled duskywing eats buckthorns (*Rhamnus* and *Frangula)* and New Jersey Tea (*Ceanothus americanus)* (Cech & Tudor 2005).

Northern metalmark feeds on roundleaf ragwort (*Senecio obovatus* (= *Packera obovatus)* (Cech & Tudor 2005).

Northern oak hairstreak feeds on white oak (*Quercus alba)* and post oak (*Q. stellata)* (Cech & Tudor 2005).

Persius duskywing eats wild indigo (*Baptisia tinctoria)* (Cech & Tudor 2005).

Regal fritillary feeds on various violets including arrow-leaved violet (*Viola sagittata)* (Cech & Tudor 2005).

Tawny crescent feeds on wavy-leaved aster (*Symphyotrichum undulatum [Aster undulatus])* (Glassberg 1993).

Invasive Species Interactions

Although interrelationships between host plants and butterflies are very strong and sometimes restricted to a single species, shifts in preference do occur. Wild indigo duskywing switched from wild indigo to crown-vetch (*Securigera varia [Coronilla varia]),* a nonnative weed widely planted on interstate right-of-ways to control erosion (Shapiro 1979, Cech & Tudor 2005). Henry's elfin was found eating nonnative smooth buckthorn (*Rhamnus frangula)* in the Boston area (Glassberg 2003) and Ontario (Catling et al. 1998). Northern metalmark uses one host plant, roundleaf ragwort, but there is speculation it may also feed on golden ragwort (*Senecio aureus [Packera aureus]*) and common fleabane (*Erigeron philadelphicus*) (Cech & Tudor 2005).

The decline of checkered white is attributed to land development rather than competition with the abundant, nonnative cabbage white (*Pieris rapae*). These two species are reported to fly together but use different host plants (Cech & Tudor 2005).

The sensitivity of rare butterflies to habitat and host plants indicates that invasive plants or animals that affect the species composition of vegetation would affect associated butterflies. We would expect this problem where nonnative weeds form large, highly dominant patches that replace native plant assemblages, or where a nonnative animal kills butterfly host plants. Despite the logic of this idea, we have not found examples relevant to the LH PRISM region except for those cited below.

Management Considerations

Habitat loss and degradation, deer consumption of butterfly host plants and nectar plants, afforestation and increasing numbers of nonnative species are considered the primary threats to rare butterfly populations (CWCS Plan 2005). In situations where a single host plant is used by a rare butterfly species, preservation of that host plant population and any crucial nectar sources is of critical importance.

In an effort to manage two New Jersey colonies of northern metalmark, invasive plants were removed by Wade Wander and Sharon Wander (personal communication). The weeds were stiltgrass (*Microstegium vimineum),* autumn-olive *(Elaeagnus umbellata),* Morrow honeysuckle (*Lonicera morrowii),* Japanese barberry (*Berberis thunbergii),* multiflora rose (*Rosa multiflora),* garlic-mustard *(Alliaria petiolata)* and Oriental bittersweet (*Celastrus orbiculatus).* These plants had overgrown colonies of the only confirmed host plant, roundleaf ragwort. These same nonnative weeds also shade out nectar plants, primarily butterfly milkweed (*Asclepias tuberosa),* black-eyed Susan (*Rudbeckia hirta),* and ox-eye daisy (*Leucanthemum vulgare).* Metalmark colonies may also be affected by shading from native eastern redcedar (*Juniperus virginiana).*

Butterflies that require open, sunny habitats are sometimes favored by modest levels of land use development (or recovery from earlier development). For example, there is a population of the northern metalmark associated with an electric transmission right-of-way (Barbour 1997). This, of course, does not argue for deforestation to create more open habitats, but it does argue for conservation where rare species occur in the habitats that have already been created by human activities, and for management of certain open habitats supporting rare species. Among habitats that may be of conservation concern are utility rights-of-way, abandoned crop fields and pastures, brownfields (post-industrial areas), old wetland fill, inactive garbage landfills, golf course roughs or abandoned golf courses, and cemeteries.

Moths

One SGCN moth was reported in the LH PRISM region: Regal Moth (= royal walnut moth, *Citheronia regalis).*

The regal moth belongs to the giant silkworm family (Saturniidae), medium to large moths including our largest species. The regal moth has a wingspan from 9.5 to 15.5 cm and the female is larger than the male. The horns on the larva give it a threatening appearance and the name hickory horned devil, although it does not sting (Covell 1984). Young larvae resemble bird droppings when resting on the tops of leaves (Opler et al. 2012).

Occurrence in Lower Hudson PRISM Region

Regal moth was reported in Rockland, Putnam, Dutchess and Orange counties (Opler et al. 2012). This species is more common southward (Covell 1984).

Habitat

Deciduous woodland (Opler et al. 2012).

Host Plants

Larvae feed on hickories (*Carya*), butternut (*Juglans cinerea),* black walnut (*Juglans nigra),* sweet gum (*Liquidambar styraciflua)*, persimmon (*Diospyros virginiana),* sumac (*Rhus)* and cultivated cotton (*Gossypium*; Opler et al. 2012). The larvae are often seen in late summer as they leave the host plant to burrow into the ground to pupate (Covell 1984).

Invasive Species Interactions

The threats to moth populations have not been well documented, but habitat loss and degradation caused by land development, land clearing, habitat fragmentation, vegetation change in shrubland, woodland, and barrens habitats, coastal erosion and sea level rise, and the use of chemical biocides (traditional pesticides and growth regulators) are likely major threats to moth populations in varied habitats (Anonymous 2005). Another likely but poorly known threat is the continued impact of biological agents introduced beginning in 1906 for control of gypsy moths and other pests. The introduced parasitoid fly (*Compsilura concinnata*, Tachinidae) may be the cause of reported declines of silk moth populations in New England and may affect other native Lepidoptera (Boettner et al. 2000). Although widespread spraying is rare today, chemical biocides, and to a lesser extent the microbial insecticide *Bacillus thuringiensis* var. *kurstaki* (Btk) applied locally, continue to kill native Lepidoptera (Schweitzer 2004 as reviewed in Anonymous 2005). Other possible threats to moths and their habitats are invasive plants, animals, and pathogens, and the effect of night lighting on reproductive success (Anon. 2005).

Management Considerations

Regal moth is considered rare in peripheral parts of its range and is listed as S1 in New York State (Anonymous 2005). Globally this species is listed as secure with no conservation management recommended (Opler et al. 2012). The wide diversity of host plants and an extensive habitat imply other causes of decline. Failure of these larger moths to recover in some areas is probably due mostly to the introduced parasitoid *Compsilura concinnata* (Schweitzer 2004). Many of the most widely eradicated species, including the regal moth, occasionally to frequently remain as pupae for two or three years and therefore could not be eradicated by one year of 100% larval mortality over a large area (Schweitzer 2004). We found no other reported interactions with invasive plants or animals in the literature. Population monitoring of this moth should be implemented since much of its life history has been described.

Odonates of Rivers and Streams

Ten SGCN odonates (dragonflies or damselflies) of lotic (flowing) habitats occur in a variety of rivers and streams in the LH PRISM region:

Common Name	**Scientific Name**
Arrow clubtail	*Stylurus spiniceps*
Blue-tipped dancer	*Argia tibialis*
Brook snaketail	*Ophiogomphus aspersus*
Cobra clubtail	*Gomphus vastus*

Midland clubtail	*Gomphus fraternus*
Rapids clubtail	*Gomphus quadricolor*
Russet-tipped clubtail	*Stylurus plagiatus*
Septima's clubtail	*Gomphus septima*
Sparkling jewelwing	*Calopteryx dimidiata*
Spine-crowned clubtail	*Gomphus abbreviatus*

Two species are damselflies: blue-tipped dancer and sparkling jewelwing. The remaining eight species belong to the clubtail family of dragonflies.

Occurrence in the Lower Hudson PRISM Region

Blue-tipped dancer was verified in Orange County during the New York Dragonfly and Damselfly Survey (NYDDS) (White et al. 2010). Only one site was known for this species in the Hudson Highlands along the Ramapo River (Alan Wells, personal communication). Sparkling jewelwing is known historically from Westchester County and Manhattan (Erin White, personal communication) but verified in northern New Jersey. Arrow clubtail was reported for Dutchess County during the NYDDS (White et al. 2010), but was not confirmed. Brook snaketail was verified in Dutchess County during NYDDS (White et al. 2010). Midland clubtail and Septima's clubtail were confirmed in Orange County during NYDDS (White et al. 2010). Rapids clubtail was confirmed in Orange and Ulster counties during the NYDDS (White et al. 2010). Spine-crowned clubtail was verified in Orange and Westchester counties during NYDDS (White et al. 2010). Cobra clubtail is historically known from Orange County but may not be in the LH PRISM region (White, personal communication). Russet-tipped clubtail was confirmed in Dutchess, Ulster, Putnam and Rockland counties (White et al. 2010 and personal communication).

Habitat

Damselflies
Blue-tipped dancer prefers small wooded, sandy streams with slow to moderate current, with or without riffles. They are less often found in larger rivers but are linked to forest streams and occasionally found in degraded, urban streams (Paulson 2011). Sparkling jewelwing is found in sandy streams and rivers with abundant aquatic vegetation and moderate to swift current. It is less associated with woodlands and more with non-wooded areas (Paulson 2011).

Clubtails
Arrow clubtail occurs in large rivers that usually have a sandy bottom and rarely in smaller streams (Dunkle 2000). Brook snaketail is found in clear streams in the open with shrubby banks and sandy, gravelly or rocky riffles (Dunkle 2000). Midland clubtail is found in moderately to rapidly flowing rivers and large streams with clay or fine sand bottoms, as well as large lakes with emergent vegetation (Dunkle 2000). Rapids clubtail is associated with large streams and rivers with gravelly to rocky substrates, riffles or rapids, and also in sluggish, mud-bottomed rivers (Dunkle 2000). Septima's clubtail is found in clean, rocky rivers (Dunkle 2000). Spine-crowned clubtail occurs in clean streams and rivers with either sandy or rocky substrates and

"muck" (silt?) deposits (Dunkle 2000). Cobra clubtail is found mostly at large rivers with a moderate to rapid current, as well as large streams or large lakes (Dunkle 2000). Russet-tipped clubtail is found in rivers, streams or lakes, often with silty sand bottoms (Dunkle 2000). However, NYDDS records were all from freshwater tidal swamps on the Hudson River (White et al. 2010). James (Spider) Barbour (personal communication) observed this species in 2005, 400 m from the Roeliff Jansen Kill well inland from the Hudson River in Dutchess.

Diets

Adult odonates are generalized, obligate carnivores, taking any food item that is small enough to be carried and slow enough to be captured (Carpenter 1997). Odonate larvae also feed on invertebrates as well as amphibian larvae and small fish.

