Wildlife Risk Assessment

Abstract

Risk assessments were conducted for 27 habitats and 157 Species of Greatest Conservation Need using a standard methodology adopted by the northeast states. Eleven different threat categories with 37 sub-categories were ranked in terms of their potential impact on each species and habitat throughout New Hampshire. Saltmarshes, warmwater rivers and streams, dunes, lowland spruce-fir forest, and vernal pools had the greatest number of high-ranking threats. Pollution was identified as the risk factor that most frequently impacts wildlife, followed by climate change, natural system modifications, invasive and other problematic species, genes and diseases, and residential and commercial development. Threat ranks were compared to 2005 results.

Overview

New Hampshire's habitats and wildlife are affected by many challenging issues, ranging from broad-scale threats such as climate change to local-scale threats such as undersized culverts blocking fish passage. Conservation and management programs depend on an objective assessment of the degree of risks posed to species and habitats of greatest concern. In this chapter, the words risk and threat are used interchangeably.

Wildlife populations and habitats are exposed to enormous pressure from human population growth and recreational activities. Residential and commercial development is the most challenging issue for most of New Hampshire's wildlife and habitats. Many habitats are rapidly disappearing or are fragmented by roads and dams, and many ecosystems are disrupted by human activities.

Even if all the land necessary to support New Hampshire's critical wildlife populations and habitats could be protected from development the long-term viability of New Hampshire's wildlife will not be sustained without improving air and water quality and addressing wildlife diseases. Runoff polluted with agrochemicals and urban waste is toxic for many species, and atmospheric pollution causes degradation to all habitats.

Likewise, if climate change is not addressed, New Hampshire's wildlife and natural resources will be altered, particularly those in geographic extremes such as mountaintops, saltmarshes, and coastal islands. To prevent impacts from increased ultraviolet radiation, warmer temperatures, and the many attendant effects of ozone depletion, emissions of greenhouse gases and other pollutants must be addressed.

This chapter addresses Element 3 of the NAAT Guidelines, which requires that states identify "the problems which may adversely affect Species of Greatest Conservation Need (SGCN) or their habitats, and priority research and surveys needed to identify factors which may assist in restoration and improved conservation of SGCN and their habitats."

This chapter is based on the results of a structured qualitative assessment of factors that influence wildlife and their habitats. Using expert opinion of regional scientists and managers, available data, and scientific literature, New Hampshire sought to meet the following objectives:
• Describe risk factors in a consistent format
• Compile an overview of challenging issues
• Objectively prioritize conservation actions within and among species and habitats (this objective addressed in Chapter 4, Chapter 5 and Appendices A and B)

For all habitat assessments, wildlife was assumed to be an integral part of the habitat. Therefore, in this chapter, risks to broad groups of wildlife are considered risks to the habitat at large. Thorough peer-reviewed qualitative assessments were completed for 27 habitat types and 157 species.

Threat Classification System

State Wildlife Action Plans must include descriptions of problems adversely affecting Species of Greatest Conservation Need (SGCN) or their habitats. The Best Practices Report for State Wildlife Action Plans recommends the use of the International Union for Conservation of Nature (IUCN) threat classification system (Salafsky et al. 2008). Threats are viewed as important factors in prioritization of actions and ranking of conservation need.

Threats come from many different sources, and impacts can be observed at different spatial, temporal, and biological scales. As a result, the risk of the impacts is wide-ranging, as are actions taken in response. Terwilliger Consulting Inc. and the Northeast Fish and Wildlife Diversity Technical Committee developed a standardized lexicon for the Northeast (Crisfield et al. 2013) that provides a hierarchical system for classifying and naming threats, based on the IUCN classification system (Salafsky et al. 2008) and threat characteristics that are important in determining threat risk and appropriate responses.

The Northeast Lexicon adopts the IUCN threat classification system to classify and name threats. This system is hierarchical, with three tiers. The top tier indicates the broadest categorization of threats and includes:

- Agriculture and Aquaculture
- Biological Resource Use
- Climate Change and Severe Weather
- Residential and Commercial Development
- Energy Production and Mining
- Human Intrusions and Disturbance
- Invasive and Other Problematic Species and Genes
- Natural System Modifications
- Pollution
- Transportation and Service Corridors

NH adopted the Northeast Lexicon approach of evaluating these 11 threat categories identified by the IUCN. In addition to naming threats, understanding threat characteristics can help highlight opportunities for species and habitat management or protection. Proposals to fund conservation actions typically explain the threat being addressed in the project justification, Reporting systems, such as Wildlife TRACS, are helpful to integrate threat identification into action implementation. Using a standardized threat classification system across the region will help states prioritize threats (and/or associated actions) for regional coordination.

Risk Assessment Ranking Process

All of the challenges that wildlife face can be viewed as having two commonalities. First, each has certain “risk factors” that potentially have negative impacts on wildlife; and second, each has a series of events or an “exposure pathway” that brings a risk factor to fruition for wildlife. It is more difficult and expensive to repair the damage once it is done than it is to address risk and avoid exposure in the first place. Addressing underlying causes or factors that pose a risk to wildlife, rather than waiting to manipulate dwindling populations or habitats after the fact, is a powerful and pre-emptive long-term approach.

Some of the wildlife and habitats that showed symptoms of declining health in NH were identified in Chapter 2. A structured approach was developed, both to understand the most prevalent risk factors for these declines and to work toward their recovery. Patterns of cause and effect were organized systematically to diagnose the main exposure pathways for factors that threaten wildlife. Next, species and habitat experts completed scoring forms that ranked five variables (spatial extent, severity, immediacy, likelihood, and certainty) for each known threat. The scores given were based on standardized criteria, and were subject to a peer-review process. Evidence to support or refute scores was carefully evaluated by NHFG biologists. Finally, scores were cross tabulated and summarized to clarify which sources pose the greatest threats to species and habitats, and which species and habitats are at greatest risk. The process allowed biologists to critically analyze the range of expert opinions and focus on critical problems.

NHFG adopted a list of 11 challenging issues (IUCN level 1) that are most relevant to New Hampshire’s habitats and species of conservation concern, and conducted a risk assessment for each one. NHFG developed a process to determine the applicability and severity of different risk factors within each challenging issue, using a categorical scoring system to determine rank for comparative purposes. Numerous partners (e.g., government, NGO, academic scientists, taxa or habitat experts) were contacted to complete the ranking process, drawing on professional experience and a review of published and unpublished sources.

The summary rank is a planning and decision-making tool, not a true quantitative measure. The purpose of the ranking process was to provide a consistent basis for comparing risk factors across all species and habitats, and for placing those factors into categories of appropriate conservation action. The ranking process formed the basis for the risk assessment summaries presented in this chapter. Although the ranking process can be somewhat subjective, each step of the process was clearly described and fully transparent, allowing NHFG to assess and revise ranks as new information emerges. The frequency of overall threat ranks were tabulated by species, habitats, and threat categories (IUCN Level 1 and 2).

RISK FACTOR RANKING PROCESS

Step One: Identifying Risks to Habitats and SGCN
Working from a list of IUCN threats provided by NHFG (Appendix F), experts and expert panels compiled a list of all the associated risk factors relevant to each species and habitat. The experts carefully evaluated the series of events, or exposure pathway, and stressors that may cause each factor to become a problem for wildlife. Risks evaluated for habitat and SGCN during 2005 were provided as background.

Step Two: Ranking Risks
Risk factors were ranked using categorical criteria to assign scores (H = High, M=Moderate, L =Low). Each risk factor received five scores (spatial extent, severity, immediacy, likelihood, and certainty). These are described briefly here and more fully in Appendix E.

<u>Magnitude of Threat factors:</u>

- Spatial Extent: Percent of habitat/population negatively impacted by threat. Consider impact of threat within 10 years
- Severity: Intensity of stress impacting exposed target under Spatial Extent

<u>Urgency of Threat Factors:</u>

- Immediacy: This characteristic assesses the time scale over which impacts of the threat will be observable.
- Certainty: Amount of information available; understanding of threat and response.
- Likelihood: Consider impact of the threat within 10 years. This characteristic is used to assess the certainty surrounding the threat and its impacts. Probability that Spatial Extent, Severity, and Immediacy of threat will be realized.

<u>Action Feasibility</u>

- Reversibility: used to determine action feasibility; consider the likelihood of reversing the impacts within 10 years.

Qualitative scores and ranks were compiled in a database, submitted to wildlife biologists for final review, and edited for internal consistency.

Step 3: Assign Overall Threat Ranks for Species and Habitats
An overall rank (H,M,L) was computed for each risk factor, using a 3-step procedure (Appendix E). Step 1 combined Spatial Extent and Severity into a combined Magnitude Score. Step 2 combined the Magnitude score from step 1 with the Immediacy score. Step 3 combined the result from step 2 with a Certainty score. Likelihood was not used in the Stepwise procedure in determining overall threat rank. Reversibility was used in a 4th step to determine Action Feasibility but this wasn't included in the overall threat score. Reversibility will be used during implementation to prioritize actions.

Risk Assessment Results

Overall Risk Rank Summary

1793 individual threats were assessed across 27 Habitats and 157 SGCN (Lepidoptera associated with pine barrens and not listed as threatened or endangered were grouped during threat assessment). Ten percent (n = 189) of threats evaluated during 2015 were categorized as '*high*' ranking and 32% (n = 576) were categorized as '*moderate*' ranking threats (Table 4-1). Fifty-seven percent of threats ranked during 2015 were categorized as '*low*' ranking.

Table 4-1. Summary of risk assessment results from 2015. The # Risks includes the number of threats determined to be 'H', 'M,' or 'L' for all of the habitats and SGCN combined. Individual habitats and SGCN often assessed multiple threats and these are included separately.

	# Risks	%
H	189	10.5
M	576	32.1
L	1028	57.3
Total	**1793**	100.0

Frequency of Risk Categories and Action Prioritization

This distribution of ranks (*high* threat rank having fewest and *low* threat rank having greatest number) allows for an appropriate prioritization of actions based on threat rank. That said, it is recognized that overall threat ranks are simply a tool for assessing risk and developing actions and that threat ranks may change based on a variety of conditions. We present the frequency of '*high*', '*moderate*', and '*low*' ranking threats as a tool for assessing risk to habitats and species. It is understood that in some cases, one '*high*' ranking threat may be catastrophic to a habitat (e.g., sea level rise to saltmarsh habitat) or species and as such this habitat is not less threatened overall than a habitat having a greater number of '*high*' (but perhaps not catastrophic) ranking threats. Also, actions taken for a '*low*' or '*moderate*' ranking threat may prevent that threat from becoming a '*high*' ranking threat in the future. As such, developing actions for '*moderate*' and '*low*' ranking threats is both appropriate and important. '*Low*' ranking threats are not necessarily a minimal or no threat. Threats could be ranked low due to a variety of factors including lack of certainty/information, a threat that may impact species and habitats over a longer-term, and where the impact is localized and not known to be severe (Appendix E – detailed ranking methodology). It is recognized that threat ranks will change over time as new information becomes available. It is also recognized that localized threats may warrant action, especially for threatened or endangered species.

Greatest Risks to Wildlife and Habitats

Pollution was identified as a risk factor with the greatest frequency (Table 4-2), followed by climate change, natural system modifications, invasive & other problematic species, genes & diseases, and residential & commercial development. These major risk categories, along with human intrusions & disturbance, were also assessed for the greatest number of habitats and species (Table 4-3). Similar major threat categories were identified when evaluating threat categories by the frequency of '*high*', '*moderate*', and '*low*' ranking threats (Table 4-4). Natural system modifications, for both aquatic and terrestrial systems, included the greatest frequency of '*high*' ranking threats (n=45). Pollution also had a large number (n=25) of high ranking threats, but many of the risks assessed (n=221) were ranked as '*low*', often due to a lack of information.

Table 4-2. Summary of NH risk assessment results for each IUCN Level 1 threat category (n=11). Table sorted by the total number of overall threats assessed for that category.

IUCN Level 1	Total
Pollution	351
Climate change & severe weather	243
Natural system modifications	232
Invasive & other problematic species, genes & diseases	225
Residential & commercial development	200
Biological resource use	159
Human intrusions & disturbance	158
Transportation & service corridors	114
Energy production & mining	62
Agriculture & aquaculture	48
Geological events	0

Table 4-3. Number of habitat types and SGCN evaluated for risk under each IUCN level 1 (n=11) in NH's Wildlife Action Plan risk assessment 2015. IUCN categories were sorted by the # habitats evaluated, then the # of SGCN.

IUCN Level 1	# Habitats	# SGCN
Pollution	24	112
Invasive & other problematic species, genes & diseases	24	106
Climate change & severe weather	24	91
Residential & commercial development	22	115
Human intrusions & disturbance	22	80
Transportation & service corridors	20	77
Natural system modifications	19	91
Biological resource use	18	84
Energy production & mining	10	37
Agriculture & aquaculture	5	33
Geological events	0	0

Table 4-4. Summary of NH risk assessment results for each IUCN Level 1 threat category (n=11). Table sorted by the number of 'H' ranking risks, then the number of 'M', followed by the number of 'L' ranking risks. Histograms are comparisons within columns (e.g., H) but not between columns. The number of habitats and SGCN are included for each risk category (i.e., H, M, L).

IUCN Level 1	H	# Habitats	# SGCN	M	# Habitats	# SGCN	L	# Habitats	# SGCN
Natural system modifications	45	8	28	85	11	48	102	14	55
Residential & commercial development	28	5	23	92	17	59	80	12	61
Invasive & other problematic species, genes & diseases	26	7	17	83	11	54	116	14	53
Pollution	25	6	15	105	14	37	221	23	91
Climate change & severe weather	23	2	18	61	14	36	159	21	65
Biological resource use	13	2	11	43	7	28	103	14	63
Human intrusions & disturbance	13	2	8	37	7	26	108	20	56
Transportation & service corridors	10	4	5	37	8	23	67	11	50
Agriculture & aquaculture	3	0	3	12	2	7	33	4	26
Energy production & mining	2	0	2	22	5	16	38	7	23
Geological events	0	0	0	0	0	0	0	0	0

Table 4-5. Summary of NH risk assessment results for each IUCN Level 1 and Level 2 threat categories. Table sorted by the number of 'H' ranking risks, then the number of 'M', followed by the number of 'L' ranking risks. Histograms are comparisons within columns (e.g., H) but not between columns.