Invasive Species Interactions

Odonates are vulnerable to many threats: water pollution (including salinization from de-icing salts), siltation, pesticides, alteration of flows or water levels, changes in terrestrial vegetation near larval habitats, and release of fish in previously fish-free water bodies. It is not clear that nonnative fishes are more harmful to odonates than native fishes, if the size and diet of the fish species are similar; however, introduction of a nonnative fish could increase predator pressure that might affect odonates. Changes in aquatic vegetation may clog certain types of shallow open water habitats, or replace plant species critical for egg laying.

The blue-tipped dancer (*Argia tibialis)* does not seem selective regarding the plant species it perches on; however, introduced fish species including largemouth bass, bluegill, and rainbow trout are potential predators in the Ramapo River where there is a small dancer population (Wells, personal communication).

In eastern Canada, several nonnative fishes, several nonnative, predaceous crayfishes, the nonnative spiny water flea (*Bythotrephes longimanus*), and habitat-altering, nonnative aquatic plant species, are suspected threats to the rare pygmy snaketail (*Ophiogomphus howei)* (Environment Canada 2013). However, the basis for these concerns are not stated and a document cited is currently unavailable on the Web.

It is well established that odonates are sensitive to insolation (light and heat from the sun) conditions and shade alone reduced dragonfly abundance (Remsburg et al. 2008). Invasive alien trees shading riparian habitat in South Africa were a threat to rare odonates (Magoba & Samways 2010). During the 1900s many South African riparian corridors were altered by the invasion of alien trees, especially acacia (*Acacia).* Removal of the dense canopy of nonnative trees enabled recovery of aquatic biodiversity (Magoba & Samways 2010).

Management Considerations

Fish of any species, including mosqitofish (*Gambusia*) for control of mosquito larvae, should not be introduced into fish-less waters that support odonates.

Lotic or lentic waters supporting rare odonates should be monitoried for colonization or spread of nonnative plants. Ideally, weeds can be managed on an EDRR basis. If a nonnative weed such as water-chestnut or common reed (or a native weed such as cattail) is spreading and consolidating such that the habitat space (e.g., in shallow open pools) available to rare odonates is threatened, many weeds can be removed by repeated hand-pulling or cutting. Use of herbicides may be a threat to the rare odonates, their egg-laying substrates (such as water-lilies), or other desirable species.

Odonates of Forest Seeps and Small Streams

There are five SGCN dragonflies that occur in the LH PRISM region where they are associated with seeps, rivulets, and small forest streams:

Common Name	**Scientific Name**
Arrowhead spiketail	*Cordulegaster obliqua*
Gray petaltail	*Tachopteryx thoreyi*
Mocha emerald	*Somatochlora linearis*
Sable clubtail	*Gomphus rogersi*
Tiger spiketail	*Cordulegaster erronea*

Arrowhead spiketail is reported to perch low on weed stems and twigs along forest edges, with a unique habit of shooting up and over trees like an arrow when disturbed (Dunkle 2000). Recently metamorphosed dults spend a week or more away from water until they mature sexually (Paulson 2011). Tiger spiketail males patrol up and down forest stream corridors much of the day (Paulson 2011). Gray petaltail is a large, dull-colored dragonfly that rests on flat surfaces at any angle, typically camouflaged against tree bark (Paulson 2011). Mocha emerald is most active at dawn and near dusk, cruising open areas at various heights up to tree tops (Paulson 2011). Sable clubtail is a small, secretive dragonfly that perches in the shade (Dunkel 2000); males also perch on sunlit vegetation overhanging streams or on flat rocks in shade and fly up into trees when disturbed (Paulson 2011).

Occurrence in the Lower Hudson PRISM

The following data are from the New York Dragonfly and Damselfly Survey (White et al. 2010). Arrowhead spiketail was verified in Orange, Rockland, Putnam, Westchester and Ulster counties. Both tiger spiketail and mocha emerald were verified in Orange, Rockland, Westchester, and Dutchess counties. Gray petaltail was verified in Orange and Rockland counties. Sable clubtail was verified in Orange County.

Habitat

Arrowhead spiketail can be found in small, swift forest streams especially with soft bottoms and muddy seeps (Paulson 2011), as well as spring-fed rivulets with rocks (Dunkle 2000). Tiger spiketail is associated with tiny forest streams often near skunk cabbage (*Symplocarpus foetidus*;

Paulson 2011) and in habitats described as small, spring trickles too small for fish (Dunkle 2000). Gray petaltail frequents shallow, mucky forest seeps associated with streams and ponds (Paulson 2011). Mocha emerald occurs in small forest streams 1-3 m wide with mud and leaf litter, with or without riffles (Dunkle 2000; Paulson 2011). Sable clubtail is found in clean, moderately flowing forest streams usually with silt and sand and especially below an obstruction or dam (Dunkle 2000).

Diet and Feeding Behavior

Dragonfly larvae are aquatic and feed on other aquatic invertebrates and amphibian larvae. Spiketails forage mostly in fields where they generally perch on vertical twigs at oblique angles to the ground. Both arrowhead and tiger spiketail males patrol great distances along forest streams (Dunkle 2000). Gray petaltail takes large prey (Dunkel 2000) and may be encountered in forest clearings and edges (Paulson 2011). Mocha emerald usually feeds high over clearings, but sometimes hunts by hovering in forest undergrowth (Dunkle 2000). Sable clubtail forages near semi-shaded leaves at forest edges, often well above ground (Dunkle 2000).

Predators

The main predators of dragonfly larvae are fish, birds, other larval dragonflies, and to a lesser extent herpetofauna (Corbet 1999). The predators of adult dragonflies are diverse and include mammals, birds, herpetofauna, fish, larger dragonflies, other insects, and spiders (Corbet 1999). When emerging from the larval stage, odonates may be especially vulnerable to certain birds. Adult dragonflies are also trapped by plants that have spines, sharp hairs, or sharp culms (Corbet 1999).

Invasive Species Interactions

The main threats to odonates include altered hydrology, pollution and removal of aquatic vegetation that provides critical oviposition and larval habitat (Barlow et al. 2009). We found no literature reports of invasive species interactions with forest odonates.

Certain habitats where arrowhead spiketail, tiger spiketail, and gray petaltail were observed in Orange and Rockland counties are being colonized by common reed (*Phragmites*) which may fill in or dry out and degrade habitats for these dragonflies (Alan Wells, personal communication). Arrowhead spiketail was observed perching on multiflora rose, Japanese barberry and Japanese knotweed at Doodletown and on common reed at Jones Point (Wells, personal communication).

We are not aware of invasive predators or prey species affecting dragonflies.

Management Considerations

Encroachment of common reed that alters shallow open water or another important odonate habitat, or the potential drying effect of reed colonization in a small pool or seep, appear to pose a threat to these five SGCN species associated with seeps, rivulets and small forest streams. We recommend considering common reed as an early detection, rapid response species (EDRR) in the habitats of SGCN forest odonates. Small patches (a few square meters) of reed can be controlled by repeated pulling or cutting (cut or pulled material must be disposed of in existing reedbeds or in a dry area where rooting will not occur). Larger reedbeds are difficult to manage without undesirable nontarget impacts which must be weighed against the benefits to rare native species (see Kiviat 2010). Fortunately in this respect, the habitats of these forest odonates are often very small.

Introduction of fish to fishless waters should be avoided.

Odonates of Lakes and Ponds

Four SGCN odonates that occur in lakes and ponds in the LH PRISM region:

Common Name	**Scientific Name**
Comet darner	*Anax longipes*
New England bluet	*Enallagma laterale*
Spatterdock darner	*Rhionaeschna mutata [=Aeshna mutata]*
Taper-tailed darner	*Gomphaeschna antilope*

Comet darners belong to a genus that includes some of the largest dragonflies, with males unmistakable as the only dragonfly with a red abdomen and green thorax (Dunkle 2000). The Comet darner is a large, powerful, insect which flies with a steady flight. Females oviposit in the stems of water-lilies or other aquatic plants (Carpenter 1997). New England bluet is a small, pale, blue and black-banded damselfly, characterized by a conspicuous but variable black mark on the sides of the 8^{th} abdominal segment. It is found in early spring and has a brief flight period (Carpenter 1997). This species may be more common that thought, but missed due to its early and short flight season (Alan Wells, personal communication). Spatterdock darner is the only eastern darner with all-blue markings and forked cerci (Dunkle 2000) and is usually associated with water-lilies, particularly spatterdock, a floating or erect yellow water-lily (*Nuphar lutea [Nuphar advena]*; Wells, personal communication). Taper-tailed darners are rare and can be found perching on tree trunks or hanging from small branches in sun or shade (Dunkle 2000).

Occurrence in Lower Hudson PRISM Region

Comet darners are uncommon and scattered northward (Dunkle 2000) ranging primarily along the Atlantic Coastal Plain from Massachusetts south to Florida and Texas (Carpenter 1997), and verified in Ulster and Putnam counties in the New York Dragonfly and Damselfly Survey (NYDDS) with records in Westchester, Dutchess, Rockland and Orange prior to 2005 (White et al. 2010). New England bluet ranges from southern Maine to northern New Jersey and Pennsylvania (Carpenter 1997) and was verified in Orange, Rockland and Westchester counties in the NYDDS (White et al. 2010). Wells (personal communication) added five new sites from Rockland and Orange counties and believes this species is more common than thought. Spatterdock darner was verified in Rockland County in the NYDDS with unvouchered reports listed in Orange, Westchester and Ulster and records reported in Dutchess previous to 2005 (White et al. 2010). Wells (personal communication) reported this uncommon species at

Doodletown, Lily Pond, Goose Pond Mountain and along the Mahwah River near Ramapo. There was one record for taper-tailed darner in Ulster County in 1994 in the NYDDS (White et al. 2010). It is considered a vagrant and has not been confirmed as a breeder in New York (Erin White, personal communication).

Habitat

Comet darners prefer semi-permanent, grassy ponds with few or no fish (Dunkle 2000). New England bluets are found briefly in early spring and prefer heavily vegetated ponds with emergent rushes and mucky or boggy edges (Carpenter 1997). Spatterdock darners prefer fishless ponds with water-lilies but are occasionally found in bog ponds (Dunkle 2000). Both male and female spatterdock darners pay special attention to spatterdock where females lay their eggs in the underwater stems (Dunkle 2000). Taper-tailed darner prefers swamps and bogs; males patrol over land, not water (Dunkle 2000). Females lay eggs in wet wood above the waterline (Dunkle 2000), hang under branches, and may mate away from water (Paulson 2011).

Diet and Feeding Behavior

Adult dragonflies are generalized, obligate carnivores, taking any food item that is small enough to be carried and slow enough to be captured (Carpenter 1997). Adult darners primarily eat medium-size prey (Dunkle 2000) and comet darners feed on insects as large as medium-size dragonflies, traveling distances to find food (Dunkle 2000). Comet darners prey on small insects and have been observed flying toward tree-tops with larger or sometimes multiple prey (Carpenter 1997). Male spatterdock darners feed on insects found over fields by patrolling low over vegetation with a leisurely, erratic flight (Dunkle 2000). They can also be found cruising over the center of ponds rather than along the edges in early summer with both sexes hanging on shrubs in nearby woodlands (Paulson 2011). New England bluet takes smaller prey, mostly flies (Diptera; Carpenter 1997).