IUCN Level 1	IUCN Level 2	H	M	L
Residential & commercial development	None specified	26	85	73
	Housing & urban areas	0	2	1
	Commercial & industrial areas	2	4	0
	Tourism and recreation areas	0	1	6
Agriculture & aquaculture	None specified	2	2	12
	Annual & perennial non-timber crops	1	10	9
	Livestock farming & ranching	0	0	6
	Marine & freshwater aquaculture	0	0	6
Energy production & mining	None specified	0	0	0
	Mining & quarrying	2	8	14
	Renewable energy	0	14	24
Transportation & service corridors	None specified	1	9	11
	Roads & railroads	9	20	42
	Utility & service lines	0	1	0
	Shipping lanes	0	7	13
	Flight paths	0	0	1
Biological resource use	None specified	3	6	4
	Hunting & collecting terrestrial animals	2	13	30
	Gathering terrestrial plants	0	0	2
	Logging & wood harvesting	4	16	51
	Fishing & harvesting aquatic resources	4	8	16
Human intrusions & disturbance	None specified	1	3	0
	Recreational activities	9	30	100
	War, civil unrest & military exercises	0	0	1
	Work & other activities	3	4	7
Natural system modifications	None specified	7	34	39
	Fire & fire suppression	0	7	4
	Dams & water management/use	20	25	36
	Other ecosystem modifications	18	19	23
Invasive & other problematic species, genes & diseases	None specified	3	11	37
	Invasive non-native/alien species/diseases	9	50	49
	Problematic native species/diseases	13	17	22
	Introduced genetic material	0	2	2
	Diseases of unknown cause	1	3	6
Pollution	None specified	6	32	67
	Domestic & urban waste water	1	22	30
	Industrial & military effluents	8	11	21
	Agricultural & forestry effluents	9	19	31
	Garbage & solid waste	0	0	8
	Air-borne pollutants	1	20	62
	Excess energy	0	1	2
Geological events	None specified	0	0	0
Climate change & severe weather	None specified	0	11	49
	Habitat shifting & alteration	7	24	46
	Droughts	0	3	11
	Temperature extremes	4	3	17
	Storms & flooding	6	15	23
	Other impacts	6	5	13

All threat categories other than geologic events had at least two *high* ranking threats for a species or habitat. Geologic events were not addressed in any threat assessment and are therefore not discussed any further in this document. Biological resource use, human intrusions & disturbance, transportation &

‘moderate’ ranking threats. However, these threat categories were of serious concern for some species and habitats and shouldn’t be overlooked in developing and implementing appropriate actions. Pollution, climate change, natural system modifications, and invasive & other problematic species, genes, & diseases were the broadest threats and as such included the largest variation within IUCN Level 2. IUCN Level 2 results (Table 4-5) will be discussed in more detail within the Risk Assessment sections following this introduction. Pollution was the only major threat category (IUCN Level 1) that included a detailed assessment to IUCN Level 3 (*See Pollution section*).

Habitats at Risk

Risk assessments were conducted for 27 habitats identified in the NH Wildlife Action Plan (*See Chapter 2*). Saltmarsh, warmwater rivers and streams, dunes, lowland spruce-fir forest, and vernal pools had the greatest number of ‘*high’* ranking threats (Table 4-6). Twenty of the habitats had at least one high ranking threat. When habitats were grouped, coastal habitats had the greatest number of ‘*high*’ ranking threats (n=14), despite having fewer total threats assessed (n=89). Aquatic (freshwater) systems were also considered at ‘*high*’ risk, followed by freshwater wetlands, matrix forests, and other terrestrial habitats (non-matrix forest) (Table 4-7). Matrix forests and freshwater wetlands had a large number of risks assessed (111 and 102), but many were ‘*low*’ ranking, potentially due to the large size and large spatial distribution of these habitats in New Hampshire, in many cases coupled with insufficient information to assess the risk.

Table 4-6. Summary of NH risk assessment results for each Wildlife Action Plan habitat type (n=27). Table sorted by the number of 'H' ranking risks, then the number of 'M', followed by the number of 'L' ranking risks. Habitat summaries do not include SGCN risk assessment scores. Histograms are comparisons within columns (e.g., H) but not between columns.

Habitats (2015)	Habitat Grouping	H	M	L	Total
Salt Marsh	Coastal	5	5	13	23
Warmwater rivers and streams	Aquatic (freshwater)	3	10	13	26
Dunes	Coastal	3	8	1	12
Lowland Spruce-Fir Forest	Matrix Forest	3	3	15	21
Vernal Pools	Wetland	3	2	8	13
Estuarine	Coastal	2	10	10	22
Coldwater rivers and streams	Aquatic (freshwater)	2	9	14	25
Large warmwater rivers	Aquatic (freshwater)	2	9	11	22
Marine	Coastal	2	7	12	21
Floodplain Forests	Wetland	2	6	11	19
Shrublands	Terrestrial	2	4	4	10
Coastal Islands	Coastal	2	3	6	11
Hemlock-Hardwood-Pine Forest	Matrix Forest	1	9	20	30
Warmwater lakes and ponds	Aquatic (freshwater)	1	9	11	21
Appalachian Oak Pine Forest	Matrix Forest	1	8	15	24
Northern Hardwood-Conifer Forest	Matrix Forest	1	7	12	20
Temperate Swamp	Wetland	1	7	7	15
Lakes and ponds with coldwater habitat	Aquatic (freshwater)	1	5	17	23
Marsh and Shrub Wetlands	Wetland	1	5	16	22
High Elevation Spruce-Fir Forest	Matrix Forest	1	5	10	16
Peatlands	Wetland	0	7	11	18
Grasslands	Terrestrial	0	9	5	16
Pine Barrens	Terrestrial	0	5	6	11
Alpine	Terrestrial	0	4	7	11
Talus Slopes, Rocky Ridges, Cliffs	Terrestrial	0	4	17	21
Northern Swamp	Wetland	0	2	13	15
Caves and Mines	Terrestrial	0	1	7	8
TOTALS		**39**	**163**	**292**	**496**
RANGE		**0-5**	**0-10**	**0-20**	**2-30**
MEAN		**1.4**	**6.0**	**10.8**	**18.4**

Table 4-7. Summary of risk assessment results by habitat groupings.

Habitat Grouping	# Habitats	H	M	L	Total
Aquatic (freshwater)	5	9	42	66	117
Coastal	5	14	33	42	89
Matrix Forest	5	7	32	72	111
Terrestrial	8	2	27	46	75
Wetland	6	7	29	66	102

Species at Risk

1289 threats were assessed for 157 species. Not surprisingly, the number of threats assessed per species varied considerably (mean = 8.2; range = 1: rock vole, to 26: softshell clam). Fifty-six percent of species threats assessed were ranked as '*low*', 32% as 'moderate', and 11% as '*high*'. Despite a low percentage of overall 'high' ranking threats, seventy-five (48%) species assessed had at least one *high* ranking threat. Of these, forty-three species (27%) had greater than one *high* ranking threat and twenty-three species (15%) had 3 or more *high* ranking threats. Sixty-five species (41%) had a moderate threat as the highest threat category. Seventeen species (11%) had only '*low'* ranking threats assessed.

Species Risk-Action Groups

SGCN were grouped into three categories based on the primary action needed within the next 10 years (Table 4-8). These action categories often corresponded with risk assessment scores. SGCN were categorized as 'species-specific action' if actions are known and unique to the needs of a particular species. Most species in the species–specific category had at least one high ranking threat. Species in the 'species-specific action' category may have habitat-based and research actions prescribed. SGCN were categorized as 'habitat-based action' if the primary action needed for the species is associated with the habitat and minimal specific effort is warranted for the species at this time. SGCN falling into the habitat-based action category had a range of threats from high to low. Species in the 'habitat-based actions' category may also have research and monitoring actions prescribed. SGCN were placed in the 'research & monitoring' category if more information was needed before detailed actions can be prescribed. These species generally had lower ranking threats during the risk assessment. These groupings are a tool to prioritize implementation of species actions. The numbers of high, medium, and low threat ranks are provided in Table 4-10 and this information will be used during action prioritization. Action implementation will also depend on feasibility of action including factors such as costs, and staff and partners' capacity to implement.

Table 4-8. Categorization of action categories for SGCN**.** Species of greatest conservation need (SGCN) were placed into one of three action categories (Species-specific action, habitat actions, research & monitoring). The numbers of high, medium, and low threat ranks are listed for each species (# High, # Medium, # Low). Action categories do not consider regulatory actions and as such regulated species (* = state and federal threatened and endangered) appear in each of the three categories. All regulated species would require species-specific actions such as review of permit proposals in order to avoid illegal take.

Table 4-8. *Continued from previous page.*

Species-Specific Action	(H,M,L)	Habitat Actions	(H,M,L)	Research & Monitoring	(H,M,L)
Mammals		***Mammals***		***Mammals***	
American Marten*	(1,5,4)	Fin Whale*	(0,1,4)	American Water Shrew (Eastern)	(0,0,4)
Big Brown Bat	(1,3,6)	Humpback whale*	(0,1,4)	Long-tailed Shrew	(0,0,2)
Eastern Red Bat	(0,0,7)	North Atlantic Right Whale*	(0,1,4)	Northern Bog Lemming	(0,0,3)
Eastern Small-footed Bat*	(2,0,6)	***Birds***		Rock Vole	(0,0,3)
Little Brown Bat	(3,1,6)	American Black Duck	(0,2,4)	Southern Bog Lemming	(0,0,1)
Lynx*	(3,3,1)	American Three-toed Woodpecker*	(0,3,8)	Wolf*	(0,0,4)
Moose	(3,1,4)	American Woodcock	(0,2,1)	***Birds***	
New England Cottontail*	(2,1,3)	Bay-breasted Warbler	(1,2,7)	American Pipit	(0,0,3)
Northern myotis (Northern Long-eared Bat)*	(2,2,6)	Black-billed Cuckoo	(2,2,1)	Cerulean Warbler	(0,4,5)
Silver-haired Bat	(0,0,6)	Blue-winged Warbler	(2,3,2)	Golden Eagle*	(1,3,2)
Tri-colored Bat	(3,1,6)	Bobolink	(0,7,4)	Purple Finch	(0,4,3)
Birds		Brown Thrasher	(2,4,1)	***Reptiles***	
American Kestrel	(1,2,2)	Canada Warbler	(0,5,7)	Box Turtle	(0,2,7)
Bald Eagle*	(1,7,7)	Cape May Warbler	(1,2,7)	Ribbon snake	(0,2,1)
Bank Swallow	(2,2,3)	Common Gallinule	(0,2,3)	Smooth Green Snake	(0,0,7)
Bicknell's Thrush	(1,4,8)	Eastern Meadowlark	(0,7,2)	***Amphibians***	
Chimney Swift	(1,2,5)	Eastern Towhee	(2,4,1)	Fowlers Toad	(0,3,5)
Common Loon*	(1,3,7)	Eastern Whip-poor Will	(0,5,1)	Jefferson/Blue-Spotted Salamander Complex	(0,5,7)
Common Nighthawk*	(2,5,9)	Field Sparrow	(2,4,1)	Mink Frog	(0,0,3)
Common Tern*	(3,5,5)	Golden-winged Warbler	(2,3,0)	Northern Leopard Frog	(0,4,5)
Grasshopper Sparrow*	(1,4,3)	Horned Lark	(1,2,1)	***Fish***	
Hoary Bat	(0,0,7)	Least Bittern	(0,1,5)	Atlantic Sturgeon	(0,0,3)
Least Terns*	(2,3,1)	Marsh Wren	(0,1,4)	Burbot	(0,0,4)
Peregrine Falcon*	(0,5,10)	Nelson's Sparrow	(3,3,4)	Rainbow Smelt (diadromous)	(0,4,4)
Piping Plover*	(4,7,3)	Northern Goshawk	(0,1,3)	Swamp Darter	(0,3,0)
Purple Martin	(0,4,5)	Northern Harrier*	(0,2,6)	***Invertebrates***	
Roseate Tern*	(3,5,5)	Olive-sided Flycatcher	(0,1,5)	Appalachian Tiger Beetle	(0,0,3)
Upland Sandpiper*	(1,1,2)	Pied-billed Grebe	(0,2,8)	Coppery Emerald	(0,1,5)
Reptiles		Prairie Warbler	(2,4,1)	Creeper	(0,2,9)
Blandings Turtle*	(2,4,15)	Purple Sandpiper	(0,1,4)	Kennedy's Emerald	(0,1,5)
Hognose Snake*	(1,4,6)	Red Knot	(0,3,7)	Lyre-tipped Spreadwing	(0,1,4)
Northern black racer*	(1,8,4)	Ruddy Turnstone	(0,2,8)	Margined Tiger Beetle	(2,1,0)
Spotted Turtle*	(2,3,15)	Ruffed Grouse	(0,2,1)	Ocellated Emerald	(0,1,3)
Timber Rattlesnake*	(3,6,0)	Rusty Blackbird	(2,5,1)	Pine Barrens Bluet	(0,1,3)
Wood Turtle	(4,4,7)	Saltmarsh Sparrow	(4,2,8)	Rapids Clubtail	(0,2,3)
Amphibians		Sanderling	(0,2,8)	Ringed Emerald	(0,0,4)
Marbled Salamander*	(1,2,6)	Scarlet Tanager	(0,6,3)	Sedge Darner	(0,0,3)
Fish		Seaside Sparrow	(3,3,3)	Skillet Clubtail	(0,2,3)
Alewife	(1,2,4)	Sedge Wren	(0,1,2)	Triangle Floater	(0,2,12)
American Brook Lamprey*	(1,2,2)	Semipalmated Sandpiper	(0,2,8)	White Mountain Arctic*	(0,2,7)
American Eel	(1,2,4)	Sora	(0,2,3)	White Mountain Fritillary*	(0,2,7)
American Shad	(1,3,2)	Spruce Grouse	(3,1,6)		
Blueback Herring	(1,1,4)	Veery	(0,6,4)		
Bridle Shiner*	(3,2,0)	Vesper Sparrow	(0,7,3)		
Brook Trout	(1,7,2)	Whimbrel	(0,2,7)		
Lake Trout	(0,1,2)	Willet	(0,2,4)		
Lake Whitefish	(0,1,2)	Wood Thrush	(0,8,2)		
Round Whitefish	(1,2,1)	***Fish***			
Sea Lamprey	(1,1,3)	Banded Sunfish	(1,4,0)		
Invertebrates		Finescale Dace	(1,0,2)		
American Oysters	(1,7,9)	Northern Redbelly Dace	(1,0,2)		
Atlantic Sea Scallop	(2,6,10)	Rainbow Smelt (landlocked)	(0,1,2)		
Brook Floater*	(3,4,4)	Redfin Pickerel	(0,2,3)		
Dwarf Wedgemussel*	(5,3,3)	Shortnose Sturgeon*	(0,1,2)		
Eastern Pondmussel	(1,2,11)	***Invertebrates***			
Frosted Elfin*	(3,4,3)	Alewife Floater	(4,1,9)		
Horseshoe Crab	(1,11,9)	American Bumble Bee	(3,2,5)		
Karner Blue Butterfly*	(3,6,4)	Cobblestone Tiger Beetle*	(0,1,9)		
Monarch	(1,5,4)	Eastern Pearlshell	(1,1,9)		
Northern Shrimp	(2,5,6)	Hessel's Hairstreak	(0,1,2)		
Softshell Clam	(2,11,13)	Pine Barrens Lepidoptera	(0,5,18)		
		Puritan Tiger Beetle*	(0,1,2)		
		Ringed Boghaunter*	(0,2,7)		
		Rusty-patched Bumble Bee	(3,2,5)		
		Yellow Bumble Bee	(3,2,5)		
		Yellowbanded Bumble Bee	(3,2,5)		

Change in Risk – NH Wildlife Action Plan 2005 to 2015

NH evaluated threats for habitats and species in both 2005 and 2015 using a systematic and repeatable approach. Threat ranking methodology was similar between years; deviations were mostly due to an adoption of a new regional approach during 2015 (see Appendix G for detailed description of methodology and results). As such, we were able to compare how risk assessments changed in New Hampshire within the last 10 years. This change in risk assessment serves as a measure of performance (i.e., did actions result in threats being reduced) and a reassessment of the condition of habitats and species.

611 unique threat ranks were evaluated in both 2005 and 2015 (Table 4-9). Fifty-four percent (n = 338) of threats evaluated during both 2005 and 2015 did not change in categorized threat. Thirty-two percent (n=201) of threats decreased in assessed risk score and 13.5% increased in assessed risk score (Table 4-10). The majority (24% of all categories) of changes in threat scores were from M (2005) to L (2015).

Table 4-9. Frequencies and percentages of risk ranks that remained the same, increased, or decreased in risk rank between the 2005 NH Wildlife Action Plan and the 2015 Wildlife Action Plan. Only threats that were assessed in both plans are included here.

	#	%
Same Rank	330	54.0
Increase Risk	83	13.6
Reduced Risk	198	32.4
	611	100

Table 4-10. Frequencies of risk categories for the 2005 NH Wildlife Action Plan and the 2015 Wildlife Action Plan. Only threats that were assessed in both plans are included here.

2005 Rank	**2015 Rank**	**#**	**Percent**
H	H	24	3.9
H	M	29	4.7
H	L	20	3.3
M	H	33	5.4
M	M	112	18.3
M	L	149	24.4
L	H	9	1.5
L	M	41	6.7
L	L	194	31.8
		611	100

Changes in risk category from 2005 to 2015 may have been due to actual changes in risk or other assessment measurements such as changes in the amount of information available for making assessments. Increased information can either increase or decrease risk scores. As an example, climate change was included in the 2005 Wildlife Action Plan but it was not consistently evaluated across all species and habitats. An abundance of recent climate change information aided in this evaluation during 2015. Wildlife diseases have also become a larger concern in recent years. During 2005, little brown bats were abundant and not even considered a SGCN. Now, little brown bats, long-eared bats, and other species have been decimated by White-nose syndrome, a fungus that wasn't known to be present in the United States in 2005. Similarly, disease has become a greater concern for snakes (e.g., snake fungal disease), amphibians (*Chytrid*, ranavirus), fish, and other mammals. A regional assessment of wood turtles elucidated threats for the species and as a result, the species overall risk in NH was elevated from 2005 to 2015.

Several habitat types shifted in overall assessed risk. Grasslands, Pine Barrens, alpine, caves & mines, cliffs, and talus slopes and rocky ridges all had lower risk scores compared to 2005. Floodplain forests had two high ranking threats during 2015 and could be considered one of the more threatened habitats considering the historic impacts that have already occurred to the habitat. Coastal islands, dunes, lowland spruce-fir forests, salt marshes, and vernal pools scored as high risk in both years. Five new freshwater aquatic habitats and two coastal habitats were added during 2015 and all had at least one high ranking threat.

Summarizing risk across species and habitats, climate change was more frequently identified as severe during 2015 compared to 2005. Residential and commercial development was identified as a top risk for species in habitats in both 2005 and 2015. Human intrusions & disturbance (named 'Recreation' in 2005 WAP) was identified as a pervasive threat for habitats and species in both assessments. Pollution was identified as a top threat during 2015 based on the frequency and intensity of evaluations. However, it is difficult to compare to 2005 because pollution was previously split into several different categories (mercury, acid deposition, oil spills, non-point source pollution).

Taking Action

Eleven major risk categories are evaluated and summarized in this Chapter. Actions identified to address these risks are identified in Chapter 5 and within species and habitat profiles (Appendices A and B). Conservation actions developed for species and habitats focus on '*high*' and '*moderate*' ranking risks. However, research was commonly prescribed for '*low*' ranking threats because of low certainty scores and information needs during 2015 assessment. It is also recognized that some longer-term threats such as climate change require both research and actions in the near-term.

Literature Cited

Crisfield, E and the Northeast Fish and Wildlife Diversity Technical Committee. 2013. The Northeast Lexicon: Terminology Conventions and Data Framework for State Wildlife Action Plans in the Northeast Region. A report submitted to the Northeast Fish and Wildlife Diversity Technical Committee. Terwilliger Consulting, Inc., Locustville, VA.

Salafsky, N. D. Salzer, A. J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S. H.M. Butchart, and N. Cox. 2008. A Standard Lexicon for Biodiversity Classification: Unified Classifications of Threats and Actions. Conservation Biology. 15 pp.

Agriculture and Aquaculture

Threats under the ‘agriculture and aquaculture’ category (IUCN 2) address impacts from farming and ranching as a result of agricultural expansion and intensification, including silviculture, mariculture and aquaculture. These threats include habitat conversion, disturbance or direct mortality of species. These threats can be placed into three categories (IUCN Level 2):

- Annual and perennial non-timber crops (farms, household swidden plots, plantations, orchards, vineyards, mixed agroforestry systems), crops planted for food, fiber, fuel or other uses.
- Wood and pulp plantations (silviculture, Christmas tree farms), stands of trees planted for timber or fiber outside of natural forests often with non-native species.
- Livestock farming and ranching - domestic terrestrial animals raised in one location on farmed or nonlocal resources; also domestic or semi-domesticated animals allowed to roam in the wild and supported by natural habitats.

Risk Assessment Summary

A total of 48 unique threats were evaluated for agricultural and aquaculture across five habitats and 33 species. The majority of the threat assessment scores were ranked as low (n=33, 69%), followed by moderate (n=12, 25%) and high ranking threats (n=3, 6%). For a summary of threats related to agricultural and aquaculture evaluated for SGCN and habitats, see Table 4-11.

Within this category, grasslands had the highest ranked threats. Mortality and nest disturbance resulting from frequency and timing of mowing, and habitat conversion to cropland or sod, both ranked high in grassland settings. Species having the highest-ranked threats in this category (final overall score of ‘moderate’) include grasshopper sparrow and northern harrier for issues related to mowing, and common and roseate terns for habitat degradation from aquaculture contamination.

Threats associated with annual and perennial non-timber crops were the primary type of agricultural issues identified in the habitat and species risk assessment. Most of these threats were related to unintentional mortality of species from mowing and the use of agricultural machinery. Mowing was identified as a potential issue for thirteen SGCN, and ranked a ‘moderate’ threat or higher for six of these species. Livestock farming and ranching was evaluated only for grasslands, and was evaluated as a low threat.

Known Wildlife Exposure Pathways

Hay Cropping

Mowing practices, such as haying before July 15, are in use throughout the state and are known to present a moderate to high threat to grassland nesting species such as bobolink, eastern meadowlark, vesper sparrow, and the state endangered grasshopper sparrow. Farmers mow their hayfields 2-3 times during the summer to provide high quality forage for livestock. The peak nesting period for grassland nesting birds is mid-May through mid-July, coinciding with the first and second hay crops. Reproduction is reduced through direct mortality of eggs and nestlings or subsequent egg and chick loss caused by nest abandonment or predation on exposed nests (Bollinger et al. 1990). Death by collision with mowing equipment is a localized but high-ranking problem for wood turtle and a moderate threat to northern leopard frog.

Habitat Conversion

Conversion of Grassland and Floodplain Forest habitats are both ranked as a moderate risk, with somewhat localized but catastrophic consequences where it occurs. Conversion of floodplains to agriculture has led to significant losses of natural floodplain habitat historically. While there is much opportunity for restoration, there is a low likelihood of future losses of floodplain habitat to agriculture. The conversion of grasslands to cropland and sod farms will reduce the amount of habitat available to grassland-dependent species. Active agricultural land acreage dropped by 50% in Rockingham and Strafford Counties between 1962 and 1998. The loss of agriculture to other non-grassland habitat uses reduces the amount of potential quality habitat available to grassland-dependent species.

Species specific risks from habitat conversion include herbicide applications on crop lands, which reduces the amount of milkweed available for monarch butterflies. In addition, habitat conversion to agriculture of winter grounds outside of the U.S. ranked moderate and high for Wood thrush and Bicknell's Thrush. Widespread conversion to agriculture has occurred in the bottomland hardwood forests in the Rusty Blackbird's primary wintering range, ranking as a high threat for the species.

Pesticides and Runoff

See the threat category summary for 'Pollution' for detailed information.

Research Needs

- Survey existing large grasslands for important bird species and current management practices.
- Identify and assess threats (e.g., land use practices in agricultural areas) to specific populations of wood turtles.
- Demographic studies on monarch butterflies in NH and mapping of existing large patches of habitat in the state.

Literature Cited

Bollinger, E. K., P. B. Bollinger, and T. A. Gavin. 1990. Effects of hay-cropping on eastern populations of the bobolink. Wildlife Society Bulletin 18:142-150.

Francis F., and A. Mulligan. 1997. Connecticut River Corridor Management Plan. Connecticut River Joint Commission. Charlestown, New Hampshire, USA.

Saumure, R. A., and J. R. Bider. 1998. Impact of agricultural development on a population of wood turtles (*Clemmys insculpta*) in southern Quebec, Canada. Chelonian Conservation and Biology 3:37-45.

United States Department of Agriculture. 2004. 2002 census of agriculture. National Agricultural Statistics Service, U.S. Department of Agriculture, Washington, D.C. http://www.nass.usda.gov/census/.

Table 4-11. Habitats and species at highest risk from the effects of agriculture and aquaculture (threats ranked as *Low* not included). Some habitats were evaluated for multiple specific threats separately and therefore listed multiple times below. See Appendix E for detailed threat ranking methodology.

Habitat	IUCN Level 2	Overall Threat Score
Grasslands	Annual & perennial non-timber crops	M
Floodplain Forests	Not Specified	M
Common Name		**Overall Threat Score**
Bicknell's Thrush*	Not Specified	H
Bobolink	Annual & perennial non-timber crops	M
Eastern Meadowlark	Annual & perennial non-timber	M
Grasshopper Sparrow	Annual & perennial non-timber crops	M
Monarch	Annual & perennial non-timber crops	M
Northern Leopard Frog	Annual & perennial non-timber crops	M
Rusty Blackbird*	Annual & perennial non-timber crops	H
Vesper Sparrow	Annual & perennial non-timber crops	M
Wood Thrush*	Not Specified	M
Wood Turtle	Not Specified	H

** Wintering grounds outside NH*

Biological Resource Use

The 'biological resource use' category (IUCN 5) includes any "threat of consumptive use of wild biological resources including the effects of deliberate and unintentional harvesting; including the persecution or control of specific species" (Salafsky et al. 2008). The types of biological resource use include:

Hunting and collecting of terrestrial animals: This is defined as the killing or trapping of terrestrial wild animals or animal products for commercial, recreation, subsistence, research or cultural purposes, or for control/persecution. This also includes accidental mortality and bycatch.

Fishing and harvesting aquatic resources: This is the harvesting of aquatic wild animals or plants for commercial, recreational, subsistence, research, or cultural purposes, or for control/persecution reasons. This also includes accidental mortality and bycatch.

Gathering of terrestrial plants: This is defined as the harvesting of plants, fungi, and other non-timber/non–animal products for commercial, recreational, subsistence, research or cultural purposes, or for control reasons.

Logging and wood harvesting: This is the harvesting of trees and other woody vegetation for timber, fiber, or fuel.

Risk Assessment Summary

The biological resource use threat was evaluated for 159 unique threats across 18 habitats and 84 species (Table 4B-1). The majority of threat assessment scores were ranked as low (n=103, 65%), followed by moderate (n = 43, 27%) and high ranking threats (n = 13, 8%). Only the moderate and high ranking threats are summarized for each category in Table 4-12.

Hunting and collecting terrestrial animals

In NH, hunting and collecting of terrestrial animals was identified as a threat for 10 species (Table 4B-1). Hunting and collection of terrestrial animals can include commercial collection, collection or impacts due to human values, incidental take from activities such as hunting and trapping and scientific collection. Many of these threats were identified in the 2005 WAP, yet the 2015 analysis appears to be a more comprehensive list of species potentially impacted. The scope and severity of this issue is largely unknown because it can be difficult to monitor and assess.

Fishing and harvesting aquatic resources

Fishing and harvesting aquatic resources was identified as a high or moderate-ranking threat for two habitats and 10 species (Table 4B-1). This was also identified as a low ranking threat for an additional 16 species. Most threats in this category focused on unintentional impacts from large-scale fishing practices, where the species being assessed is not the target for harvest. Overfishing and by-catch are both forms of resource depletion that were noted in this threat evaluation. For most harvestable species, threats were evaluated by looking at how fishing pressure may add additional stress on a declining population. In most cases, this threat is acting on species now, and is often well documented. Fishing and harvesting was having the greatest impact on northern shrimp, Atlantic sea scallop, and softshell clam, and is a high threat to marine habitat. Some birds were included in this threat category because over-harvesting of their marine prey species can have negative impacts on their populations.

Gathering of terrestrial plants
Gathering of terrestrial plants was identified as a threat in two habitats, both of which were ranked as low and were not summarized in the table. Although this threat was considered low ranking overall, it could become a larger concern within local populations of imperiled plants. Gathering of terrestrial plants can be for commercial purposes or even individual use. Additionally, there are potential impacts on plant populations from scientific collection and collection of plants for personal interest from specialized habitats. The scope, severity and certainty of these issues are poorly understood. Additionally, enforcement of regulation would be difficult to implement.

Logging and wood harvesting
Logging and wood harvesting was identified as a threat for 12 species and five habitats. Logging and wood harvesting was considered a low ranking threat for most of the habitats and species assessments (n=51, 72%). It was considered a moderate threat for 16 assessments (23%) and a high ranking threat for four species or habitat assessments (6%) (Table 4B-1). Logging and wood harvesting includes: direct species mortality from equipment, and practices such as liquidation harvesting and soil compaction that can cause forest type conversion or that can affect overall site quality. The scope of these issues is statewide and the severity and certainty varies by region. Impacts to wildlife have been well documented for these threats, yet the specific severity and extent in NH may be poorly understood or there may be a lack of tools to deal with the threats. Many of these issues were identified in 2005, but the current review seems to be more inclusive and defined.

Known Wildlife Exposure Pathways

Hunting and collecting terrestrial animals

Commercial collection
Many reptiles and amphibians are popular pets, and the international pet trade market is large (Franke and Telecky 2001). Most native reptiles and amphibians are vulnerable to commercial collection and sale. Those species characterized by late ages of maturity and high adult survival rates are generally most vulnerable (e.g., turtles and some snakes). Also, some species are extremely vulnerable due to the congregation of individuals (e.g., timber rattlesnakes and wood turtles). New state regulations within the last 10 years have prohibited the sale of all native reptiles and amphibians with a few exemptions. Possession rules are also in place for all native reptiles and amphibians where possession is prohibited for some species and limited for all others (NHFG Rules 800, 1400). It is not known to what extent illegal collection of protected species occurs in New Hampshire, but some rare species have been sold in the past (Levell 2000) and at least one conviction for illegal possession and sale of regulated turtles has occurred more recently.

Human values

Humans have a negative perception of some species and regard others as pests. Negative perceptions may lead people to destroy wildlife regardless of actual danger. Slaughter of individuals or purposeful destruction of critical habitat (e.g., den sites) may result in the local or state extirpation of some species (e.g., timber rattlesnakes, Brown 1992). Bats found in homes may be killed. Bug zappers often kill non-target species such as beetles and moths that are attracted to light. Some insect control programs are implemented to ease public concern (e.g., mosquito spraying to control West Nile virus), but may harm non-target species.