Invasive Species Interactions

The main threats to odonates include altered hydrology, pollution, removal of aquatic vegetation that provides critical oviposition and larval habitat (Barlow et al. 2009), and introduction of predatory fishes. There is limited information on invasive species interactions with odonates in the Northeast, but the impact of two invasive wetland plants on odonates were evaluated in wetlands of restored prairie pothole wetlands in Iowa (Mabry & Dettman 2010). Both reed canary grass (*Phalaris arundinacea*) and hybrid cattail hybrid had a negative relationship with odonate species richness, particularly those odonate species with more specialized habitat requirements (Mabry & Dettman 2010). Wells (personal communication) reported common reed (*Phragmites)* encroachment in habitats of New England bluet, especially along favored shorelines at Lily Pond in Harriman State Park. Both New England bluet and spatterdock darner were reported by Wells (personal communication) to use Japanese barberry for perches and spatterdock darner also used multiflora rose, but he felt they were not selective about perch species. If common reed has a negative impact on SGCN odonates, it is more likely structural alteration (e.g., reduction in water depth or clogging of the water column with plant stems) of the habitat than a species-specific influence of this plant. It would be helpful to know if other native or nonnative emergent species have similar effects on odonates.

Odonates are often associated with fishless ponds and predation by introduced, nonnative fish species such as largemouth bass, common carp, fathead minnow, mosquitofish and bluegill may be a problem for New England bluet and spatterdock darner (Wells, personal communication). A Hawaiian study of gut contents of nonnative rainbow trout (*Oncorhynchus mykiss)* found dragonfly and damselfly larvae and cautioned that nonnative fishes could harm odonates via predation or competition for food (Kido et al. 1999).

Management Considerations

Odonates respond to many habitat variables including hydropattern (water levels and flows throughout the year), substrate, water quality, fish and other predators, and surrounding upland habitats (Mabry & Dettman 2010). Odonates vary in life history, but many rely upon emergent or woody wetland vegetation to complete their life cycles. Odonate species richness was substantially greater in mixed-structure vegetation than in monotypic stands and this trend was also true for odonate species with "vulnerable" or "uncommon" conservation status (Mabry & Dettman 2010). However, Mabry and Dettman also stated that vegetation structure was more important than species composition. In the New Jersey Meadowlands, where there is moderate diversity of lentic-habitat odonates (Kiviat 2007), many wetland habitats are highly dominated by nonnative common reed with minor occurrence of other plants. Although we do not want to see semi-natural ponds and marshes densely overgrown by nonnative plants, we need to be aware that abiotic factors (hydropattern, water quality, predators, etc.) are important influences on odonate assemblages, and that stands of nonnative plants vary from site to site and some may be more favorable for odonates than others (see Needham's skimmer account). Two damselflies (scarlet bluet and Pine Barrens bluet) found in the New Jersey Pine Barrens are dependent on Coastal Plain ponds with water levels that have not been drawn down by human activities, i.e., that retain adequate water throughout the year for the larvae (Barlow et al. 2009). Also, maintaining or establishing emergent herbaceous or woody vegetation on at least part of a pond shore may be a critical habitat feature for certain odonates.

Because spatterdock is an important habitat element for spatterdock darner, water-chestnut (*Trapa natans*) or possibly European frog's-bit (*Hydrocharis morsus-ranae*) that have the potential to displace spatterdock could be a threat.

A 13-year study conducted in Africa determined that vegetational and hydrological factors were essential for maintaining an assemblage of dragonfly species in a reservoir. Marginal forest, percentage of vegetation cover and percentage of shade were the most important environmental variables. Tall, medium and short grasses, submergent vegetation, water flow, and extent of open water were important factors in dragonfly species composition. The study showed that to maintain high species richness, including endemics, it is essential to maintain a variety of habitats using selective management of the marginal vegetation without allowing land development to proceed to a point where overgrowth of the bank and silting of the bottom begin to impoverish the fauna (Suh & Samways 2005).

Needham's Skimmer (*Libellula needhami)*

Occurrence in the Lower Hudson PRISM

Needham's skimmer has a mostly coastal distribution. It was verified in Orange, Rockland and Putnam counties during the New York Dragonfly and Damselfly Survey (NYDDS; White et al. 2010). Individuals were reported at Doodletown, Lily Pond, Goose Pond Mountain and along the Mahwah River near Ramapo (Alan Wells, personal communication). Needham's skimmers have also been observed at Iona Island Marsh (Rockland) during the last several years (Nancy Slowik, personal observation; Erik Kiviat personal observation).

Habitat

Needham's skimmer usually breeds in brackish, mineral rich or fertilized waters including marshes, lakes, ponds, tidal rivers, coastal marshes, and canals (Dunkle 2000; Paulson 2011). All sightings by Alan Wells (personal communication) were near waterbodies with water-lilies except at Goose Pond Mountain, an upland area not near a waterbody.

Diet and Feeding Behavior

Needham's skimmer eats flying insects and forages from weed stems or during sustained flights. Territorial males perch on weed tips along open shores (Dunkle 2000). Males perch along shore and in tall marsh vegetation, typically at waist to head height on stems or tips of grass stalks and cattails (Paulson 2011). One male was observed hunting from his perch on common reed (*Phragmites australis)* at Iona (Slowik, personal observation). Needham's skimmers in the Meadowlands selected common reed culms for perching (Kiviat 2007).

It seems unlikely that nonnative prey organisms would affect Needham's skimmer adversely.

Predators

Dragonfly larvae are preyed on by fish, and adults are eaten by birds. Mature larvae emerging from the water to metamorphose, and tenerals (soft-bodied adults that have just metamorphosed) are vulnerable to predation by birds and other animals. The occurrence of Needham's skimmer at tidal wetlands and other wetlands supporting fish suggests that fish predation does not limit populations. In experimental wetlands, Knorp and Dorn (2014) found that Needham's skimmer larvae were not limited by a sunfish (Centrarchidae) but may have been limited by mosquitofish (*Gambusia holbrooki*).

Invasive Species Interactions

Odonates are often associated with fishless ponds, and predation by nonnative fishes may limit populations. Needham's skimmer seems to be associated with waters supporting fish, thus this dragonfly may be able to escape fish predation.

The individual seen along the Mahwah River was perched on multiflora rose, while the Lily Pond specimen was perching in an area of multiflora rose and Japanese barberry. The Doodletown individual was flying in an area of dense multiflora rose and Japanese barberry. This species is not expected to select particular plant species as perches (Wells, personal communication). Perch density and variety of heights and diameters did not affect dragonfly abundance in a study of a reservoir shoreline in South Africa whereas shade alone reduced dragonfly habitat selection (Remsburg et al. 2008).

Management Considerations

Multivariate analyses identified structure and species composition of vegetation, especially marginal forest, the percentage of vegetation cover, and the percentage of shade as the most important environmental variables determining dragonfly species composition (Suh & Samways 2005). Too little is known about Needham's skimmer and other SGCN odonates to discern what if any roles nonnative plants may play in their habitats.

Research is needed to determine whether nonnative fishes are a threat to Needham's skimmer. It will also be important to learn whether the application of herbicide to common reed (as at Iona) is adverse to Needham's skimmer either through direct toxicity, effects on prey, or alteration of habitat.

Allegheny Woodrat (*Neotoma magister)*

Occurrence in Lower Hudson PRISM Region

Allegheny woodrat was extirpated by 1987 from New York and most of eastern Pennsylvania and New Jersey. One of the last remaining populations occurs along the Hudson River in northern New Jersey (Whitaker & Hamilton 1998). A few woodrats were live-trapped in Rockland County just north of the New Jersey border in 2001 and 2003; it is not known if this New York population persists. Ed McGowan (personal communication) considered the habitat of the Palisades better in New Jersey than in New York. The prominent field signs of the woodrat are their debris piles and middens on remote rock ledges (Whitaker & Hamilton 1998). The Allegheny woodrat populations in New Jersey continue to decline after an increase in number in the early 1990s (K. LoGiudice, personal communication).

Habitat

The Allegheny woodrat depends on rocky cliffs, caves, fissures, or talus (Whitaker & Hamilton 1998). When woodrats were still common in the Northern Shawangunk Mountains, they even used buildings (Kiviat 1988). The extensive talus slopes of the New Jersey and New York Palisades provide large boulders that are nearly bare of vascular vegetation, with crevasses that offer excellent den sites.

Diet

Allegheny woodrats consume almost anything (Kathleen LoGiudice, personal communication). Woodrats were observed to run over boulders with great agility, visiting brush and open thickets in search of food (Whitaker & Hamilton 1998). In New York two of the six piles examined by Ed McGowan (personal communication) could be described as hybrid debris piles - middens containing food items such as acorns, mushrooms, and plant clippings in addition to plastic debris, sticks and bones. McGowan also found raccoon scats in the middens, the possible source of raccoon roundworm (*Baylisascaris procyonis)* infection, lethal to woodrats (Whittaker & Hamilton 1998).

Invasive Species Interactions

Allegheny woodrats in Indiana stored foliage and fruits of tree-of-heaven (*Ailanthus altissima)* in their food middens (Whitaker & Hamilton 1998). In southern Indiana, the most important foods found in woodrat stomachs included two nonnative plants: tree-of-heaven and Japanese honeysuckle (*Lonicera japonica)* (Whitaker & Hamilton 1998). In New Jersey, woodrats ate flower buds of princess-tree (*Paulownia tomentosa)* under natural conditions and as trap baits (K. LoGiudice, personal communication). The princess-tree is an ornamental tree from East Asia that thrives on cliff-and-talus habitat, among other habitats. It is considered an invasive species in the Northeast and is abundant at the last remaining woodrat site in New Jersey. Princess-tree was documented to be eaten by woodrat and is known to be a rich source of iridoid glucosides, including verbascoside, which is reported to have antiviral, antibacterial and antiproliferative properties. Princess-tree probably contains antiparasitic compounds that protect the woodrat from raccoon roundworm and may help to explain the persistence of the Allegheny woodrat in this location (Spector 2007; Smith et al. 2010).

Management Considerations

More information is needed about the population status, habitat use, diet, and health of woodrats in New York and New Jersey before IS management recommendations can be made. For now, it is appropriate to not remove princess-tree where it grows on cliff-and-talus habitats of the Palisades in Rockland County and New Jersey.

Tree Bats (*Lasionycteris* and *Lasiurus* species)

Tree bats do not commonly hibernate in caves or mines, and in summer roost primarily in trees and not normally in buildings or rock crevices. Tree roosting usually involves hanging from leaves or twigs rather than hiding in bark voids or cavities. Tree bats are typically long-distance seasonal migrants and either pass through our region in spring and fall, or if they summer in our region they fly southward in fall.

Common Name	Scientific Name
Eastern red bat	*Lasiurus borealis*
Hoary bat	*Lasiurus cinereus*
Silver-haired bat	*Lasionycteris noctivagans*

Tree bats tend to solitary behavior, are hard to find when roosting, and consequently their behavior and ecology are relatively poorly known (Whitaker & Hamilton 1998). In addition to foraging on the wing over or near surface waters, tree bats may forage at outdoor lights where moths gather (Whitaker & Hamilton 1998).

Habitat

In summer and in migration, tree bats are most often found in or near forests. Red bats and hoary bats roost in trees among dense foliage, and sometimes red bats roost in the corn in corn fields (Whitaker & Hamilton 1998). Occasionally hoary bats roost on buildings, in a tree cavity, in a squirrel nest, or under a plank (Whitaker & Hamilton 1998). Unlike the red bat and hoary bat, silver-haired bats roost in tree cavities in summer, and may congregate in nursery colonies in a hollow tree (Whitaker & Hamilton 1998). Tree bats use various tree species, and have also been found in rock crevices and leaf litter (Cryan & Veilleux 2007). Silver-haired bats often roost in abandoned woodpecker holes (Barclay & Kurta 2007). Roost site selection of tree bats is apparently related to energy conservation (Barclay & Kurta 2007).

Although tree bats normally winter in the southern states, occasionally individuals are found dormant or active in winter in the northern U.S. Silver-haired bats may also winter as far north as the southern portion of the LH PRISM region (Whitaker & Hamilton 1998). Occasionally tree bats are found in winter in caves or mines (Cryan & Veilleux 2007). Silver-haired bats sometimes occur in buildings in fall migration (Cryan & Veilleux 2007).

Tree bat foraging activity is reduced in forests with higher understorey density, because the larger-bodied tree bats are less maneuverable in dense vegetation than smaller-bodied cave bats (Scott 2007). Urban forests in the Chicago metropolitan area “restored” by means of prescribed fire or removal of nonnative shrubs and small trees (e.g., common buckthorn [*Rhamnus cathartica*]) were favorable habitats for bats and bat activity was correlated with lower shrub density and greater abundance of small trees (Scott 2007). However, this effect was not necessarily related to plant species *per se*.

Food

Silver-haired bat eats many taxa of insects and may feed heavily on chironomid midges and other Diptera; moths, beetles, and true bugs (Hemiptera) are prominent in the diet of the red bat; moths may make up the greatest proportion of the diet of the hoary bat which also eats beetles and odonates (Odonata, day fliers that must be taken before dark). The large hoary bat can eat larger insects than the other two tree bats (Whitaker & Hamilton 1998).

Predators

Birds and snakes have been reported to prey on tree bats. Blue jays and hawks are important predators of the red bat, and hawks may take migrating red bats (Whitaker & Hamilton 1998). Predators of the silver-haired bat have not been reported (Whitaker & Hamilton 1998).

Invasive Species Interactions

It is possible that replacement of native trees by nonnative trees, or the proliferation of nonnative shrubs or vines in forests, could adversely alter forest habitat for roosting or foraging tree bats. However, we did not find sufficient information to justify recommendations regarding management of invasive plants to benefit tree bat habitat.

The possibility of invasive predators or prey affecting tree bats is comparable to the discussion of these issues for cave bats (see). We found no specific information.

Tree bats may be especially vulnerable to collisions with wind turbines, perhaps related to mating behavior associated with tall trees (Cryan 2008). Migrating red bats also collide with buildings (Whitaker & Hamilton 1998).

Cave Bats (Chiroptera, genus *Myotis*, in part)

Cave bats usually hibernate in caves or underground mines, and in summer may roost in trees as well as in other habitats. Tree roosting usually involves void microhabitats such as spaces beneath loose bark.

Common Names	Scientific Names
Indiana bat	*Myotis sodalis*
Little brown bat	*Myotis lucifugus*
Northern bat	*Myotis septentrionalis [=Myotis keenii* in part]

Indiana bat is federally and state listed as Endangered; northern bat has been proposed for federal listing; and little brown bat has been recommended for federal listing (Kunz & Reichard 2010). The primary threat to all three species is the fungal pathogen that causes white nose syndrome (WNS); this disease is communicated from individual to individual in the cave hibernacula. In this account, "SGCN cave bats" refers to these three species; the small-footed bat and three species of SGCN tree bats are profiled separately.

Habitats

All three SGCN cave bats hibernate underground in caves or mines, and occasionally in structures including dams and buildings (Whitaker & Hamilton 1998). These bats spend the active (warm) season roosting by day and part of the night, and (the females) caring for young, in trees, buildings, and other places that offer small protected crevice-like (void) microhabitats.

Summer roost trees of Indiana bat were in upland livestock paddocks, riparian areas, and a wetland in Illinois (Gardner et al. 1991). Tree roost microhabitats for Indiana bat may be under loose bark of dead trees, under exfoliating bark of live trees, or in tree cavities; dead trees may be more commonly used than live trees but dead tree suitability may only last for a few years (Gardner et al. 1991, Kurta et al. 1993). Many species and sizes of trees are used by Indiana bats and northern bats including oaks, conifers, and red ash (*Fraxinus pennsylvanica*) (Kurta et al. 1993; Foster & Kurta 1999, Britzke et al. 2003); twelve different tree species were used in one Illinois roost (Gardner et al. 1991). Physical structure, temperature regime, and probably other factors are important in shaping suitability of summer roosting and nursery microhabitats. Larger trees and dead trees are often preferred, and although many species are used by Indiana bats, shagbark hickory seems especially favorable due to the structure of exfoliating bark (Callahan et al. 1997; Barclay & Kurta 2007, CWFNJ 2015, BCM no date). Larger black locusts are also favorable (Michael Fishman, personal communication).

Trees used for roosting by Indiana bats are typically exposed to the sun (Humphrey et al. 1977; Kurta et al. 1993), although shaded trees were used during hot summer weather (Gardner et al. 1991) and by northern bats (Foster & Kurta 1999). Individual Indiana bats and northern bats may change roost trees frequently (Kurta et al. 1993, Foster & Kurta 1999). Northern bats moved as far as 2 km between roost trees (Foster & Kurta 1999). Bats may migrate considerable distances between hibernacula (hibernating places) and summer habitats, although this does not necessarily imply that suitable summer roosts are in short supply.

See comments on forest restoration and bats in the tree bats account. Lumsden et al. (2005) found that isolated (i.e., not in forest) trees in rural areas of Australia were important foraging locations for insectivorous bats in Australia.

Food

The cave bats forage on the wing over many kinds of habitats. Aquatic and wetland habitats, and forest edges, are often important foraging habitats, presumably because more night or twilight-flying insects of particular kinds are available there. Indiana bat foraging was associated with trees, especially in riparian areas (Humphrey et al. 1977).

The cave bats eat many kinds of insects with diet varying by place and time. Moths are often the most common prey of Indiana bat, for example, although many other taxa are consumed and a taxon other than moths may be most common (Whitaker & Hamilton 1998). Northern bat may also be a moth specialist, but also eats other taxa of insects as well as spiders (the last thought to be gleaned from leaves) (Whitaker & Hamilton 1998). Little brown bat is partial to chironomid midges and takes many other insects as well (Whitaker & Hamilton 1998).

Predators

Various mesocarnivores, including raccoon, “skunk” (striped skunk?), and house cat eat cave bats, and other predators, such as snakes and predatory birds, are thought to take bats too

(Whitaker & Hamilton 1998). Predators are not believed a major cause of mortality, relative to disease, wind turbines, pesticides, and occasionally vandalism in hibernacula.

Invasive Species Threats

It seems unlikely that known nonnative predators would present a significant threat to SGCN cave bats, although free-ranging or feral house cats might be occasionally important (see Whitaker & Hamilton re house cat).

We have seen no information indicating that nonnative insect prey or potential prey are a threat. It is possible that an abundant, nonnative, night-flying insect could be toxic to bats. The toxic nonnative browntail moth *Euproctis chrysorrhoea* comes to mind; this species has undergone a longterm decline and is now very restricted geographically (Elkinton et al. 2006). Another possible threat would be an unpalatable nonnative insect that replaces native insects that are a significant part of the prey base.

Although bats roost in many tree species and many sizes of both live and dead trees, because summer roost and nursery microhabitats must have particular characteristics it is possible that replacement of the most intensively used native tree species by nonnative trees could affect SGCN cave bats. Native shagbark hickory (*Carya ovata*) and nonnative black locust (*Robinia pseudoacacia*) are commonly used by Indiana bat. Although there is some ambiguity (see, e.g., NatureServe 2014; Weldy et al. 2014; USDA 2014), black locust is probably native not too far south of New York but not in our region. Large black locusts with deeply furrowed bark and voids beneath loose bark are the locusts used by Indiana bat. Black locust appears to have a positive effect on Indiana bat, and perhaps the other SGCN cave bats as well. Although we have not found any relevant information, it is possible that replacement of favorable native tree species by relatively smooth-barked nonnative species (such as tree-of-heaven *Ailanthus altissima*, bird cherry (*Prunus avium*), honey locust (*Gleditsia triacanthos*), princess-tree (*Paulownia tomentosa*) or by non-arborescent invasive plants, could be adverse to SGCN cave bats.

Ash mortality caused by emerald ash borer might adversely affect some summer roost habitats, for example, if bats are roosting in green (red) ash trees in swamps. Also, large, open-grown white ash (*Fraxinus americana*) with cavities or bark damage are fairly common in forest edges and open areas. These trees, vulnerable to EAB, could be important for cave bat roosting or foraging.

Overgrowth of roost trees by nonnative vines, such as Oriental bittersweet (*Celastrus orbiculatus*), mile-a-minute (*Polygonum perfoliatum*), or wintercreeper (*Euonymus fortunei*), as well as certin native vines, e.g., poison-ivy (*Toxicodendron radicans*) or Virginia creeper (*Parthenocissus* spp.), might adversely affect thermal characteristics of roosts.

Little brown bats have been reported caught on burdock (*Arctium*) burs. All three *Arctium* species in our region are nonnative (USDA Plants Database 2014). Bat fouling by burdock is probably rare inasmuch as bats are very good at avoiding obstacles. Miller and Harry (2014) considered burdock a threat to northern long-eared bat in Wisconsin but did not present data.

Management of Threats

In the absence of other information, it might be prudent to hand-pull burdock plants close to known bat hibernacula in caves and mines. Similarly, free-ranging and feral house cats should not be allowed near known underground hibernacula (of course the best management of house cats is to keep them indoors).

Shagbark hickories, including small trees (because they are the large trees of the future), should be protected where feasible from encroachment of smooth-barked nonnative trees. However, we do not see replacement of native trees by nonnative trees as an imminent threat to SGCN cave bats. Other, non-IS, threats to habitat quality, including land development and certain forestry practices (Gardner et al. 1991; Callahan et al. 1997; Sheets 2010), and, of course, disease, are probably far greater threats.