Conversely, many humans are fascinated with wildlife. Humans with positive intentions may move animals from what seems unfavorable habitat to another location, with adverse consequences. For example, relocating turtles may be the functional equivalent of removing the turtle from the wild because the relocated turtle can no longer interact with wild individuals.

Incidental take

Some species, including those that are rare or endangered in New Hampshire, are incidentally taken because of legal harvesting activities (hunting, trapping, and recreational or commercial fishing). For example, lynx may be incidentally captured in leg hold traps designed for restraining species (possibly resulting in injury) or body gipping traps designed for killing. American marten may be incidentally captured in body gripping traps. Spruce grouse may be confused with ruffed grouse and taken by hunters. Turtles may be taken in body gripping traps set under water for beaver and otter, but the impact on at-risk turtle populations is unknown.

Scientific collection

Scientific research has been conducted on a variety of taxonomic groups in New Hampshire, often resulting in take of individuals. Although this activity is often regulated, some species, especially invertebrates that are not state or federally threatened or endangered, are not regulated. Also, those species that are protected may be difficult to identify. For example, collection of some pine-barrens Lepidoptera (butterflies and moths) could have an impact on highly fragmented or small populations.

Fishing and harvesting aquatic resources

Commercial harvesting

In New Hampshire, harvestable species are partly managed through issuing licenses and specific harvest regulations. Fishing and harvesting of aquatic resources can have unintentional negative impacts on species and habitats. Commercial harvest can have unintended bycatch mortality on species not specifically targeted. Harvest of particular species can have a compounding effect on species already affected by environmental stressors. For example, the Northern shrimp population has other stressors that are impacting the population (i.e., warming water temperatures), which in turn have triggered changes in harvest limits and seasons. Commercial gear and fishing can directly affect habitat features and cause unintended mortality on various benthic communities and species. Within marine habitats, fishing and harvesting gear can cause physical damage to the bottom, impacting habitat suitability, potentially causing accidental mortality, and creating other issues for marine species. Actual physical impacts of harvesting are of low severity in New Hampshire, since the incoming tide helps reverse some damage from disturbed mud and other substrate.

Gathering of terrestrial plants

Commercial collection

The spring fiddleheads of ostrich fern (*Matteuccia struthiopteris* ssp. *pensylvanica*) are a popular local seasonal food. In New Hampshire, large populations of ostrich fern occur only on the floodplains of the Connecticut River, where fiddleheads are sometimes collected for commercial sale. Overcollection of fiddleheads can lead to the long-term decline of individual ostrich fern plants (University of Maine Cooperative Extension 2012). However, there is currently no evidence that overcollecting is occurring on New Hampshire floodplains.

American ginseng (*Panax quinquefolius*) is a threatened species in New Hampshire (S2) that is collected and sold as a medicinal herb. According to the Native Plant Protection Act (RSA 217-A:9), it is a violation "to export, import, transport, take, possess, sell, or ship any protected species." However, the root of this species can bring a significant price, and illegal collection occurs regularly.

Scientific collection

Many alpine plant species are rare and populations may be impacted by over-collection. Rare alpine species can be illegal targets for collectors, but the threat of current-day collections is likely quite low. Legal collectors are required to get a permit from WMNF, who can ensure that collection pressure remains low (Sperduto, pers. comm.). However, some plant species may still be experiencing impacts of over-collecting that occurred many decades ago. Based on herbaria research, it appears that for at least one species, there are more specimens in herbaria than there are individual plants in the wild (Cogbill 1993).

Logging and wood harvesting

Direct mortality

The act of removing trees and use of machinery may cause direct mortality to wildlife. Mortality may more problematic for imperiled populations where activity patterns are clustered at certain times of year.

Liquidation harvesting

Liquidation harvesting is often defined as the purchase of timberland followed by a harvest that removes most or all commercial value in standing timber, without regard for long-term forest management principles, and the subsequent sale or attempted resale of the harvested land within a short period of time. This type of harvesting commonly leads to subdivision and development that causes a decrease in available wildlife habitat and fragmentation of what remains. Liquidation harvesting is of greatest concern in northern NH where the majority of the state's large land owners exist. Liquidation harvesting can have serious implications for American marten, three-toed woodpecker, spruce grouse, and other species.

Forest type conversion

Forest type conversion is most pronounced in low elevation spruce-fir forests when stands are clear-cut prior to the establishment of adequate levels of advanced regeneration (Frank and Bjorkbom 1973, Demming et al. 1995). In these situations, spruce-fir is generally replaced by light tolerant hardwoods (e.g., pin cherry, birch, aspen, red maple) (Demming et al. 1995). Eventually, spruce-fir forest may become reestablished, but it will take many more decades than if harvests were carefully planned to ensure advanced regeneration. Removal of trees within Temperate and Northern Swamps will change habitat structure and composition and machinery in wetlands could alter wetland hydrology if not adequately planned and executed.

Impacts on non-timber values

Timber harvesting can have impacts on soil quality, wetland and water quality, plant and animal habitats, and other non-timber values. For instance, timber harvesting can compact soil, particularly organic soils such as peat, leading to increased runoff and nutrient loading (NHDFL and SPNHF 2010). Harvesting near vernal pools may reduce canopy cover, increase water temperatures (which may not be suitable for breeding amphibians), and cause premature drying of the pool (Calhoun and deMaynadier 2004).

Harvesting near streams and water bodies may reduce canopy cover and therefore increase water temperatures. Riparian areas are also important because they: control flood control areas; help to filter water by retaining sediment, nutrients and other pollutants; often contain rare natural communities; and can serve as important wildlife habitat and movement corridors (NHDFL and SPNHF 2010). Harvesting within these areas can negatively impact all these qualities.

Short rotation harvesting limits the availability of bark beetles in dead and dying spruce trees, which is the major food item for three-toed woodpeckers (Leonard 2001). It also limits the size and amount of coarse woody debris, which is required by American marten for denning and foraging (Hargis et al. 1999).

Timber harvesting can also limit the number of large trees with strong upper branches to support the nests of bald eagle, osprey, red-shouldered hawk, and Cooper's hawk, unless such trees are deliberately identified and protected during harvesting operations (Titus and Mosher 1981, Speiser and Bosakowski 1991, Bosakowski et al. 1992, Buehler 2000).

Research Needs

- Monitor focal populations to assess survivorship and loss of individuals from local populations, especially where human activity is intense (e.g., timber rattlesnakes, hognose snakes, wood turtles, Blanding's turtles, spotted turtles)
- Compile information on incidental captures (e.g., survey trappers and hunters) and assess ways to eliminate or reduce mortality of non-target species
- Assess cliff, floodplain forest, and other vulnerable habitats for risk of over collection of vegetation
- Assess current timber harvest levels and patterns in New Hampshire to better understand the extent of unsustainable harvesting in the state
- species
- Define long- and short-term impacts of clear-cutting on vernal pool wildlife survival and reproductive success
- Continue to monitor and regulate harvest seasons and limits
- Assess and implement ways to reduce non-target mortality.

Table 4-12. Habitats and species at highest risk from the effects of biological resource use (threats ranked as *Low* not included here). IUCN Level 2 provided if evaluated to that level (if not evaluated to level 2, text reads *not specified*). Some habitats and species were evaluated for multiple specific threats separately and therefore listed multiple times below. See Appendix E for additional information on specific threats and rankings.

Habitat	IUCN Level 2	Overall Threat Score
Coldwater rivers and streams	Logging & wood harvesting	M
Estuarine	Fishing & harvesting aquatic resources	M
Lowland Spruce-Fir Forest	Logging & wood harvesting	H
Lowland Spruce-Fir Forest	Not Specified	M
Marine	Fishing & harvesting aquatic resources	H
Marine	Not Specified	M
Northern Swamp	Logging & wood harvesting	M
Pine Barrens	Logging & wood harvesting	M
Temperate Swamp	Logging & wood harvesting	M

Common Name	IUCN Level 2	Overall Threat Score
Alewife	Fishing & harvesting aquatic resources	M
American Marten	Hunting & collecting terrestrial animals	M
American Marten	Logging & wood harvesting	M
American Oysters	Fishing & harvesting aquatic resources	M
Atlantic Sea Scallop	Fishing & harvesting aquatic resources	H
Atlantic Sea Scallop	Not Specified	M
Bald Eagle	Hunting & collecting terrestrial animals	M
Bald Eagle	Not Specified	H
Bay-breasted Warbler	Logging & wood harvesting	H
Blanding’s Turtle	Hunting & collecting terrestrial animals	M
Canada Warbler	Logging & wood harvesting	M
Cape May Warbler	Logging & wood harvesting	H
Common Loon	Not Specified	H
Common Tern	Fishing & harvesting aquatic resources	M
Golden Eagle	Hunting & collecting terrestrial animals	M
Golden Eagle	Not Specified	H
Hognose Snake	Hunting & collecting terrestrial animals	M
Horseshoe Crab	Fishing & harvesting aquatic resources	M
Horseshoe Crab	Not Specified	M
Lynx	Hunting & collecting terrestrial animals	H
Lynx	Logging & wood harvesting	M
Northern black racer	Hunting & collecting terrestrial animals	M

Northern black racer	Logging & wood harvesting	M
Northern Shrimp	Fishing & harvesting aquatic resources	H
Northern Shrimp	Not Specified	M
Purple Finch	Logging & wood harvesting	M
Rainbow Smelt (diadromous)	Fishing & harvesting aquatic resources	M
Red Knot	Fishing & harvesting aquatic resources	M
Roseate Tern	Fishing & harvesting aquatic resources	M
Scarlet Tanager	Logging & wood harvesting	M
Softshell Clam	Fishing & harvesting aquatic resources	H
Softshell Clam	Not Specified	M
Spotted Turtle	Hunting & collecting terrestrial animals	M
Spruce Grouse	Logging & wood harvesting	H
Timber Rattlesnake	Hunting & collecting terrestrial animals	H
Timber Rattlesnake	Logging & wood harvesting	M
Veery	Logging & wood harvesting	M
Wood Thrush	Logging & wood harvesting	M
Wood Turtle	Hunting & collecting terrestrial animals	M

Literature Cited

Bosakowski, T., D.G. Smith, and R. Speiser. 1992. Nest sites and habitat selected by Cooper's hawks, Accipiter cooperii, in northern New Jersey and southeastern New York. Canadian Field-Naturalist 106:474-479.

Brown, W.S. 1992. Biology and conservation of the timber rattlesnake. In Tyning, T.F., Editor. Conservation of the timber rattlesnake in the northeast. Massachusetts Audubon Society. Lincoln, Massachusetts, USA.

Buehler, D.A. 2000. Bald Eagle (Halieaeetus leucocephalus). In The Birds of North America, No. 564 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, Pennsylvania, USA.

Calhoun, A.J.K., and P. deMaynadier. 2004. Forestry habitat management guidelines for vernal pool wildlife. MCA Technical Paper No. 6, Metropolitan Conservation Alliance, Wildlife Conservation Society, Bronx, New York, USA.

Cogbill, C.V. 1993. The interplay of botanists and Potentilla robbinsiana: discovery, systematics, collection, and stewardship of a rare species. Rhodora 95(881):52-75.

Demming, L., L. Falk, C. Foss, J. Lanier, D. Publicover, E. Snyder, K. Staley, and T. VanRyn. 1995. Hypothesis 13. Pages III-89-101 in New Hampshire Division of Forests and Lands. New Hampshire forest resources plan assessment report. New Hampshire Department of Resources and Economic Development, Concord, New Hampshire, USA.

Frank, R.M., and J.S. Bjorkbom. 1973. A silvicultural guide for spruce-fir in the Northeast. USDA Forest Service, General Technical Report NE-6. Northeastern Forest Experiment Station, Broomall, Pennsylvania, USA.

Franke, J., and T.M. Telecky. 2001. Reptiles as pets. An examination of the trade in live reptiles in the United States. The Humane Society of the United States. Washington, D.C., USA.

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

Levell, J.P. 2000. Commercial exploitation of Blanding's turtle, Emydoidea blandingii, and the wood turtle, Clemmys insculpta, for the live animal trade. Chelonian Conservation and Biology 3:665-674.

National Marine Fisheries Service (NMFS). 1998. Managing the Nation's Bycatch: Programs, activities, and recommendations for the National Marine Fisheries Service. National Marine Fisheries Service, U.S. Department of Commerce, Silver Spring, Maryland, USA.

New Hampshire Department of Forests and Lands (NHDFL) and The Society for the Protection of New Hampshire Forests (SPNHF). 2010. Good forestry in the Granite State: recommended voluntary forest management practices for New Hampshire. The Society for the Protection of New Hampshire Forests, Concord, New Hampshire, USA.

Salafsky, N. D. Salzer, A. J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S. H.M. Butchart, and N. Cox. 2008. A Standard Lexicon for Biodiversity Classification: Unified Classifications of Threats and Actions. Conservation Biology. 15 pp.

Speiser, R., and T. Bosakowski. 1991. Nesting phenology, site fidelity, and defense behavior of northern goshawks in New York and New Jersey. Journal of Raptor Research 25(4):132-135.

Titus, K., and J.A. Mosher. 1981. Nest site habitat selected by woodland hawks in the central Appalachians. Auk 98:270-281.

University of Maine Cooperative Extension. 2012. Bulletin #2540, Ostrich Fern Fiddleheads.

Climate Change and Severe Weather

The ‘climate change and severe weather’ category (IUCN 11) includes threats from long-term climatic changes which may be linked to global warming and other severe climatic/weather events that are outside of the natural range of variation, and potentially can alter the composition of species in a given habitat as species die or move in response to these changes. These threats include increased flooding, increased winter and summer temperatures, changes in the amount and distribution of precipitation, reduced winter conditions, and sea level rise. In addition, the human response to these changes such as the building of flood control structures to accommodate more severe precipitation events can also pose a threat to species and habitats.

The following details represent predicted changes in New Hampshire’s climate by 2099. The results are provided for both the low and high emissions scenarios, i.e. the minimum and maximum climate changes expected based on whether greenhouse gas emissions are curbed or continue to grow at the current rate (data compiled from Wake et al 2014a and 2014b except where indicated). It is important to recognize that these changes are based on predictions from models, and there is already compelling evidence to indicate that actual changes in climate may exceed the most extreme predictions with corresponding effects on wildlife and their habitats.

Annual average precipitation is predicted to increase 14 to 20% with higher increases in southern NH. These changes vary by season, with summer and fall increasing less. Precipitation may be less evenly distributed, with up to three times more extreme events than currently occurs, i.e. we can expect to see a general shift in New Hampshire from relatively frequent low intensity precipitation events to more infrequent severe storm events with longer dry periods in between.

Average annual temperatures are predicted to rise 4 to 9°F with winter temperatures and summer temperatures rising similar amounts. As a consequence, the number of days the temperature could be above 90°F will increase to 10-47 days, up from the current average of 3-7 days. This may combine with changes in extreme precipitation events to double the frequency of 1-6 month droughts. Extreme cold days (below 0°) may correspondingly decrease by 9-21 days and the days below freezing may decline 19-45 days. This will shorten the winter season and snowpack. Snow-covered days are predicted to decrease by 23-52 days. While the growing season is expected to lengthen, increased severe precipitation events and short term drought may mean that growing conditions are not improved, particularly for crops. Freezing soils due to lack of snow cover may also impact trees and other forest plants by damaging roots and killing vegetation, degrading habitats (Campbell et al 2014). Hotter summers are likely to increase the temperatures in some coldwater streams too high for native species such as brook trout to thrive.