Small-Footed Bat (*Myotis leibii*)

This species is profiled separately from the other SGCN *Myotis* bats because its roost microhabitats are often in rocks and rarely in trees. Small-footed bat is less affected by white nose syndrome than the other three SGCN cave bats.

Habitat

Small-footed bat favors mountainous or rocky regions, overwinters in caves, mines, and talus, and in summer roosts in crevices or holes in rocks, soil, trees, buildings, or bridges (Whitaker & Hamilton 1998; Thomson 2013). Rock crevices appear to be the most commonly used roosting microhabitat. Summer roosts of this species in West Virginia were in talus and cliffs exposed to the sun and near vegetation and water (Johnson et al. 2011). Small-footed bats changed roosts frequently (Johnson et al. 2011). Roosting may occur in rock fissures as little as 1 cm wide.

Food

Moths (Lepidoptera), true flies (Diptera), and beetles (Coleoptera) predominated in a diet study of small-footed bat in New Hampshire; spiders and crickets were also taken, presumably by gleaning these non-flying arthropods (Moosman et al. 2007). In fall in West Virginia, moths were the most prevalent food item, among diverse groups of insects (Johnson & Gates 2007).

Predators

We did not find information on predators of this species. It seems likely that the same mammals and birds that prey on other cave bats would also prey on small-footed bat. Although snakes may be more common in the rock and soil habitats favored by small-footed bat, the small size of the crevices in which this species roosts may help protect it from predation.

Invasive Species Threats

We found no specific information on IS threats to the small-footed bat. Potential threats posed by nonnative prey or predator species would be similar to threats to other cave bats (see), with variation due to the small size of the small-footed bat and its rock and soil roosting behavior. Overgrowth and shading of talus, cliff, and soil bank roosting habitats by nonnative herbs, vines, shrubs, or trees might be a threat in some areas inasmuch as small-footed bat selects roost fissures in sun-exposed rocks.

Management of Threats

Shading nonnative (or native) plants may be removed from known small-footed bat roosting habitats if this does not cause unacceptable harm to other elements of conservation concern. Of course, most small-footed bat roosts probably go undetected.

New England Cottontail *(Sylvilagus transitionalis)*

The decline of New England cottontail (NEC) in the Northeast has been attributed to the stocking and expansion of the larger eastern cottontail (*S. floridanus)* (Litvaitis & Litvaitis 1996, reviewed in Whitaker & Hamilton 1998) as well as the loss of "early successional" habitat. Because both the New England cottontail and the eastern cottontail often occur together, and the similarity of appearance, much confusion surrounds attempts to distinguish them in the field (Whitaker & Hamilton 1998). A small black dot typically marks the forehead of the New England cottontail; nonetheless, definitive identifications should be made with recourse to the skull or DNA (e.g., in fresh scats).

Occurrence in Lower Hudson PRISM

The extant global range of NEC extends from the Hudson River and Cape Cod to southern Maine in five disjunct regions where there was formerly a much more extensive and continuous range (Anonymous 2011). There are populations in Dutchess and Putnam counties, and probably eastern Westchester. Eastern New York and northwestern Connecticut may contain the largest remaining populations. An old specimen in the mammal collection of the American Museum of Natural History is catalogued as a New England cottontail collected in Harriman State Park (Orange County). The current concept of NEC locates its range east of the Hudson River, and the closely related Appalachian cottontail (*Sylvilagus obscurus*) west of the Hudson but with a large area supporting no native cottontail just west of the Hudson and including the entire area of the LH PRISM west of the Hudson. The identification of the specimen and its label data should be checked.

Habitat

New England cottontails do best in patches of five hectares or larger of dense thickets of shrubs and small trees (Anonymous 2011). NEC depends on this dense woody vegetation for food and refuge from predation. These shrubland habitats have declined by 86 percent since the late 19th century (Fergus 2013).

Diet

NEC eats green plant material as well as fruits in summer, and woody material in winter (Whitaker & Hamilton 1998). Recent studies indicate that eastern cottontail is able to use a wider variety of foods than NEC (Nottage 1972, reviewed in Whitaker & Hamilton 1998).

Predators

Predation is considered the major cause of death for NEC, and the most important predators are coyote, red fox, bobcat, and owls (Arbuthnot 2008).

Invasive Species Interactions

Eastern cottontail was introduced from the Midwest from 1920 to 1950 into habitat occupied by New England cottontail in order to augment game populations (Arbuthnot 2008). Competition from eastern cottontail is considered a major factor in the decline of NEC (Arbuthnot 2008). The eastern cottontail was found throughout eastern US except for northern New York and northern New England and is now moving into the southern Adirondacks (Whitaker & Hamilton 1998). Prior to 1930, the occurrence of eastern cottontails in New England was only in northwestern Connecticut. This introduced species has since invaded all of Connecticut, Rhode Island, eastern Vermont and southern New Hampshire (Litvaitis & Litvaitis 1996, reviewed in Whitaker & Hamilton 1998).

Japanese barberry, Oriental bittersweet, multiflora rose, “shrub honeysuckles” (presumably *Lonicera* X *bella* or its parent species), and “buckthorn” (*Frangula alnus?)* are common in New England cottontail habitats (Novak 2011). Multiflora rose thickets provide good habitat for New England cottontail (Fuller & Novak 2009) including where the rose occurs in a woodland understorey (Litvaitis et al. 2013). “Buckthorn” does not seem to provide the right habitat structure and, inasmuch as it is toxic to certain other vertebrates, could be toxic to New England cottontail (del Puerto 2011). Multiflora rose is eaten by New England cottontail and appears to be nutritionally suitable (Novak 2011). Many of these nonnative shrubs and vines are capable of forming especially dense thickets that may be favorable for NEC.

Management Considerations

The continued decline of shrubby old field and young forest habitat is strongly linked with the loss of NEC. Federal and state agencies, and private landowners under their supervision, are restoring shrubland habitat for NEC and other shrubland wildlife with selective tree removal, clear-cutting, and prescribed burning (Burk 2014). Minimum patch sizes of 5-10 ha (12-25 acres) have been recommended for NEC (Arbuthnot 2008; Anonymous 2011; Fergus 2013). Shrubland, especially on fertile mesic soils, may need management at intervals to prevent development of forest with a reduced shrub layer; shrubland on infertile, xeric, or acidic soils (e.g., on rocky crests or sandy barrens) may persist longer without active management.

There are contradictory statements concerning nonnative woody plants in various guidelines for managing NEC habitat; this may arise because of federal and state guidance for removal of IS. Litvaitis et al. (2013) recommended leaving nonnative shrubs such as multiflora rose in New England cottontail habitat, if they are not creating a "monoculture" or threatening to spread to adjacent habitats where they do not occur. Litvaitis et al. considered a mixture of native shrubs and certain nonnative shrubs beneficial to New England cottontail.

Although the eastern cottontail is nonnative or largely so in eastern New York and New England, and competition with eastern cottontail is believed to be a threat to NEC, agencies apparently do not advocate control of eastern cottontail because of its game value. It is believed that creation and maintenance of high quality thicket habitat for NEC will allow NEC to persist despite competition and predation.

River Otter (*Lontra canadensis [Lutra canadensis]*)

The river otter is a large, aquatic member of the weasel family that lives in wild and developed areas although often inconspicuous.

Occurrence in Lower Hudson PRISM Region

The river otter occurs in Dutchess, Ulster, and Orange counties (Whitaker & Hamilton 1998) and is surely present in Putnam and Rockland as well. It would not be surprising to find this species in Westchester and the Bronx.

Habitat

River otters favor fresh water and occur in lakes and large rivers with abundant aquatic vegetation (Whitaker & Hamilton 1998). River otters also frequent freshwater tidal and brackish waters of estuaries, wetlands, ponds, lakes, and modest-size streams (Erik Kiviat, personal observations).

River otter habitat must include adequate cover for escape, resting and den sites. River otters commonly den in hollow trunks of large trees, abandoned beaver dens and hollow logs (Tesky 1993). Understorey bank cover is important and areas in Montana with less than 25% cover were less likely to be used by river otter (Tesky 1993). Riparian habitat quality for rivers inhabited by European otters (*Lutra lutra)* was dependent on an abundance of bankside vegetation, channel vegetation and mature trees (Bedford 2009).

Diet

River otters primarily eat fish but are opportunistic feeders, consuming insects, crustaceans (crayfish), freshwater mussels, amphibians, turtles, rodents, and birds, as well as aquatic insects, and plant material including blueberries, privet (presumably *Ligustrum*) fruits, and rose hips (Whitaker & Hamilton 1998; Skyer 2006; Razzano 2013). They feed more heavily on abundant, slower moving fish that include suckers, chubs, daces, darters and catfish and schooling species like bluegills and sunfish but also consume trout. An analysis of scat collected from a population of river otter reintroduced in western New York found the most frequent food was fish in 70.4% of the scat, followed by crayfish with 53.5%. Half of the fish identified in the scat were sunfish (35.7%) and carp (18.3%) (Skyer 2006). Other major prey categories included plant matter (25.3%) identified as corn, privet berries and bark (Skyer 2006).

Predators

The river otter is considered an apex predator with few predators, although otters occasionally fall prey to bobcat, eagles, coyote, and domestic dog (Razzano 2013) and are especially vulnerable when traveling overland and away from water (Tesky 1993).

Invasive Species Interactions

Otters are opportunistic feeders and some of their Eurasian counterparts have adapted to feeding on novel prey that includes invasive species. European otters (*Lutra lutra)* were reported feeding on the nonnative mitten crab (*Eriocheir sinensis*) in a nature preserve in Germany (Weber 2008). Small-clawed otters (*Aonyx cinereus)* found in Sumatra foraged on nonnative golden apple snails (*Pomacea canaliculata)* in rice fields *(*Aadrean et al. 2011). New York river otters preyed on common carp (*Cyprinus carpio*) and brown trout (*Salmo trutta*), both nonnative (e.g., Skyer 2006); there is no indication that this is harmful to otters.

Otters have been observed in nontidal marsh pool (New Jersey) and a stream (LH PRISM region) habitat where common reed dominated the emergent vegetation (Erik Kiviat, personal observations). Common reed expansion in ponds (e.g., Lily Pond, Orange County) might reduce habitat available to river otters and their prey (Alan Wells, personal communication).

Management Considerations

As a furbearer in New York, the river otter is managed by the DEC. Infilling of ponds or marsh pools by common reed or other invasive plants should be monitored by property managers, and decisions about reed management should balance its positive and negative habitat functions for various species as well as non-habitat ecosystem services provided by reed (Kiviat 2013).

Freshwater Mussels (Pearly Mussels, Unionoida)

David Strayer collaborated in preparing this account.

The eastern U.S. is a global megadiversity region for freshwater mussels, and this is the most endangered taxon known on the continent (Stein et al. 2000). Freshwater mussels are threatened by hydrological alterations, siltation, other forms of pollution, and in the case of certain species by declines in the populations of the fishes that host the immature stage (glochidia). Formerly, certain species were adversely affected by harvest for food and the shell button industry (Strayer & Jirka 1997).

Common Name	Scientific Name
Alewife floater	*Anodonta implicata*
Brook floater	*Alasmidonta varicosa*
Dwarf wedge mussel	*Alasmidonta heterodon*
Eastern pearlshell	*Margaritifera margaritifera*
Eastern pondmussel	*Ligumia nasuta*
Tidewater mucket	*Leptodea ochracea*
Yellow lamp mussel	*Lampsilis cariosa*

Habitat

The mussel SGCNs occur in medium to large streams, sometimes smaller streams, and in the freshwater tidal Hudson River. Tidewater mucket also occurs in coastal ponds (Strayer & Jirka 1997), although it has not been found in that habitat in the LH PRISM region. Eastern pondmussel may occur in canals (Strayer & Jirka 1997).

Invasive Species Interactions

Zebra mussel (*Dreissena polymorpha*) may attach to the larger freshwater mussels in large numbers, and in combination with other environmental stressors was causing freshwater mussels to disappear from zebra mussel-invaded environments in the Mississippi River drainage (Ricciardi et al. 1998; also see Van Appledorn & Bach 2007). The negative impact of zebra mussel on freshwater mussels is widespread (Strayer 1999). Tidewater mucket declined in the fresh-tidal Hudson River after the buildup of the zebra mussel population (Strayer & Jirka 1997). Zebra mussels are not parasitic but are capable of smothering freshwater mussels and also competing with suspension-feeding species for food; the latter process may be more harmful (Strayer & Malcom 2014). The zebra mussel occurs in the fresh-tidal Hudson River but not currently in nontidal streams or lakes of our region.

Native freshwater mussels, including alewife floater and tidewater mucket, underwent serious declines in the freshwater tidal Hudson River, and the zebra mussel is believed a major factor in those declines. Recently the Hudson River zebra mussel population declined and there was an indication of freshwater mussel recovery (Strayer & Malcom 2014). However, more recent data show continuing declines of freshwater mussels (David Strayer, personal communication).

Quagga mussel (*Dreissena rostriformis bugensis*), another Old World bivalve, also occurs in the Hudson River but so far is uncommon (Strayer & Malcom 2014). It is unclear whether quagga mussels will affect native freshwater mussels.

In a laboratory study, the nonnative rusty crayfish (*Orconectes rusticus*) depredated freshwater mussels of relatively small sizes (Klocker & Strayer 2004). The threat to freshwater mussels in the wild is undetermined, although the rusty crayfish population overlaps widely with the ranges of freshwater mussels in the LH PRISM region including the brook floater population in the Shawangunk Kill (David Strayer, personal communication).

The freshwater drum (*Aplodinotus grunniens*), a nonnative fish of recent occurrence in the Hudson River estuary, is a mollusk feeder and could have a detrimental effect on freshwater mussels (Strayer, personal communication).

Currently, other IS threats to freshwater mussels are unknown (Strayer, personal communication).

Management

There is currently no feasible safe management technique for free-living dreissenids (zebra mussel and quagga mussel). Because zebra mussel, however, is associated with hard substrates (rocks, timbers, etc.), tidal marshes and other shallow water habitats with soft muddy or sandy bottoms may serve as refuges for freshwater mussels which are adapted to soft substrates. This phenomenon was documented in Lake St. Clair, Michigan (Zanatta et al. 2002). Possibly soft substrate habitat for freshwater mussels could be created in habitat management (restoration) projects.

Similarly, there is no management technique for rusty crayfish.

Recommendations

Because of the current infeasibility of controlling dreissenids (except in pipes), we recommend no management action. It is possible that biocontrol capability will be developed eventually inasmuch as dreissenids cause great expense by fouling pipes and other equipment.

Blue Mussel (*Mytilus edulis*)

The southern range limit of the blue mussel has receded northward 350 km during the past 50 years due to rising summer temperatures (Jones et al. 2010). Blue mussels are also affected by heavy metals (Rault et al. 2013) and oil (Ruiz et al. 2014), among other anthropogenic impacts. Moreover, acidification of seawater from increasing atmospheric concentration of carbon dioxide may affect blue mussels (Gazeau et al. 2010).

Habitat

The blue mussel lives in brackish to saline waters from the intertidal zone to deep water. It attaches to rocks, pilings, and other hard surfaces, and may form extensive shoals where mudflats contain sufficient rocks or shells (Gosner 1978). Larvae (veligers) are planktonic.

Food

Blue mussels filter algae from the water (Riisgård et al. 2011).

Predators

Many large invertebrates, birds, and fishes prey on blue mussels.

Invasive Species Threats

In the Gulf of Maine, the nonnative green crab (*Carcinus maenas*) preys on blue mussels, but is somewhat deterred by the nonnative carpet sea squirt (*Didemnum vexillum*) (Auker et al. 2014). Predation by the nonnative shore crab (*Hemigrapsus sanguineus*) may cause significant mortality of blue mussels in Long Island Sound (Brousseau et al. 2014). It is not yet possible to sort out the relative harms caused to blue mussels by invasive species compared to other anthropogenic impacts.

Management of Threats

Information is insufficient to recommend any particular management. Furthermore, management of tidal wetlands and shallows typically is the province of state and federal agencies.

Freshwater snails (three species)

David Strayer collaborated in preparing this account.

Three freshwater gastropods (snails) on the SGCN list occur, or could occur, in the LH PRISM region.

Common name	Scientific name
Canadian duskysnail	*Lyogyrus walkeri (=Amnicola walkeri)*
Fringed valvata	*Valvata lewisi*
Mossy valvata	*Valvata sincera*

These are all small and poorly known species. Mossy valvata was reported from the Hudson River at the northern end of the LH PRISM region by Strayer (1987).

The mossy valvata is associated with large water bodies and submergent vegetation in New York (Jokinen 1992). Mossy valvata was found in mats of filamentous algae near shore in a small, hard water, Connecticut Lake (Jokinen 1983); however, Jokinen 1983 did not separate mossy valvata from fringed valvata thus it is unclear which species she was referring to.

Canadian dusky snail occurs in varied stream and lake habitats in Michigan (Anonymous, no date).

Food

As is common among small freshwater snails, we presume these species scrape biofilms from submerged surfaces.

Predators

Probably a variety of larger invertebrates and small vertebrates.

Invasive Species Interactions

Unknown. There could be competition from nonnative aquatic snails, mortality from introduced predators, or habitat degradation due to nonnative aquatic weeds. One freshwater snail species in Michigan was adversely affected by zebra mussels (Van Appledorn & Bach 2007). However, other studies found that freshwater snails were benefited by zebra mussels (Stewart & Haynes 1994; Ricciardi et al. 1997; Stewart et al. 1998). Snails are important prey of the nonnative rusty crayfish (*Orconectes rusticus*) which is spreading through the LH PRISM region (David Strayer, personal communication). Rare snails might also be affected by habitat changes due to nonnative submergent plants, or interactions with nonnative aquatic snails such as the New Zealand mudsnail (*Potamopyrgus antipodarum = P. jenkinsi*) or Chinese mystery snail (*Cipangopaludina chinensis malleata*).

Management Considerations

Zebra mussel management is an issue that is being addressed at a larger scale across North America. We are unable to make specific recommendations for the LH PRISM region.

Lance Aplexa (*Aplexa elongata*)

David Strayer collaborated in preparing this account.

Habitat

The lance aplexa lives in woodland pools where it is often overlooked; it may be more common than the SGCN designation suggests (David Strayer, personal communication). This species has been recorded in Dutchess, Ulster, and Westchester counties (Strayer 1987) and is probably present in most or all of the other LH PRISM counties.

Intermittent, and also perennial, woodland pools (a subset of "vernal pools") are crucial habitats for certain amphibian species and also important for many other organisms (Kiviat and Stevens 2001). Because woodland pools are mostly small and shallow, and many are not even captured in wetland mapping or wetland laws and regulations, they are extremely vulnerable to degradation and loss from human activities.

Diet

This freshwater snail presumably scrapes microorganisms and detritus off submerged surfaces as most freshwater snails do.

Predators

Not specifically known, but presumed to be birds and turtles, and possibly small mammals, marbled salamander larvae, leeches, and other invertebrates.

Invasive Species Interactions

Not known. Nonnative predators are a possibility. Feral swine rooting for food in woodland pools would alter this ecosystem and potentially affect lance aplexa and many other species, perhaps some negatively and some positively.

Mortality of ashes, due to emerald ash borer infestation, could affect shade, chemistry, leaf litter, and coarse woody debris at the edge of, and within, some woodland pools; we don't know if this would be unfavorable or favorable for the lance aplexa. Common reed (*Phragmites*) or other nonnative weeds colonizing woodland pools could alter habitat sufficiently to affect lance aplexa.

Management Considerations

No recommendations other than that inconspicuous organisms such as snails need much more research and monitoring to allow conservation where it is needed.

Ribbed Mussel (*Geukensia demissa*)

Habitat

Ribbed mussels live in the intertidal zone of brackish and saline marshes (Gosner 1978). Larvae (veligers) are planktonic.

Food

Ribbed mussels filter phytoplankton, bacteria, and plant detritus from the water (Galimany et al. 2013).

Predators

Fishes and crabs prey on ribbed mussels (Scyphers et al. 2014). There are presumably bird and mammal predators as well.

Invasive Species Threats

Green crabs (*Carcinus maenas*) and shore crabs (*Hemigrapsus sanguineus*) both preyed on ribbed mussels in Long Island salt marshes and when crabs are present at high densities may have an additive effect that depresses mussel populations (Peterson et al. 2014).

McClary (2004) found larger numbers of ribbed mussels near *Phragmites* than near *Spartina* at a site on the Hackensack River estuary in northeastern New Jersey.

Management of Threats

It is unclear what management, if any, would be appropriate. Reduction of threats from nonnative crabs may require development of biological control if that is possible.

Summary of Results

Table 2 shows the IS - SGCN interactions mentioned in the species accounts. These interactions are classified in three categories:

A. At least one published, evidence-based threat (or benefit) to an SGCN (species or group)

B. Assertion(s) of threat(s) or benefit(s) in the literature or expert consultations for which we did not find supporting data studies

C. Our hypothesis(es) of threats or benefits to SGCN (species or groups) that we did not find mentioned in the literature.

Some IS pertain to more than one SGCN or more than one of the above three categories. We have exercised judgment concerning the categories of threat and other information summarized in Table 2, because the available information is often ambiguous or without detail. Most of the 19 unspecified "Plants" entries in Table 2 pertain to nonnative plants overgrowing bare or partly-bare soil habitats needed by nesting birds, basking and nesting reptiles, or insects.