Sea level is expected to rise 1.6 to 6.6 feet over the next century (Kirshen et al 2014). This will lead to inundation of coastal habitats and saltwater intrusion into freshwater habitats. The extent to which tidal habitats such as estuaries and salt marshes can respond to these changes by moving inland will be limited by the concentration of land development in coastal New Hampshire. Other ocean changes that may affect wildlife include ocean acidification, and temperature and salinity changes.

Scientific research has also shown that some of the most significant effects of climate change and severe weather on wildlife and their habitats result from interactions with other threats. In the past, organisms have responded to climate change by moving to stay within conditions they can tolerate, but habitat fragmentation means that this movement is no longer possible in many places leading to a greater risk of local extinction. Climate change has also been linked to an increased spread in invasive species and more severe disturbance events; for example the 2015 wildfires in the western United States. While these “synergistic” effects likely represent some of the most damaging effects of climate change on wildlife, they are difficult to predict and further scientific study is warranted.

Risk Assessment Summary

The threats assessment determined that 45 species and 16 habitats were affected at least moderately by climate change (see Table 4-13). However, there was considerable uncertainty about the actual extent, severity and immediacy of the effects of climate change on species and habitats. All 27 habitats had a least one type of climate threat associated with it, and 91 species did as well.

IUCN Level II categories Habitat Shifting & Alteration and Storms & Flooding affected the most species and habitats. Habitat shifts are caused by changing temperatures, precipitation, and sea level rise as well as chemical changes in water and soil. These changing conditions alter the distribution of suitable habitat for species and communities, thus wildlife must move to remain within conditions they can tolerate. Flooding alters flows of stream and rivers and increases the amount of pollutants and sediments that wash into them, altering habitat, affecting reproduction, and causing direct mortality.

In 2013 NHFG published the Ecosystems and Wildlife Climate Change Adaptation Plan (NHFG 2013), intended as an implementation plan under the state’s Climate Action Plan and as an amendment to the Wildlife Action Plan. This was a comprehensive look at the effect of climate change on species and habitats, and was conducted using an expert review assessment of the state’s habitats, as it was determined that most climate effects would be due to changes in habitats. The plan includes individual habitat assessments and a compilation of the overall threats. It also outlines strategies to address the threats, separated into 12 categories. This document was referred to during the 2015 threats assessment and is incorporated in the 2015 WAP.

Known Wildlife Exposure Pathways

Extreme storms and flooding

Over the last decade, there have been several storm events which have met the standards for 100-year flood state in NH including the Mother’s Day flood in 2006, April of 2007, Hurricane Irene in 2011 and Hurricane Sandy in 2012. These floods cost millions of dollars in infrastructure damage such as blown out culverts, flooded roads and severe erosion in stream banks. The resulting sediment and debris such as asphalt also polluted the streams, rivers, lakes and ponds, and changed habitat structure and function. Cleanup efforts sometimes involved driving backhoes right into the stream bed, a practice ordinarily prohibited and which is damaging to the instream habitat. For wildlife, the erosion increased sedimentation, washed away or covered spawning habitat and swept animals downstream or killed them. Mussels are particularly sensitive to sedimentation, and can be buried under the load, which also clogs their filter feeding mechanisms, killing them. Stormwater also floods nest sites along the banks of rivers and ponds or in the saltmarshes downstream, affecting loons, wood turtles and others.

The number of extreme storms is predicted to increase up to threefold by 2099 (Wake et al 2014a and

2014b). Extreme storms can disrupt bird migrations and make breeding and nesting sites inhospitable, forcing birds into marginal habitats. Coastal ecosystems are particularly susceptible to storms which disrupt dunes, salt marshes, and estuaries, and bring additional stress to species living there (Michener et al. 1997). In New Hampshire these species include nesting plovers, saltmarsh birds, and colonial seabirds. In estuarine systems, influxes of freshwater from increased storm events may alter salinity and change water temperatures leading to shifts in the distribution of species and communities, increased stress, and mortality. Floodplain habitats may experience more flooding, possibly with altered timing and duration, and will also be affected by summer droughts. The end result may be altered species composition, including more invasives and the replacement of cold-associated species with more southern species. Human responses to flooding may change flow patterns, if flood control dams or other structures alter where and how stormwater is stored. Conversely, one human response is to abandon flood prone areas, thus there is the potential for increased habitat restoration opportunities in floodplains. Storm protection ("gray") infrastructure in coastal areas may prevent the movement of sediments on beaches and dunes leading to degradation of these habitats.

Shifts in plant communities and wildlife

The structure of forests including the types of tree species, which species are most abundant, and the distribution of different ages of trees, is expected to change in response to climate change, but the degree and how it will change may differ amongst forest types. It is likely that our species-based definition of Natural Communities may change, as individual plants react differently to increases in temperature and changes in the hydrological regime (NHFG 2013). Species' ranges will shift individually based on unique tolerances, and different associations may occur. Changes will occur due to specific site conditions, so will vary across the landscape. High elevation spruce-fir forests may be the most affected, as warmer temperatures will allow species like yellow birch to migrate to higher elevations. The warmth will also reduce recruitment (seedling production) for species such as balsam fir. Other factors likely to influence forest composition and condition include disturbance, invasives, extreme weather and drought. Terrestrial wildlife whose southern range extends into New Hampshire will likely shift their range northward as climate warms. These include species such as the northern bog lemming, moose, and snowshoe hare. Similarly, species whose northern range extends into southern New Hampshire will move northwards.

There is some uncertainty regarding climate-induced changes in alpine habitats in New Hampshire. Alpine habitats in New Hampshire tend to occur above the planetary boundary layer (the lowest part of the atmosphere directly influenced by the planet surface). Above that the winds and temperatures move more freely above the earth. This means that climatic trends are usually decoupled from those at lower elevations (e.g. temperatures have not risen as significantly at the highest elevations) (Seidel et al 2009). As a result, this habitat may be more resilient to climate change than previously believed. However, other studies conclude that alpine herbaceous communities are strongly affected by climate change (Walker et al. 1995, Kimball and Weihrauch 2000, Lesica and McCune 2004, Sperduto and Nichols 2004). In a review of ecological changes over the last third of the 20th century, Walther et al (2002) documented climate-related elevation shift of alpine plants, rising tree line, and northward range shifts of 39 butterfly species. For two state-listed butterflies, *Boloria titania montinus* and *Oeneis melissa semidea*, the combination of climate change and isolation may result in local extirpation without a northward range shift (e.g. extinction). That said, there could be increased encroachment of trees if snowfall increases at high elevation and shelters woody growth against the effects of wind and ice. Earlier snowmelt may allow alpine plants to bloom earlier, making them more susceptible to frost and potentially lowering seed production (NHFG 2013).

Phenology

Phenology is the timing of biological events throughout the year. This includes events like leaf out, arrival of migrating birds, emergence of adult insects and the like. In the last 50 years, dates of the last hard frost and lilac blooming have both become significantly earlier in New England (Cooter and Leduc 1995, Schwartz and Reiter 2000). This trend is predicted to continue, with leaf out occurring 6.7-15 days earlier, and lilacs blooming 6.3-16 days earlier by 2100 (Hayhoe et al 2008). Scientists in Wisconsin studied 55 springtime events—from the appearance of pussywillows to robins to trillium blooms—and found that for all combined, these events occurred an average of 0.12 days earlier per year over 61 years (7.3 days) (Bradley et al. 1999). Many species of migratory birds have shifted their arrival dates as much as 3 weeks earlier over the last several decades (Price and Root 2002). Such shifts in migration phenology have the potential to decouple bird migration peaks from peaks in food supply (e.g., McCarty 2001). This phenological decoupling may occur in other circumstances where the timing of some key biological events changes in response to climate change while other key events do not.

Snow depth and winter ice

In New Hampshire, average wintertime air temperatures increased by 3.5 F during the period from 1895-1999 (well above the regional average) (NERA 2001). By 2099, average winter temperatures will increase 3.8-9.2 F (Wake et al 2014a and 2014b) similar to the entire northeast (5-13 F, Northeast Climate Impacts Assessment 2007 and 3.1-9.7 F (Rustad et al 2012). Freeze-free periods have increased, snow cover has decreased, and lake ice duration (as measured by ice-out dates) has decreased (NERA 2001, Hodgkins et al. 2002, Huntington and Hodgkins 2004, Wake and Markham 2005). The number of snow covered days is expected to decrease by 27-42 days by 2099 (Wake et al 2014a). Snow depth and frequency are important factors affecting distribution of American marten (Krohn et al. 1995, Raine 1983) and lynx (Hoving et al. 2005). They also have direct effects on species that change their winter coat color to white such as snowshoe hare and weasel. These species may become more vulnerable due to loss of snow camouflage in the late fall and early spring. Changes to lake ice duration and surface water temperatures will strongly affect primary productivity, dissolved oxygen, thermal habitat, and invertebrate and fish communities (Rustad et al 2014). However, in the more near term, there will also be more extremes of cold and snow due to the shifting polar jet stream, which is caused by melting of artic regions (Francis and Skific 2015).

Loss of thermal habitat

Many fish species, such as brook trout and salmon, have narrow temperature tolerances. Others, such as yellow perch and smallmouth bass, are more tolerant. As climate change causes water to warm, many of New Hampshire’s coldwater fish will be replaced by warmwater species (Eaton and Scheller 1996). Some of the fish hosts of New Hampshire’s two endangered freshwater mussel species (dwarf wedgemussel and brook floater) are coldwater fish whose thermal habitat will likely diminish as climate warms, ultimately affecting the reproductive success of the mussels.

In marine systems, more problematic are trophic cascades (where an effect of climate on one level of a food chain, for example a predator, has subsequent effects on other levels, for example prey) and northward species migrations in response to warmer temperatures. Plankton blooms may no longer coincide with fish breeding and migration, thus impacting survival and reproduction. Invasive species and pathogens may also increase as the ocean warms. Marine productivity may also be affected by changes in thermohaline circulation of coastal waters, a changing thermal regime, and reduced oxygen availability.

Some terrestrial species at the southern limit of their range may also be directly affected by warmer temperatures. At summer temperatures above 57 F and winter temperatures above 23 F moose start to show symptoms of heat stress. When moose experience heat stress, their respiration and heart rates increase, they seek shade and cooling winds or cool water and they bed down and eventually cease foraging increasing their risk of mortality (Franzmann & Schwartz 1998).

Rising sea level

One of the most dramatic predicted effects of climate change in coastal habitats will be sea level rise. Sea level in the United States is rising 2.5 to 3.0 mm/yr. Global warming could raise the sea level by 0.6 to 2 feet by 2050 and 1.6 to 6.6 feet by 2100 (Kirshen et al 2014). The predicted high water levels will inundate salt marshes, deepen estuaries, and convert marsh grass to mudflat and mudflats to subtidal zones. If the rate of sea level rise is rapid, affected habitats will be inundated more frequently, putting their associated species at high risk. Total habitat and species losses are particularly likely in developed areas where there are no natural habitat retreat areas to allow for salt marsh migration.

Dune and beach habitats are important for nesting and loafing seabirds, including Roseate terns, common terns, and marine mammals. Sea level rise may affect habitat availability and the timing of nesting and migration for seabirds (Kushlan et al. 2002, Galbraith et al. 2002). The sand and sediment making up coastal dunes will be driven inland by high tides and storm surges, with the lack of natural sediment movement and coastal development meaning that in many places dunes will be lost altogether. The degradation and loss of dunes will increase the impacts of storms and high tides further inland.

As well as being inundated, salt marsh habitats may also lose pioneer species and salt pannes due to reduced incidence of ice scour. This habitat is also sensitive to changes in salinity from freshwater inputs (NHFG 2013). Rocky shores and islands will not be as affected except in low lying areas. Most intertidal species may shift to higher elevations but will be subject to more heavy surf during storms. Island-nesting birds may lose habitat or experience reduced productivity as a result of changes to available prey (NHFG 2013).

Invasive Species

Climate change will facilitate the introduction and spread of invasive species (including new diseases and pathogens) in New Hampshire. For instance, the hemlock woody adelgid, whose range is limited by temperature, has been steadily pushing north and has reached Moultonborough New Hampshire (NH Forests and Lands 2015). Loss of hemlock would have dramatic effects on forest composition, wildlife habitat, and ecosystem processes in terrestrial and aquatic ecosystems. New pest invasions are also likely including spruce-fir pests currently attacking southern Appalachian forest. The wasting disease pathogen (*Labyrinthula zosterae*), which has decimated eelgrass beds in the past, might become more of a problem because it prefers higher salinity waters (which are expected in some estuaries because of sea-level rise) and warmer water. Many non-native warmwater fish will become more predominant in many watersheds, especially where they are currently limited by temperature. West Nile Virus will likely become more of a threat if climate conditions (milder winters, wetter summers) facilitate mosquito survival and breeding. Floodplain habitats may experience increased erosion due to floods and provide more disturbed habitat for invasive plants. Transmission lines create areas of shrublands and avenues for invasive species. Control of invasive could exacerbate existing issues if chemical or biological controls are used in sensitive areas, affect non-target organisms or are used improperly.

Research Needs

- Use data from Anderson et al. 2012 and other studies and models with New Hampshire-based data to create a statewide/local map showing habitats and areas that may be most resilient to climate change.
- Incorporate the resiliency work and other adaptation issues into the ranking for creating the Wildlife Action Plan Highest Ranked Habitat map. Use this to identify key high-priority areas for conservation in the context of climate change for both natural and ecosystem service demands.
- Identify priority landscapes to provide connectivity between habitat patches.
    - Perform connectivity analyses throughout the state to identify key road crossings and current and incipient bottlenecks for movement of plant propagules and wildlife. These analyses could be done statewide or in smaller regions.
    - Identify networks of corridors and associated fragmentation barriers whose restoration facilitate species movement over the long term.
    - Develop predictive models and assess accuracy based on permanent monitoring sites (including Surface Elevation Tables (SETs), which measure saltmarsh accretion rates in salt marshes; and rocky shore, aerial mapping of rocky shores and dune extent; and biomonitoring for key indicators of climate change in all habitats.) Then develop an understanding of the feasibility of modifying policies on development and sea level rise, etc.
- Identify, through modeling, watersheds where water conflicts between humans and natural systems due to drought and flooding are likely to occur and protect a broad suite of interrelated ecosystem services that also protect natural habitats.
- Model hydrologic change based on climate models including the new US Geological Survey precipitation models for NH.
- Use Sea Level Affecting Marshes Model (SLAMM) and associated sea level rise measurement infrastructure to understand where sea level rise will most affect the coast and where habitats might migrate. Create future scenarios that show the differences if obstacles to habitat migration are removed or mitigated (e.g. roads and other infrastructure abandoned or removed, culverts appropriately sized, head-of-tide dams removed). Assess feasibility of these mitigation measures. Then re-zone and work to protect these areas that may be able to evolve to productive coastal habitats.
- Use Forest Inventory Analysis (FIA) and other data to assess how forest communities have already changed to demonstrate potential associations with climate patterns, and use this information to project changes onto future landscapes.
- Research how climate impacts soil and soil ecology, and use this to begin to determine how natural communities and habitats may change.
- Connect soil-water movements across different catenas (topographic complex of soils) to shifts in plant community structure to better understand future effects of shifting groundwater.
- Promote research on silvicultural techniques that can be used to manage forests for likely future species composition. Explore forest management techniques in the southern states with similar geology and soils so we can prepare for possible impacts.
- Evaluate biomass projects for potential impacts on forest type (e.g., does it speed community shifts in certain habitats?). Develop new BMPs for biomass harvesting as appropriate.
- Assess potential changes of fire risk from drier weather and increased downed wood.

- Assess potential phenological decoupling which may cause species to become endangered with a focus on species/taxa that are reliant on synchronized phenology for critical life history events, and where climate change is likely to shift the timing of some of these biological events at a pace different from that of others.
- Establish or expand a network of monitoring plots to observe climate related changes, and coordinate among monitoring efforts. This includes continuing existing chemical and physical monitoring and the addition of new parameters and locations. Monitoring should include long-term wildlife population monitoring, invasive plant species, forest tree and other plant species composition, wetland hydrology, and phenology. In coastal areas, sentinel monitoring for climate change approaches should be instituted to track primary stressors such as temperature, sea level rise and changing physical and chemical regimes that affect ecosystem health. Monitoring efforts should integrate and take advantage of existing programs such as FIA and work in partnership with state and federal agencies, NGOs, universities, co-ops and others. This monitoring should provide data to inform adaptive management of species and habitats and to direct necessary changes in policies.
- Establish locally relevant tide gauges and SETs in order to measure and predict sea level change hydrodynamics within Great Bay and Hampton/Seabrook. These could be set up on a short-term basis in order to establish the elevation relationship and changes in SLR between Fort Point data (the nearest active National Water Level Observation Network tide station) and other areas of the coast.

Table 4-13. Habitats and species at highest risk from the effects of climate change and severe weather (threats ranked as *Low* not included here). IUCN Level 2 provided if evaluated to that level (if not evaluated to level 2, text reads *not specified*). Some habitats and species were evaluated for multiple specific threats separately and therefore listed multiple times below. See Appendix E for additional information on specific threats and rankings.

Habitat	IUCN Level 2	Overall Threat Score
Appalachian Oak Pine Forest	Habitat shifting & alteration	M
Coastal Islands	Habitat shifting & alteration	M
Coldwater rivers and streams	Storms & flooding	M
Coldwater rivers and streams	Temperature extremes	M
Dunes	Habitat shifting & alteration	M
Estuarine	Storms & flooding	M
Hemlock-hardwood-pine forest	Habitat shifting & alteration	M
High Elevation Spruce-Fir Forest	Habitat shifting & alteration	M
Large warmwater rivers	Storms & flooding	M
Lowland Spruce-Fir Forest	Habitat shifting & alteration	M
Marine	Habitat shifting & alteration	M
Marine	Temperature extremes	H
Northern Hardwood-Conifer Forest	Habitat shifting & alteration	M

Northern Swamp	Temperature extremes	M
Peatlands	Droughts	M
Peatlands	Temperature extremes	M
Salt Marsh	Habitat shifting & alteration	H
Warmwater rivers and streams	Storms & flooding	M

Common Name	**IUCN Level 2**	**Overall Threat Score**
Alewife Floater	Storms & flooding	H
American Black Duck	Lowered reproduction	M
American Bumble Bee	Changes in phenology	H
American Marten	Habitat shifting & alteration	M
American Oysters	Habitat shifting & alteration	M
American Oysters	Storms & flooding	M
Atlantic Sea Scallop	Habitat shifting & alteration	M
Atlantic Sea Scallop	Temperature extremes	H
Bank Swallow	Droughts	M
Brook Floater	Storms & flooding	H
Chimney Swift	Storms & flooding	M
Cliff Swallow	Droughts	M
Common Loon	Lowered reproduction	M
Common Nighthawk	Temperature extremes	M
Common Tern	Altered food chains	M
Creeper (Mussel)	Storms & flooding	M
Dwarf Wedgemussel	Storms & flooding	H
Eastern Brook Trout	Temperature Extremes	M
Eastern Pearlshell	Storms & flooding	H
Horseshoe Crab	Habitat shifting & alteration	M
Horseshoe Crab	Storms & flooding	M
Horseshoe Crab	Temperature extremes	H
Karner Blue Butterfly	Lowered reproduction	M
Least Terns	Storms & flooding	M
Lynx	Habitat shifting & alteration	M
Margined Tiger Beetle	Habitat shifting & alteration	H
Moose	Changes in temperatures	H
Nelson's Sparrow	Habitat shifting & alteration	H

Nelson's Sparrow	Storms & flooding	H
Northern Shrimp	Habitat shifting & alteration	M
Northern Shrimp	Temperature extremes	H
Peregrine Falcon	Storms & flooding	M
Piping Plover	Storms & flooding	M
Purple Martin	Storms & flooding	M
Purple Sandpiper	Habitat shifting & alteration	M
Red Knot	Habitat shifting & alteration	M
Roseate Tern	Altered food chains	M
Ruddy Turnstone	Habitat shifting & alteration	M
Rusty-patched Bumble Bee	Changes in phenology	H
Saltmarsh Sparrow	Habitat shifting & alteration	H
Saltmarsh Sparrow	Storms & flooding	H
Sanderling	Habitat shifting & alteration	M
Seaside Sparrow	Habitat shifting & alteration	H
Seaside Sparrow	Storms & flooding	M
Semipalmated Sandpiper	Habitat shifting & alteration	M
Softshell Clam	Habitat shifting & alteration	M
Softshell Clam	Storms & flooding	M
Spruce Grouse	Habitat shifting & alteration	H
Timber Rattlesnake	Storms & flooding	M
Triangle Floater	Storms & flooding	M
Whimbrel	Habitat shifting & alteration	M
Willet	Habitat shifting & alteration	H
Willet	Storms & flooding	M
Wood Turtle	Storms & flooding	M
Yellow Bumble Bee	Changes in phenology	H
Yellowbanded Bumble Bee	Changes in phenology	H

Literature Cited

Anderson, M.G., M. Clark, and A. Olivero Sheldon. 2012. Resilient Sites for Terrestrial Conservation in the Northeast and Mid-Atlantic Region. The Nature Conservancy, Eastern Conservation Science. 168 pp.

Bradley, N.L., A.C. Leopold, J. Ross, and W. Huffaker. 1999. Phenological changes reflect climate change in Wisconsin. Proceedings of the Natural Academy of Sciences 96:9701-9704.

Campbell, John L., Anne M. Socci, and Pamela H. Templer. 2014. Increased Nitrogen Leaching Following Soil Freezing Is due to Decreased Root Uptake in a Northern Hardwood Forest. Global Change Biology 20 (8): 2663-2673 doi:10.1111/gcb.12532

Cooter, E.J., and S.K. Leduc. 1995. Recent frost date trends in the north-eastern USA. International Journal of Climatology 15:65-75.

Eaton, J.G., and R.M. Scheller. 1996. Effects of climate on fish thermal habitat in streams of the United States. Limnology and Oceanography 41:1109-1115.

Francis J, Skific N. 2015. Evidence linking rapid Arctic warming to mid-latitude weather patterns. Philosophical Transactions A, Royal Society Vol:373 Issue: 2045:20140170. http://dx.doi.org/10.1098/rsta.2014.0170

Franzmann, A.W. and C.C Schwartz. 1998. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington D.C. and London, England. 733 pp.

Galbraith, H., R. Jones, R. Park. J. Clough, S. Herrod-Julius, B. Harrington, and G. Page. Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. Waterbirds 25:173-183.

Hayhoe, K., C. Wake, B. Anderson, X. Ling, E. Maurer, J. Zhu, J. Bradbury, a. DeGaetane, A.M. Stoner, D. Wuebbles. 2008. Regional climate change projections of the Northeastern USA. Mitigation and Adaptation Strategies for Global Change 13:425-436.

Hoving, C.L., D.J. Harrison, W.B. Krohn, R.A. Joseph, and M. O'Brien. 2005. Broad-scale predictors of Canada lynx occurrence in eastern North America. Journal of Wildlife Management 69(2):739-751.

Huntington, T.G., and G.A. Hodgkins. 2004. Changes in the proportion of precipitation occurring as snow in New England. Journal of Climate 17:2626-2636.

Kimball, K.D., and D.M. Weihrauch. 2000. Alpine vegetation communities and the alpine-treeline ecotone boundary in New England as biomonitors for climate change. USDA Forest Service Proceedings 3:93-101.

Kirshen, Paul, Cameron Wake, Matt Huber, Kevin Knuuti, Mary Stampone. 2014. Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Future Trends. New Hampshire Coastal Risks and Hazards Commission. 45 pp.Hodgkins, G.A., I.C. James, and T.G. Huntington. 2002. Historical changes in lake ice-out dates as indicators of climate change in New England, 1850-2000. International Journal of Climatology 22:1819-1827.

Krohn, W.B., K.D. Elowe, and R.B. Boone. 1995. Relations among fisher, snow, and martens: Development and evaluation of two hypotheses. The Forestry Chronicle 71:97-105.

Kushlan, J.A., M.J. Steinkamp, K.C. Parsons, J. Capp, M. Acosta Cruz, M. Coulter, I. Davidson, L. Dickson, N. Edelson, R. Elliot, R.M. Erwin, S. Hatch, S. Kress, R. Milko, S. Miller, K. Mills, R. Paul, R. Phillips, J.E. Saliva, B. Sydeman, J. Trapp, J. Wheeler, and K. Wohl. 2002. Waterbird conservation for the Americas: the North American waterbird conservation plan, Version 1. Waterbird Conservation for the Americas, Washington, DC, USA.

Lesica, P., and B. McCune. 2004. Decline of arctic-alpine plants at the southern margin of their range following a decade of climatic warming. Journal of Vegetation Science 15:679-690.

McCarty, J.P. 2001. Ecological consequences of recent climate change. Conservation Biology 15:320-331.

Michener, W.K., E.R. Blood, K.L. Bildstein, M.M. Brinson, and L.R. Gardner. 1997. Climate change, hurricanes and tropical storms, and rising sea level in coastal wetlands. Ecological Applications 7: 770-801.

NERA (New England Regional Assessment). 2001. Preparing for a Changing Climate. The New England Regional Assessment Overview. U.S. Global Change Research Program, University of New Hampshire, Durham, NH. Available online at http://www.necci.sr.unh.edu/2001-NERA-report.html.

NH Division of Forests and Lands. 2015. NH Towns with Known Hemlock Woolley Adelgid Infestations. http://extension.unh.edu/resources/files/Resource003870_Rep5501.pdf Accessed 6 June 2015.

NH Fish and Game Department. 2013. Ecosystems and Wildlife Climate Change Adaptation Plan. NHFG. Concord, NH. 133 pp.

Northeast Climate Impacts Assessment. 2007. Confronting Change in US Northeast: New Hampshire. Union of Concerned Scientists. Cambridge MA. 6pp.

Price, J.T., and T.L. Root. 2002. No orioles in Baltimore? Climate change and Neotropical migrants. Bird Conservation 16:12.

Raine, R.M. 1983. Winter habitat use and responses to snow cover of fisher (*Martes pennanti*) and marten (*Martes americana*) in southeaster Manitoba. Canadian Journal of Zoology 61:25-34.

Rustad, Lindsey; Campbell, John; Dukes, Jeffrey S.; Huntington, Thomas; Fallon Lambert, Kathy; Mohan, Jacqueline; Rodenhouse, Nicholas. 2012. Changing climate, changing forests: The impacts of climate change on forests of the northeastern United States and eastern Canada. Gen. Tech. Rep. NRS-99. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 48 p.

Schwartz, M.D., and B.E. Reiter. 2000. Changes in North American spring. International Journal of Climatology 20: 929-932.

Seidel, T. M., D. M. Weihrauch, K. D. Kimball, A. A. P. Pszenny, R. Soboleski, E. Crete, G. Murray. 2009. Evidence of Climate Change Declines with Elevation Based on Temperature and Snow Records from 1930s to 2006 on Mount Washington, New Hampshire, U.S.A. Arctic, Antarctic, and Alpine Research. 41: 362-372.

Simas, T., J.P. Nunes, and J.G. Ferreira. 2001. Effects of global climate change on coastal salt marshes. Ecological Modeling 139:1-15.

Sperduto, D.D., and W.F. Nichols. 2004. Natural communities of New Hampshire. New Hampshire Natural Heritage Bureau. Concord, New Hampshire, USA.

Wake, Cameron, Elizabeth Burakowski, Peter Wilkinson, Katharine Hayhoe, Anne Stoner, Chris Keeley and Julie LaBranche. 2014a. Climate Change in Northern New Hampshire: Past, Present, and Future. Sustainability Institute at the University of New Hampshire. Durham NH. 76pp.

Wake, Cameron, Elizabeth Burakowski, Peter Wilkinson, Katharine Hayhoe, Anne Stoner, Chris Keeley and Julie LaBranche. 2014b. Climate Change in Southern New Hampshire: Past, Present, and Future. Sustainability Institute at the University of New Hampshire. Durham NH. 76pp.

Wake, C., and A. Markham. 2005. Indicators of Climate Change in the Northeast. Joint publication of Clean Air-Cool Planet and the Climate Change Research Center, University of New Hampshire, Durham, New Hampshire.

Walker, M.D., R.C. Ingersoll, and P.J. Webber. 1995. Effects of interannual climate variation on phenology and growth of two alpine forbs. Ecology 76:1067-1083.

Walther, G.R., E. Post, P. Convey, A. Menzel, C. Parmesan, T.J. Beebee, J.M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416:389-395.

Residential and Commercial Development

The International Union for the Conservation of Nature broadly defines the ‘residential and commercial development’ threat (IUCN 1) as wildlife impacts from human settlements or other non-agricultural land uses with a substantial footprint. This threat is further assigned to the following categories:

- Housing & urban areas such as cities, towns, and settlements including non-housing development typically integrated with housing.
- Commercial & industrial areas such as factories and other commercial centers. Commercial centers are typically selling a product or service, while industrial areas focus on manufacturing a product. Threats from these activities, such as level of pollution, vary by location and practice.
- Tourism & recreation areas with a substantial footprint.

Risk Assessment Summary

Residential and commercial development affects 115 SGCN species and 22 habitats. Among the 200 threats identified within this category, 28 were ranked as high, 92 as medium, and 80 as low (See Table 4-14). In the 2005 Wildlife Action Plan, development was the highest ranking threat to species and habitats. This threat was downgraded in the 2015 ranking, which was likely the result of a modification of the threat ranking methodology, and/or the economic downturn known as the Great Recession.

During the 2015 ranking process, expert reviewers were instructed to limit the assessment of risk to a 10 year time horizon and consider the risk from future development only (see Appendix E), whereas in 2005 impacts from past development and an unlimited time horizon were used to evaluate this threat, which likely resulted in development being the highest rank threat. Changes in 2015 methodology were made to adhere to a more uniform approach that was adopted by the Northeast states.