Number of Species of Greatest Conservation Need known to occur in the Lower Hudson PRISM region: 146.

Number of those 146 SGCN for which we identified one or more documented, evidence-based threat from an invasive species: 67 (Category A).

Number of those 146 SGCN for which we found one or more assertions of IS threats that did not seem to be based on available scientific data: 44 (Category B).

Number of those 146 SGCN for which we hypothesized one or more IS threats or benefits: 66 (Category C).

We could have posed additional hypotheses of IS effects (Category C; for example, rats are potential predators of the eggs of most species of turtles and ground-nesting birds). Also, with more searching of the literature and consulting with researchers, we could probably have learned of more documented effects (Category A) as well as undocumented assertions (B). Nonetheless, many SGCN (species or groups) came up without IS interactions in our survey.

Negative (-) interactions are much more common than positive (+) interactions in Table 2. This could be because IS *a priori* tend to be more harmful than beneficial to rare native animals. But it also could be that researchers and naturalists are expecting more, or looking harder for, negative interactions. We think it is a combination of the two.

Table 2. Invasive species (IS) of animals or plants and their negative or positive effects on Species of Greatest Conservation Need (SGCN) that occur in the Lower Hudson PRISM region, summarized from the species accounts in this report. A = IS effect based on research data; B = asserted IS effect with little or no evidence; C = hypothetical IS effect. – indicates negative effect(s) of an IS, + indicates positive effects of an IS.

		Category of effect		
Invasive species	**SGCN**	**A**	**B**	**C**
Adelgid, woolly	Ruffed grouse		-	
Alder, European	Prothonotary warbler		-	
Animals, aquatic	River otter		+	
Autumn-olive	Kentucky warbler		-	
Barberry, Japanese	Eastern box turtle	+		
Bass, black (2 spp.)	Northern cricket frog		-	
Beetle, Asian long-horned	Colonial- nesting herons		-	
Beetle, Asian long-horned	Prothonotary warbler			-
Borer, emerald ash	Cave bats			-
Borer, emerald ash	Lance aplexa			-
Borer, emerald ash	Prothonotary warbler			-
“Buckthorn”	New England cottontail			-
Buckthorn, smooth	Henry’s elfin	+		
Buckthorns	Canada warbler		-	
Burdock	Cave bats			-
Cat, house	Northern bobwhite			-
Cat, house	Cave bats			-
Cat, house	Common nighthawk		-	
Cat, house	Shrubland birds	-		
Cat, house	Deciduous forest songbirds			-
Cat, house	Nonvenomous snakes			

Cat, house	Wood turtle		-	
Compsilura concinnata	Regal moth		-	
Cottontail, eastern	New England cottontail	-		
Crab, green	Blue mussel	-		
Crab, shore	Blue mussel	-		
Crabs	Ribbed mussel	-		
Crayfish, rusty	Freshwater mussels	-		
Crayfish, rusty	Freshwater snails	-		
Crayfishes	Northern cricket frog		-	
Crown-vetch	Wild indigo duskywing	+		
Dog, domestic	Northern bobwhite			-
Dog, domestic	Eastern box turtle			-
Dog, domestic	Common nighthawk			-
Dog, domestic	Wood turtle			-
Drum, freshwater	Freshwater mussels			-
Earthworms	Nonvenomous snakes		+	
Earthworms	Wood turtle	+		
Earthworms	American woodcock	+		
Fishes	Dragonflies of lentic habitats			-
Fishes, piscivorous	Estuarine associates of SAV			-
Fishes, predatory	Northern red salamander			-
Forbs	Grassland birds		-	
Goldfish	Osprey	+		
Grass	Northern bobwhite		+	
Grass, reed canary	Bog turtle	-		
Grass, reed canary	Dragonflies of lentic habitats	-		
Grasses	Northern bobwhite	-		
Gypsy moth	Ruffed grouse		-	
Hare, European	Cooper's hawk	+		
Herbs	Wood turtle		-	
Honeysuckle, Amur	Eastern box turtle	-		
Honeysuckle, Japanese	Amer. black duck	+		
Honeysuckles, shrub	Wood thrush	-		
Hydrilla	Bald eagle		-	
Knotweed, Japanese	Louisiana waterthrush			-
Lizard, wall	Lizards			-
Locust, black	Cave bats	+		
Loosestrife, purple	Blanding's turtle		-	+
Loosestrife, purple	Bog turtle	-		+
Macroinvertebrates	Blanding's turtle			+
Mile-a-minute	Blanding's turtle			-
Mile-a-minute	Colonial-nesting herons		-	
Mollusks	Northern map turtle		+	-
Mollusks	Common musk turtle	+		-
Moth, browntail	Cave bats			-
Moth, browntail	Whip-poor-will			-
Moth, Gypsy	Timber rattlesnake		-	
Mussel, zebra	Freshwater mussels	-		
Mussel, zebra	Freshwater snails	- +		

Pigeon, rock	Peregrine	+		
Plants	Freshwater snails			-
Plants	Lizards			-
Plants	Longtail salamander			-
Plants	Common musk turtle		-	
Plants	Common nighthawk			-
Plants	Osprey			-
Plants	American oystercatcher			-
Plants	Timber rattlesnake			-
Plants	Small-footed bat			-
Plants	Eastern spadefoot			-
Plants	Spotted turtle	+	-	
Plants	Appalachian tiger beetle			-
Plants	Tree bats			-
Plants	Whip-poor-will			-
Plants, aquatic	Northern map turtle			-
Plants, woody	Colonial nesting herons		-	
Plants, woody	Grassland birds		-	
Plants, woody	Shrubland birds	- +		
Plants, woody	Allegheny woodrat		+	
Princess-tree	Allegheny woodrat	+		
Rat, Norway	Barn owl	+-		
Rat, Norway	Northern map turtle			-
Rats	Shrubland birds			-
Rats	Wood turtle			-
Reed, common	Amer. black duck	-		+
Reed, common	Blanding’s turtle		-	
Reed, common	Bog turtle	-	+	
Reed, common	Common pipefish	+		
Reed, common	Fowler’s toad	-		
Reed, common	Freshwater marsh birds	- +		
Reed, common	Sedge wren	-		
Reed, common	Lance aplexa			-
Reed, common	Atlantic Coast leopard frog		+	
Reed, common	Marbled salamander			-
Reed, common	Mummichog	-		
Reed, common	Needham’s skimmer	+		
Reed, common	Forest dragonflies		-	
Reed, common	Dragonflies of lentic habitats		-	
Reed, common	American oystercatcher			-
Reed, common	Prothonotary warbler		-	
Reed, common	Ribbed mussel	+		
Reed, common	River otter		-	
Reed, common	Colonial-nesting herons	+		
Reed, common	Saltmarsh sparrows	-		
Reed, common	Golden-winged warbler	-		
Reed, common	Spotfin killifish	+		-
Reed, common	Northern harrier	+		
Reed, common	Wood turtle	-		

Rodents	Northern copperhead			+
Rose, multiflora	Kentucky warbler		-	
Rose, multiflora	New England cottontail	+		
Sea squirt, carpet	Blue mussel		+	
Shad, gizzard	Bald eagle		+	
Shrubs	Northern copperhead	-		
Shrubs	American woodcock	-		
Slider, red-eared	Northern map turtle			-
Slugs	Bog turtle	+		
Slugs	Spotted turtle	+		
Snails	Freshwater snails			-
Sparrow, house	Sharp-shinned hawk	-		
Sparrow, house	Prothonotary warbler			-
Starling, European	Prothonotary warbler			-
Starling, European	Red-headed woodpecker		-	
Stiltgrass	Blue-spotted salamander			-
Stiltgrass	Grassland birds		-	
Swine, feral	Nonvenomous snakes		-	
Swine, feral	Northern bobwhite	-		
Swine, feral	Bog turtle	-		
Swine, feral	Eastern box turtle	-		
Swine, feral	Northern copperhead	-		
Swine, feral	Grassland birds		-	
Swine, feral	Ruffed grouse	-		
Swine, feral	Lance aplexa			-
Swine, feral	Marbled salamander			-
Swine, feral	Common musk turtle	-		
Swine, feral	Northern red salamander		-	
Swine, feral	Timber rattlesnake			-
Swine, feral	Eastern spadefoot	-		
Swine, feral	Wood turtle	-		
Tree-of-heaven	Colonial-nesting herons			-
Tree-of-heaven	Prothonotary warbler			-
Trees	Dragonflies of lentic habitats			-
Trees, smooth-barked	Cave bats			-
Trout, brown	Brook trout	-		
Trout, rainbow	Brook trout	-		
Trouts	Northern red salamander			-
Vines	Eastern box turtle			-
Vines	Cave bats			-
Vines	Grassland birds		-	
Water-chestnut	Bald eagle		-	
Water-chestnut	Fourspine stickleback	+		
Water-chestnut	Osprey		-	
Weatherfish	Estuarine associates of SAV			-
Weeds of open ground	Nonvenomous snakes			-
Weeds of open ground	Blanding's turtle	-		

Prioritizing Management

There are many documented and hypothesized IS threats to SGCN. Land managers often want to make decisions about managing IS where management will have the greatest benefit to biodiversity conservation. We have not created a fixed list of management recommendations because management goals and local situations are highly variable. Regarding the management of IS that pose threats to the SGCN discussed here, we recommend instead that priorities be set with reference to the following considerations (questions), not necessarily in the order given. This list of considerations is followed by a short list of selected IS - SGCN interactions which, based on our discussions in this report and our experience as field biologists, seem most deserving of management attention. (Some IS have beneficial effects on certain SGCN [see Table 2 and the species accounts]. We do not recommend introducing or propagating such IS, although in some cases the partial removal of a large population or stand can optimize the positive and negative effects.)

1. Does the manager have permission to manage on the site, and logistical access for, e.g., equipment and workers?

2. Does the SGCN occur on the site, or is there potential habitat that could support a shift or expansion of a nearby population? Has the species been correctly identified (it may be appropriate to submit voucher photographs to an expert)?

2a. Is the habitat or potential habitat of the SGCN an uncommon habitat in the region (e.g., a fen), and is the habitat especially extensive or in particularly good condition?

2b. Is the LH PRISM region a "responsibility" region for this SGCN (that is, does our region have a large or especially viable population that has greater-than-region importance)?

3. Does the IS occur onsite or nearby such that it could expand onto the site? (The most easily managed situations are those in which an IS of concern is just becoming established in an environment of concern. In these cases, the Early Detection, Rapid Response [EDRR] paradigm can be invoked.) Is expansion or consolidation of the IS an imminent threat to the SGCN? Many IS remain indefinitely at low levels, whereas some spread rapidly or remain at low levels then suddenly increase. Monitoring or examination of historic information may be appropriate. Has the IS been correctly identified (it may be appropriate to collect and submit voucher specimens to an expert for verification; we recommend this for many plants and invertebrates, among other taxa).