In addition to the change in methodology leading to a reduction in the development threat, New Hampshire, the region and the nation experienced an economic crisis that resulted in a collapse in the housing market. Norton et al. (2014) reported that during “the decade between 2000 and 2010, New Hampshire’s growth rate fell to 6.5 percent, still the highest rate in the Northeast, but the state’s slowest decade of growth since before World War II…For the forecast years beyond 2010, New Hampshire population growth rates are expected to continue to decline – with 3.3 percent growth from 2010 to 2020 and a modest 3.8 percent growth from 2020 to 2030 according to the New Hampshire Office of Energy and Planning’s 2012 population projections.”

The reduction in development was reflected in the number of standard wetland dredge and fill permits, which after reaching a high of 939 in 2006 dropped to a low of 485 in 2011. Subsequently, they rebounded to 581 applications in 2014. A similar trend occurred in the number of projects that NHFG reviewed for their potential to impact threatened and endangered wildlife; however, a sharp increase to pre-recession levels was recorded for 2014. Although improvements in the economy are leading to increases in residential and commercial development, NH housing markets are not predicted to return to levels experienced in the last two decades of the 20th century due to an aging population and loss of young workers (Norton et al 2014).

Despite the reduction in housing and commercial growth, many species of wildlife and habitats will continue to be threatened by development, especially in southern counties where rapid growth is expected to continue. Economic development programs aimed at attracting tourists, such as ATV trail development and ski area expansion, will continue to expand the footprint of development in the northern counties.

Known Wildlife Exposure Pathways

Housing and urban areas, and commercial and industrial development
Wildlife and habitat impacts associated with housing and urban areas, and commercial and industrial development, are similar enough to treat as a single category. Development is a widespread threat for habitats and species, both wetland and terrestrial. Species or habitats with a limited distribution, complex habitat requirements, and/or low population sizes often are at greatest risk. Impacts can be very extensive and serious or catastrophic for some species (i.e., timber rattlesnake, New England cottontail, Karner blue butterfly, Blanding's and spotted turtles, and salt marsh birds), in the short-term or immediately. Development of uplands surrounding salt marshes, freshwater marshes, and shrub wetlands is likely to be extensive, serious to catastrophic, and occur in the short-term. Impacts are generally somewhat or well-documented.

Development results in the loss of habitat required by native wildlife and the fragmentation of remaining blocks of habitat. Organisms may be killed during or after construction. All habitats and species are impacted by development but to varying degrees. Large forest blocks are being subdivided and remaining patches are becoming highly fragmented, especially in southern New Hampshire. As a result, area-sensitive species will decline and local populations will become more vulnerable to local extirpations. Early successional shrublands in southern New Hampshire are ephemeral by nature but are rapidly being developed and fragmented, leaving the New England cottontail at serious risk.

Thirty-two percent of New Hampshire's land area is protected, which is a 4% increase from the 28% reported in the 2005 Wildlife Action Plan (TNC and SPNHF 2014). Nevertheless, the largest land protection gains were in Northern counties (e.g. Androscoggin headwaters) and percentages of land protected in Southern counties and within certain habitats such as Appalachian–oak-pine and floodplains remain low. As an example, approximately 6% of the state is identified as 100-year floodplain, yet only 21% of floodplain is currently protected or in public ownership (TNC and SPNHF 2014). Species also remain vulnerable, with nearly two-thirds of documented rare plant and animal occurrences in the Granite State on unprotected land (TNC and SPNHF 2014).

At the current rate of protection and development, many more species will become rare, and several rare species are likely to be extirpated from the state. Loss and fragmentation of habitats resulting from development are not restricted to a particular habitat or species; however, some are at greater risk due to limited distribution, low population densities (e.g., Karner blue butterfly, timber rattlesnake), life history characteristics (e.g., low reproductive rates, late age of maturity, large home ranges), ease of development (e.g., pitch-pine barrens), or the intersection of development pressure and the distribution of the habitat type in New Hampshire. Filling of freshwater or estuarine wetlands can have immediate severe impacts on local flora and fauna. The NHDES reports a cumulative 1,600 acres of wetlands lost in association with permitted projects from 1997-2012 (NHDES 2013). Currently, freshwater wetlands (see Marsh & Shrub wetlands and Peatlands profiles), salt marshes, rivers, and streams are regulated by NHDES (RSA 482-A and Wetlands Bureau Administrative Rules). Vernal pools, although regulated by RSA 482-A, are vulnerable to filling due to small size and ephemeral hydroperiods. The greatest threat wildlife requires a relatively undeveloped upland buffer to allow for nesting, foraging, breeding, and hibernation, and/or to reduce disturbance. NHDES does not require development setbacks from wetlands, unless designated as a 'prime wetland' by the town. The Comprehensive Shoreland Protection Act (RSA 483-B) regulates tree cutting and development of major rivers and large surface bodies (> 10 ac); however, most of the smaller perennial tributaries receive no upland protection. Town zoning and wetland regulations vary considerably throughout the state.

Development of terrestrial habitats is largely unregulated in New Hampshire. Site-specific permits are required by the NHDES for impacts exceeding 100,000 sq. ft. As part of the 2005 Wildlife Action Plan implementation, wildlife and rare natural community impacts are being included in the review process for alteration of terrain permits.

Tourism & recreation areas

Two major initiatives are underway to boost the North Country economy through recreation. One is Ride the Wilds and the second is a major expansion proposed for the Balsams Ski Area and Resort in Dixville. Ride the Wilds is an initiative to attract ATV riders to Coos County for which the state developed a system of motorized vehicle trails in Jericho Mountain State Park. In addition, 10 towns have opened their roads to ATV use to provide a 1,000 mile network of riding opportunities. As riding pressure increases and new trails are developed, wildlife will experience direct mortality from vehicles and disturbance from noise. Trail development and use will also provide expansion opportunities for invasive species.

Plans are also underway for a major expansion of the Balsams ski area. High elevation spruce- fir forest and associated species such American marten, Bicknell's thrush and three-toed woodpecker will likely be impacted by new and expanded ski trails.

Research Needs

- Determine minimum patch sizes and levels of connectivity required for supporting self-sustaining populations of threatened and endangered wildlife.
- Evaluate new development patterns that emerge with changing human demographics.
- Evaluate ATV impacts to wildlife to develop best management practices.
- Identify habitat types with low levels of existing protection and high levels of development pressure as targets for conservation efforts.

Table 4-14. Habitats and species at highest risk from the effects of commercial and residential development (threats ranked as *Low* not included here). IUCN Level 2 provided if evaluated to that level (if not evaluated to level 2, text reads *not specified*). Some habitats and species were evaluated for multiple specific threats separately and therefore listed multiple times below. See Appendix E for additional information on specific threats and ranking

Habitat	IUCN Level 2	Overall Threat Score
Appalachian Oak Pine Forest	Not Specified	H
Coastal Islands	Not Specified	M
Coldwater rivers and streams	Not Specified	M
Dunes	Housing & urban areas	M
Floodplain Forests	Not Specified	H
Grasslands	Commercial & industrial areas	M
Grasslands	Not Specified	M
Hemlock-Hardwood-Pine Forest	Not Specified	M
High Elevation Spruce-Fir Forest	Not Specified	M
Large warmwater rivers	Not Specified	M
Marsh and Shrub Wetlands	Not Specified	M
Northern Hardwood-Conifer Forest	Not Specified	M
Peatlands	Not Specified	M
Pine Barrens	Not Specified	M
Salt Marsh	Not Specified	H
Shrublands	Not Specified	H
Talus Slopes, Rocky Ridges	Not Specified	M
Temperate Swamp	Not Specified	M
Vernal Pools	Not Specified	H
Warmwater lakes and ponds	Not Specified	M
Warmwater rivers and streams	Not Specified	M

Common Name	IUCN Level 2	Overall Threat Score
American Bumble Bee	Not Specified	M
American Marten	Not Specified	M
American Woodcock	Not Specified	M
Bald Eagle	Not Specified	M
Banded Sunfish	Not Specified	M

Bay-breasted Warbler	Not Specified	M
Bicknell's Thrush	Not Specified	M
Black-billed Cuckoo	Not Specified	H
Blanding’s Turtle	Not Specified	H
Blue-winged Warbler	Not Specified	H
Bobolink	Commercial & industrial areas	M
Bobolink	Not Specified	M
Box Turtle	Not Specified	M
Bridle Shiner	Not Specified	H
Brook Floater	Not Specified	M
Brown Thrasher	Not Specified	H
Canada Warbler	Not Specified	M
Cape May Warbler	Not Specified	M
Cerulean Warbler	Not Specified	M
Common Nighthawk	Not Specified	H
Common Tern	Not Specified	M
Coppery Emerald	Not Specified	M
Dwarf Wedgemussel	Not Specified	M
Eastern Meadowlark	Commercial & industrial areas	M
Eastern Meadowlark	Not Specified	M
Eastern Pearlshell	Not Specified	M
Eastern Pondmussel	Not Specified	M
Eastern Towhee	Not Specified	H
Eastern Whip-poor Will	Not Specified	M
Field Sparrow	Not Specified	H
Fowlers Toad	Not Specified	M
Frosted Elfin	Not Specified	H
Golden-winged Warbler	Not Specified	H
Grasshopper Sparrow	Commercial & industrial areas	H
Grasshopper Sparrow	Not Specified	M
Hessel's Hairstreak	Not Specified	M
Hognose Snake	Not Specified	H
Horned Lark	Commercial & industrial areas	H
Jefferson/Blue-Spotted Salamander Complex	Not Specified	M
Karner Blue Butterfly	Not Specified	H
Kennedy's Emerald	Not Specified	M

Least Terns	Not Specified	M
Lynx	Not Specified	H
Lyre-tipped Spreadwing	Not Specified	M
Marbled Salamander	Not Specified	H
Margined Tiger Beetle	Not Specified	M
Monarch	Not Specified	M
Moose	Not Specified	M
New England Cottontail	Not Specified	H
Northern black racer	Housing & urban areas	M
Northern black racer	Not Specified	H
Northern Goshawk	Not Specified	M
Northern Harrier	Not Specified	M
Northern Leopard Frog	Not Specified	M
Ocellated Emerald	Not Specified	M
Olive-sided Flycatcher	Not Specified	M
Pine Barrens Bluet	Not Specified	M
Pine Barrens Lepidoptera	Not Specified	M
Piping Plover	Not Specified	M
Prairie Warbler	Not Specified	H
Purple Finch	Not Specified	M
Rainbow Smelt (diadromous)	Not Specified	M
Ringed Boghaunter	Not Specified	M
Roseate Tern	Not Specified	M
Ruffed Grouse	Not Specified	M
Rusty Blackbird	Not Specified	H
Rusty-patched Bumble Bee	Not Specified	M
Scarlet Tanager	Not Specified	M
Sleepy duskywing	Not Specified	M
Spotted Turtle	Not Specified	H
Swamp Darter	Not Specified	M
Three-toed Woodpecker	Not Specified	M
Three-toed Woodpecker	Tourism and recreation areas	M
Timber Rattlesnake	Not Specified	H
Veery	Not Specified	M
Vesper Sparrow	Commercial & industrial areas	M
Vesper Sparrow	Not Specified	M

Wood Thrush	Not Specified	M
Wood Turtle	Not Specified	H
Yellow Bumble Bee	Not Specified	M
Yellowbanded Bumble Bee	Not Specified	M

Literature Cited

Dorciak. 2014. NHDES Wetlands Bureau Annual Report to U.S. EPA Region 1for Calendar Year2014 Department of Environmental Services Water Division / Wetlands Bureau 29 Hazen DrivePO Box 95 Concord, NH 03302-0095.

New Hampshire Department of Environmental Services (NHDES). 2013. Trends in New Hampshire's Environment – Wetlands: Wetland Loss and Mitigation. *In Environmental Dashboard.* www.des.nh.gov.

Norton,S., D. Barrick, D. Delay, and K. Decker. 2014. What is New Hampshire? An overview of issues shaping the Granite State's Future. NH Center for Public Policy Studies. Available at http://www.nhpolicy.org/UploadedFiles/Reports/WINH14_for_publication.pdf.

The Nature Conservancy (TNC) and the Society for the Protection of New Hampshire Forests (SPNHF). 2014. Land Conservation in New Hampshire: A Snapshot of Progress and Opportunities. Prepared by The NH Chapter of The Nature Conservancy and the Society of the Protection of NH Forests.

Energy Production and Mining

The 'energy production and mining' category (IUCN 3) includes threats associated with exploring, developing and producing non-living resources. Within this category are threats associated with:

- Oil and gas drilling
- Mining and quarrying
- Renewable energy (geothermal, solar, wind, tidal)

Several related threats are described under other threat summaries, including the transportation of energy (Transportation and Service Corridors, IUCN 4), biomass harvest (Biological Resource Use, IUCN 5), dams associated with hydropower (Natural System Modification, IUCN 7), and pollutants released as a result of energy production and mining (Pollution, IUCN 9).

Risk Assessment Summary

Energy Production and Mining affects 10 habitats and 37 SGCN. The majority of threat assessment scores were ranked as low (n=38, 62%), followed by moderate (n = 22, 35%) and high (n = 2, 3%). Only the moderate and high ranking threats are summarized for each category in Table 4-15.

Risk assessments indicated that mining and quarrying, and renewable energy were the primary threats to habitats and species (Table 4E-1). Mining and quarrying was identified as a moderate threat to Appalachian oak pine forest, and talus slopes/rocky ridges. Bank swallow and Tri-colored Bat were both considered at high risk from mining and quarrying due to threats that were considered moderate in scope, but severe in their impacts on these species. Mining and quarrying was identified as a moderate threat to Big Brown Bat, Little Brown Bat, Fowlers toad, hognose snake, and northern black racer. Bat species are considered at risk from modification of mines including both mine closures and re-openings. Amphibians and reptiles are considered at risk from habitat conversion and mortality as a result of sand and gravel mining.

Wind energy development and production (both terrestrial and off-shore) was considered the principle threat from renewable energy production to wildlife. Habitat conversion and fragmentation effects on wildlife as a result of ridge top wind turbines were considered a moderate threat to talus slopes and rocky ridges, hemlock-hardwood-pine forest, high elevation spruce-fir forest and northern hardwood-conifer forest. Renewable energy ranked as a moderate threat for ten species of birds including Bicknell's thrush, roseate tern, and three-toed woodpecker. Potential mortality from turbine impacts was considered a more significant threat to NH wildlife in the 2005 WAP compared to the 2015 revisions. The moderate risk posed by wind energy development and production resulted from habitat fragmentation and degradation rather than direct mortality associated with wind towers and turbines. Eastern Small-footed Bat changed from high to low risk due to a decreased likelihood that wind energy development will occur in areas affecting the species.

Mining and quarrying, and renewable (specifically wind) energy were considered the most significant threats to wildlife habitats in both the 2005 and 2015 risk assessments within this category. Two habitats: alpine, and caves and mines, changed from high to low risk when comparing the 2005 to the current risk assessments. The change in threat to alpine habitat resulted from a decreased likelihood that wind energy development will occur in these areas. No habitats or species demonstrated an increased risk from low to high as a result of energy production and mining under the revisions to the 2005 Wildlife Action Plan.

Known Wildlife Exposure Pathways

Habitat loss and degradation due to mining and quarrying

Threats posed to NH wildlife by mining and quarrying fell in two categories: (i) alteration of mines with subsequent effects on bat species that use these habitats; and (ii) sand and gravel mining including both new mining activity and reclamation of existing mines.