4. Is the IS (or the SGCN) subject to a large-scale management program that supercedes local efforts, or with which the manager should coordinate? (These are typically federal or state programs, occasionally widespread efforts coordinated by a regional group such as a PRISM. See below. There are also large-scale NGO education campaigns, such as those that urge cat owners to keep cats indoors and spay or "neuter" them, and public-private campaigns to reduce rat populations.)

4a. Is the IS an especially “noxious” species that is difficult to manage, capable of spreading and consolidating rapidly, allelopathic (emitting chemicals toxic to other organisms), or a species that fundamentally alters the structure of the habitat?

5. Are federal, state, or local permits required for the anticipated management? These might include federal or state endangered or threatened species permits, federal, state, or local wetlands permits, state stream disturbance permits, local tree ordinance permits, etc. Also, are licenses or certifications required for the workers performing management (e.g., DEC Pesticide Applicator certification)?

6. Is there a reasonable chance of management success, and will it be possible to sustain management? Rarely is a single management treatment effective, and many situations require treatments to be repeated weekly, annually, or at another interval.

7. Is restoration of soil, vegetation, hydrology, or another structural or functional feature of the habitat necessary (and feasible) in order to effectively manage the IS and maintain it at a harmless level? In some cases it is the underlying conditions rather than the IS that are at fault.

8. Would management have negative nontarget effects on the SGCN or other species of concern, onsite or offsite? These might, for example, include herbicide toxicity to nontarget species (Kiviat 2009), disturbance to soils caused by management workers, or loss of resources (e.g., food, nest sites, shade) for another species of concern. Some IS have benefits as well as detriments for rare native species, or provide non-habitat ecosystem services such as soil stabilization or carbon sequestration.

9. Would management activities pose hazards to the workers involved, or to people nearby? (Consider hazards such as poison-ivy, stinging insects, disease vectors, and pesticide toxicity.)

We do not present a specific decision-making process because there is so much idiosyncracy related to the location, management goals, species involved, and other human and non-human factors.

We do not recommend attempting to manage IS that are currently the focus of large-scale management efforts. Perhaps the best example is the DEC’s fledgling program to control feral swine in New York. This is an IS with the potential to affect many SGCN, notably the herpetofauna and ground-nesting birds, by preying on them and disturbing soil and vegetation. However, given the great mobility of feral swine and the difficulty of killing them, it makes more sense for the DEC to address this problem rather than local agencies or the managers of individual properties.

Analogously, some of the forest pests, such as emerald ash borer, Asian long-horned beetle, and hemlock woolly adelgid, are the subjects of active or developing federal and state control programs. Therefore we have deferred to these established efforts and we do not make recommendations for regional or local (LH PRISM) management of these threats. Mile-a-minute (*Persicaria perfoliata*), an invasive herbaceous vine that is becoming widespread in the LH

PRISM region, is also the subject of a biocontrol program. However, it may still be productive to control mile-a-minute locally until it is confirmed that biocontrol is effective.

Another example is the joint US Fish and Wildlife Service – DEC – private program to manage habitats for the bog turtle (federal Threatened, New York Endangered). These habitats, fens and wet meadows dominated by short vegetation, are subject to overgrowth by taller (> 1 m) native and nonnative plants. Current management involves prescribed livestock grazing, cutting, herbicide, and occasionally prescribed fire, in variable combinations. Because the bog turtle is a listed and stringently protected species, and its habitats are protected by state and federal wetlands laws, habitat management must be coordinated and permitted by state and federal agencies. Likewise, the DEC operates an intensive program of management for the bald eagle. There were reintroductions (including "hacking" of large nestlings), monitoring and protection of nest sites and their buffer zones, and public education. Foods, nest tree species, nest productivity, and other characteristics of the reestablished eagle population have been documented.

In some cases, there is no obvious management method available. One example is zebra mussels smothering or competing with native freshwater mussels. There are also nonnative species that are so abundant (and which present no documented harm to SGCN) that control would be impossible and probably a waste of resources. A few examples are house mouse (*Mus musculus*), faucet snail (*Bythinia tentaculata*), and many ruderal (roadside and waste ground) plants including scarlet pimpernel (*Anagallis arvensis*) and chicory (*Cichorium intybus*).

Here are some IS threats to particular SGCN that we think are worthy of consideration for management now. Each situation should be assessed to determine if the IS is harmful and the criteria listed above are met. Even though they stand out now, it would be desirable to have more research data on many of these interactions.

-Common reed overgrowth of amphibian breeding (larval) habitats in woodland pools and some marsh or swamp pools.

-Common reed "clogging" of surface waters that are the larval habitats of certain SGCN odonates.

-Overgrowth of turtle nesting habitats by common reed, spotted knapweed, sweet-clover, crown-vetch, potentially mile-a-minute, and other nonnative (and also native) weeds

-Overgrowth of critical basking habitats of timber rattlesnake (and other terrestrial reptiles) by IS such as angelica tree (*Aralia elata*), mile-a-minute, or other nonnative plants.

-Infilling of marsh pools by common reed, purple loosestrife, water-chestnut, European frog's-bit (*Hydrocharis morsus-ranae*), or other marsh plants where shallow pools are a critical resource for marsh and water birds.

If the decision-maker prefers to think about prospective IS management from the viewpoint of prioritizing the IS for treatment, Table 2 may be used as a tool to identify IS for consideration. If this approach is used, we urge that the SGCN and their habitats still be given priority. We remind policy-makers and managers that each local site, biota, and set of management goals needs to be considered in prioritizing and planning management. Although common reed has the largest number of documented, asserted, and hypothetical effects in Table 2, reed also potentially provides many habitat functions and non-habitat ecosystem services (Kiviat 2010, 2013) that are not discussed here, and some of its habitat functions potentially benefit SGCN. Similar detailed analyses have not been performed for most IS.

Procedure for Analyzing a Non-listed Rare Species

Below are our suggestions for identifying IS threats to a species that we have not addressed in this report. Such species could be additions to the revised SGCN list (in draft), regionally-rare species, or species that have special local significance in a nature preserve, park, or private property (such as an uncommon showy wildflower).

A preserve manager, for example, might decide that a regionally-rare animal (or a Westchester County-listed species) not on the New York SGCN list is nonetheless of conservation concern. Similarly, a manager or policy maker might want to manage a rare species in a taxon that was not reviewed for the SGCN list. Examples of such species might be the Mattox's clam shrimp (*Cyzicus [Caenestheriella] gynecia*; see Schmidt & Kiviat 2007), sycamore seed bug (*Belonochilus numenius*), rusty-patched bumble bee (*Bombus affinis*), nine-spotted lady beetle (*Coccinella novemnotata*), or eyed elater beetle (*Alaus oculatus*).

1. Ensure that the species in question occurs in your area by consulting experts. Published range maps are mostly generalized and may not accurately depict local distributions, and sometimes identifications are subject to errors.

2. Search the scientific literature via Google Scholar (see Methods, above) or a scientific literature database that may be available via an institutional library. Google Scholar links to abstracts of many publshed references and PDFs of entire items for a subset of references. You may need to visit a large scientific library or use interlibrary loan services to obtain important publications. (For particular groups of organisms there may be free online libraries, such as that of the Center for North American Herpetology. We recommend using the Web with caution, however, as there is much inaccurate information; Web sites operated by museums, professional societies, and university departments are among the most reliable.)

3. If possible, consult one or more naturalists or biologists who have conducted research on the species of interest, or related species. This is more important the less you find scientific literature discussing IS interactions with the taxon. The more experts you speak with the more you will learn. Experts may be authors of a published paper or Web page on the species of concern or its higher taxon (especially the genus or family).

4. Assess the available information (from steps 2-3, above) with reference to these criteria:

Assertions of IS effect are probably more accurate if they are based on quantitative research, or on many qualitative observations

Assertions might be more accurate if the research began from a null hypothesis of no difference between treatments (e.g., with and without the IS), rather than an alternate hypothesis that assumed an effect of the IS

Assertions are probably more accurate if they are based on a combination of wide-ranging field observations and experiments (e.g., experiments involving additions and removals of the IS)

Assertions are probably more accurate if they are based on longitudinal (before-after or long-term monitoring) studies rather than horizontal studies (space-for-time substitutions)

Assertions are probably more accurate if potential confounding factors were controlled for (e.g., other factors that could have caused the effect rather than the IS having caused the effect)

Assertions are probably more generalizable if the research or observations were conducted in multiple places and years

Assertions are probably more relevant if the research or observations were conducted in a geographically nearby area or an area with similar environmental conditions

5. Even if you are not a professional researcher, your field observations should square with the opinions in the literature. If the two are in conflict, the literature might not be relevant, or the situation may be more complex than one of simple IS effects on a rare native species. If you look carefully and without assumptions you might find something different or new. On the other hand, observations by someone not trained as a field biologist may be inaccurate for a variety of reasons.

Whatever information you have, ultimately you will need to reach your own conclusions about what and how to manage.

6. Do not assume that an IS has a negative effect on a rare species. The IS might have a positive effect, neutral effect, or more than one type of effect.

Some of the methodological weaknesses that occur in IS research were discussed by Kiviat (2013). Pretend you are an epidemiologist learning whether a disease is caused by a particular pathogen or parasite. Remember that science is a process of becoming “less wrong” (Anonymous 2000).

Discerning the IS interactions with a rare native species should be done mindful of policy and management decisions. First, the management goals should be clarified (What do you want from the site?). If you then determine that an IS is a threat to a species (or group of species) of conservation concern, you need to figure out if you can manage the threat, and how you should do that. Management should produce the desired outcome, be sustainable, and not create serious non-target effects. All techniques for managing IS (including herbicides or insecticides, biological control, mechanical control, environmental [e.g., hydrological] manipulation) have side effects. It may take years of effort to achieve the desired outcome. And be sure to monitor and record data or observations about the management actions and their results, so the next manager can benefit from your experience! Noteworthy results (and many are noteworthy in this field) should be submitted to a scientific journal in the appropriate form.

Prevention and Early Detection

Nonnative species ideally should be prevented from arriving in the habitats of SGCN or other species of conservation concern. Much prevention is the responsibility of public agencies; private entities can also help by not importing, transporting, selling, or establishing (e.g., planting) nonnative species that have not been proven harmless. This concern extends to materials such as firewood, shipping pallets, packing materials, seasonings, and intact plant materials that may act as vectors for insects, plants, or other nonnative species.

Second best, nonnative species should be managed by "Early Detection, Rapid Response" (EDRR). This principle dictates that a nonnative species be eradicated when there is just a tiny amount of it; at that stage eradication is usually feasible, inexpensive, and with fewer non-target effects (ecological side effects).

Once a weed or other nonnative species has become common in or near a habitat of concern, eradication will likely be ineffective, expensive, and harmful to other species including the conservation target species. Managing abundant weeds is a state-of-the-art challenge that is species- and site-specific as well as dependent on the goals (e.g., particular conservation target species) of management. The example of common reed was discussed by Kiviat [2010, 2013]).

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