Mines are used by bats in New Hampshire during both the summer and as winter hibernacula. Closure or reclamation of disused mines can lead to loss or degradation of this important bat habitat (Sherwin et al. 2009).

Sand and gravel mining in New Hampshire can serve as both a benefit and a risk to NH wildlife. However, assessments indicated that reclamation practices (i.e. the loss of anthropogenic habitat associated with sand and gravel extraction) represented a low risk to a limited number of bird species. Conversely, conversion of native habitat, particularly pine barrens and Appalachian oak pine forest, due to sand or gravel extraction represented a moderate threat to species and their habitats, i.e. the costs of sand and gravel mining were considered more significant than potential benefits.

Habitat loss, degradation and fragmentation due to inland wind energy development and production

Exposed locations such as ridges represent preferred sites for wind-energy development and production in New Hampshire. These same sites often represent unique and fragile habitats such as talus slopes and rocky ridges and high elevation spruce-fir forest. The development of wind farms results in a direct loss of these habitats through road and facility construction and maintenance, as well as fragmentation of remaining areas of habitat.

Habitat loss, degradation and direct mortality due to coastal and marine wind energy development and production

Coastal and offshore wind turbine facilities in NH are considered a moderate threat to piping plover. Although the likelihood of construction is low, the localized effect to the small population along our coast elevates the threat. Offshore wind farms can pose a risk of collision, short-term habitat loss during construction, long-term disturbance during turbine operation, barriers to migration, and loss of feeding sites (Exo et al. 2003, Hüppop et al. 2006). However, the risk of mortality due to collision may be low for birds flying within the vicinity of the wind farm (Desholm and Kahlert 2005). The first offshore wind project in North America has begun construction near Block Island, RI, and several other major projects have been proposed off the northeast coast of the United States.

Direct mortality due to wind-energy production

An estimated 234,000 birds are killed annually from collisions with wind turbines in the conterminous United States (Loss et al. 2013). Certain species of birds including small songbirds and some species of raptor are more prone to mortality than others (Drewitt and Langston 2006, Loss et al. 2013). When considering declines in abundance (rather than reported mortality), ducks appear to experience the most pronounced declines followed by waders, raptors, and songbirds (Stewart et al. 2005). Mortality of bats is often substantially higher than that of birds (American Wind Wildlife Insitute 2014). In 2014, New Hampshire had 70 utility-scale wind turbines generating ~2.1% of the in-state energy production (http://www.awea.org/resources/).

Research Needs

- More information is needed on the direct threats (habitat loss and mortality) associated with current and proposed wind energy projects in the Northeast and New Hampshire. This should include a minimum of three years to fully document impacts to wildlife (USFWS recommendation).
- More information relating to the spatial extent of conversion of Appalachian oak pine forest to barren lands as a result of sand and gravel extraction is needed.
- A statewide survey of optimal locations for wind energy generation, important wildlife habitat, SGCN species occurrence, and existing protected areas to support decision-making around wind-energy siting.

Table 4-15. Habitats and species at highest risk from the effects of energy production & mining (threats ranked as *Low* not included). Some habitats were evaluated for multiple specific threats separately and therefore listed multiple times below. See Appendix E for further details on specific threats and rankings.

Habitat	IUCN Level 2	Overall Threat Score
Appalachian Oak Pine Forest	Mining & quarrying	M
Hemlock-Hardwood-Pine Forest	Renewable energy	M
High Elevation Spruce-Fir Forest	Renewable energy	M
Northern Hardwood-Conifer Forest	Renewable energy	M
Talus Slopes, Rocky Ridges	Mining & quarrying	M
Talus Slopes, Rocky Ridges	Renewable energy	M

Common Name	IUCN Level 2	Overall Threat Score
Bank Swallow	Mining & quarrying	H
Bicknell's Thrush	Renewable energy	M
Big Brown Bat	Mining & quarrying	M
Canada Warbler	Renewable energy	M
Common Tern	Renewable energy	M
Fowlers Toad	Mining & quarrying	M
Hognose Snake	Mining & quarrying	M

Little Brown Bat	Mining & quarrying	M
Northern black racer	Mining & quarrying	M
Northern myotis (Northern Long-eared Bat)	Mining & quarrying	M
Piping Plover	Renewable energy	M
Purple Finch	Renewable energy	M
Roseate Tern	Renewable energy	M
Scarlet Tanager	Renewable energy	M
Three-toed Woodpecker	Renewable energy	M
Tri-colored Bat	Mining & quarrying	H
Veery	Renewable energy	M
Wood Thrush	Renewable energy	M

Literature Cited

American Wind Wildlife Insitute. 2014. Wind turbine interactions with wildlife and their habitats: A summary of research results and priority questions. Washington, D. C.

Desholm, M. and J. Kahlert. 2005. Avian collision risk at an offshore wind farm. Biology Letters 1:296-298.

Drewitt, A. L. and R. W. Langston. 2006. Assessing the impacts of wind farms on birds. Ibis 148:29-42.

Exo, K., O. Hüppop, and S. Garthe. 2003. Birds and offshore wind farms: a hot topic in marine ecology. Wader Study Group Bulletin 100:50-53.

Hüppop, O., J. Dierschke, K. Exo, E. Fredrich, and R. Hill. 2006. Bird migration studies and potential collision risk with offshore wind turbines. Ibis 148:90-109.

Loss, S. R., T. Will, and P. P. Marra. 2013. Estimates of bird collision mortality at wind facilities in the contiguous United States. Biological Conservation 168:201-209.

Sherwin, R. E., J. S. Altenbach, and D. L. Waldien. 2009. Managing abandoned mines for bats. Bat Conservation International.

Stewart, G. B., A. S. Pullin, and C. F. Cole. 2005. Effets of wind turbines on bird abundance. CEE review 04-002 (SR4). Collaboration for Environmental Evidence: www.environmentalevidence.org/SR4.html.

Human Intrusions and Disturbance

The ‘human intrusion and disturbance’ category (IUCN 6) includes all threats from human activities that alter, destroy, and disturb habitats and species associated with non-consumptive uses of biological resources. These threats include habitat conversion or degradation and disturbance to species that may result in mortality or reduced reproductive success. These threats can be placed into three categories (IUCN Level 2):

- Recreational activities: People spending time in nature or traveling in vehicles outside of established transport corridors, usually for recreational reasons.
- War, civil unrest, and military activities: Actions by formal or paramilitary forces without a permanent footprint.
- Work and other activities: People spending time in or traveling in natural environments for reasons other than recreation, military activities, or research.

Risk Assessment Summary

The human intrusions and disturbance category was evaluated for 158 unique threats across 22 habitats and 80 species (Table 4-16). The majority of threat assessment scores were ranked as low (n=108, 68%), followed by moderate (n = 37, 23%) and high ranking threats (n = 13, 8%). Low threat ranks were often associated with a perceived localized effect of the threat and a lack of information to document the threat, and do not necessarily represent a lack of effects.

Recreation included 139 of the 158 threats (88%) that were evaluated. Recreation was identified as a high threat for two habitats and eight species, and as a moderate threat to five habitats and twenty species (Table 4-16). Coastal habitats, beach-nesting birds, and bats were the most affected by the threat. The most common direct threats to species included mortality from off highway recreation vehicles (OHRV) or foot trampling and disturbance from recreational walkers, hikers and boaters in close proximity to nesting, roosting or foraging locations. Habitats were most threatened by degradation from vehicles and foot-traffic and from shoreline hardening.

War, civil unrest and military activities were evaluated for only one species and were considered a low threat.

Work and other activities included 14 of the 158 threats (9%) that were evaluated under the human intrusions and recreation threat category. Three species-threat combinations were ranked as high, four as moderate, and seven as low. Species assessed included bats and several species of nesting birds.

Known Wildlife Exposure Pathways

Direct Mortality

The most obvious impact of recreational activity on wildlife is direct mortality. Carelessly walking across a coastal island or on a dune may result in death by stepping on chicks and eggs. Motorized vehicles on beaches that are used for public safety or maintenance may run over unprotected piping plover nests or chicks (US Fish and Wildlife Service 1996). Airport mowing may crush upland sandpiper nests (NHFG Data). Freshwater mussels, especially brook floaters, can be easily crushed by wheeled vehicles operating in water or humans stepping on individual mussels in water. Local populations of freshwater mussels may be impacted when recreation is more frequent (e.g., beaches, fishing access points).

Fourteen percent of loon mortality in New England from 1989 to 1996 was due to boat trauma (Miconi et al 2000). Lead toxicosis from lead fishing tackle was the cause of death for nearly 50% of loons collected in NH from 1989-2010 (Grade 2011). Studies on recreational impact to tiger beetle populations have indicated populations were low to nonexistent where heavy recreational activities were observed, and abundance increased in areas where recreational use was limited and vehicles prohibited (US Fish and Wildlife Service 1990).

Recreation trails near important basking, foraging, or nesting areas can disrupt turtle behavior and facilitate incidental or intentional collection of turtles. A long-term study in Connecticut documented the extirpation of two wood turtle populations following an increase in human recreation (Garber and Burger 1995). The irrational fear that many people have of snakes may lead to snake mortality wherever human encounters occur. Snakes that may bask on trails are vulnerable to being run over by mountain bikes or OHRVs, and dogs have killed black racers on recreational trails at multiples sites in NH (NHFG Data). Bat exclusion measures placed on buildings during summer months may trap and kill pups.

Species Disturbance

Human disturbance can either be intentional or unintentional. Activities such as wildlife viewing, fishing, climbing, spelunking, boating, or simply hiking through an animal's territory can cause unintentional disturbance. However, given the wide range of recreational activities that may impact wildlife and the variation in tolerance between species, a specific understanding of the impacts to many species is lacking (Snetsinger and White 2009).

Disturbance may alter behavior, including nest abandonment and foraging behavior. Repeated nest-flushing of piping plovers by people or dogs may result in nest abandonment or failure, and intensive beach-use and associated mechanical beach cleaning may alter the feeding behavior of chicks (Burger 1991; Staine and Burger 1994). Similarly, flushing of shorebirds during migration may compromise their ability to forage and thus put on enough fat to successfully complete migration (Harrington and Drilling 1996).

High densities of recreational trails that are often present on lands conserved for wildlife may affect a suite of species, particularly when heavily used by people walking or training dogs, and there is increasing evidence that such "low impact" recreation can affect bird populations (Miller et al 1998, Banks and Bryant 2007, Steven et al 2011). During any time of the year, water-based recreation can deprive animals of roosting or feeding habitats whereas, in the breeding season, boating disturbance can cause reduced reproductive success or may otherwise render potential breeding areas unsuitable (Knight and Cole 1995). Motorboats, canoes and kayaks have a significant impact on behavior of common loons during pre-nesting and nesting stages in NH (McCarthy 2010). Off shore boating activities (whale watching, fishing, tour boats) can flush nesting and staging terns from coastal islands, causing them to use up energy reserves (US Fish and Wildlife Service 1994).
Disturbance of cave-hibernating bats by cave explorers stresses energy reserves (Thomas 1995) increasing the risk of mortality, particularly bats already affected by White Nose Syndrome. The presence of recreational climbers or low flying aircraft can frighten cliff nesting birds from their nests, and may result in adults inadvertently kicking out eggs or chicks from the nest (White et al 2002). Noise

disturbance from off highway recreational vehicles and boats may cause detectable changes in behaviors (Bowles 1995). Species that nest, bask or forage in active and abandoned sand and gravel pits may be disturbed by OHRVs or target-shooters. Maintenance of man-made structures may disturb several bird species that utilize them for nesting or roosting.

Habitat Conversion or Degradation

Habitat degradation, modification, and pollution are indirect forms of impact. Virtually all types of recreation can modify vegetation, soil, water, and microclimates, which in turn can impact species dependent upon those habitats (Cole and Landres 1995). The trampling of beach grass along coastal dunes can reduce the integrity of dunes and make them vulnerable to blowouts. While robust in their ability to withstand severe environmental conditions, alpine communities and their soils have low tolerances for trampling (Sperduto and Cogbill 1999). Substantial reductions in both vegetation cover and height, as well as soil erosion, results from all levels of trampling caused by hikers, with communities dominated by dwarf heath shrubs and erect forbs being least resistant (Cole 1995, Cole and Monz 2002).

The removal of vegetation to create new climbing routes can cause wind and rain to wash away any remaining soil in the cracks, preventing new plants from being established (Camp and Knight 1991). Rock climbing can introduce non-native species by propagules traveling on climbing equipment, shoes, and clothing that are transferred from one location to another (McMillian and Larson 2002). Snow-based recreation can also affect soils and vegetation. The most pronounced impacts are those associated with ski-resort development that can involve tree cutting and ground surface leveling and facility construction. Snowmobiling damages shrubs and saplings (Neumann and Merriam 1972) and may change species composition (Keddy et al. 1979). Water resources are impacted both by water-based recreational activities such as motor boating and canoeing and by land-based activities such as fishing, hiking, and off-road vehicle travel. Trampling and other recreational impacts to shorelines can alter flow regimes and eliminate protective cover. It can also result in increased sedimentation and turbidity (Cole and Landres 1995).

Research Needs

- Monitor recreation access points and high use areas where they have the potential to impact critical habitats and species in greatest conservation need.
- Determine the impacts of OHRVs on wildlife and habitats in New Hampshire.
- Determine the impacts from disturbance (i.e., OHRV use, target-shooting) to species that utilize sand and gravel pits.
- Monitor use of off-road vehicle trails near wetlands to determine to what extent users are leaving trails and riding in wetlands (i.e. monitor erosion, sediment, and nutrient inputs)
- Evaluate the impacts that dog-walking and training and other recreational activities have on wildlife on NHFG WMAs and other state lands
- Assess the impacts of recreational activities, including tour boats, to island nesting birds

Table 4-16. Habitats and species at highest risk from the effects of human intrusions and disturbance (threats ranking as *low* not included here). IUCN Level 2 provided if evaluated to that level. Some habitats and species were evaluated for multiple specific threats separately and therefore listed multiple times below. See Appendix E for additional information on specific threats and rankings.

Habitat	IUCN Level 2	Overall Threat Score
Alpine	Recreational activities	M
Caves and Mines	Recreational activities	M
Dunes	Recreational activities	H
Estuarine	Not specified	M
High Elevation Spruce-Fir Forest	Recreational activities	M
Lowland Spruce-Fir Forest	Recreational activities	M
Salt marsh	Recreational activities	H
Talus Slopes, Rocky Ridges	Recreational activities	M

Species	IUCN Level 2	Overall Threat Score
Bald Eagle	Recreational activities	M
Big Brown Bat	Work & other activities	H
Big Brown Bat	Recreational activities	M
Brook Floater	Recreational activities	M
Cliff Swallow	Work & other activities	H
Cobblestone Tiger Beetle	Recreational activities	M
Common Loon	Recreational activities	M
Common Nighthawk	Work & other activities	M
Common Tern	Recreational activities	M
Dwarf Wedgemussel	Recreational activities	M
Eastern Small-footed Bat	Recreational activities	H
Frosted Elfin	Recreational activities	M
Horseshoe Crab	Not specified	M
Karner Blue Butterfly	Recreational activities	M
Least Terns	Recreational activities	H
Little Brown Bat	Recreational activities	H
Little Brown Bat	Work & other activities	H
Northern Long-eared Bat	Recreational activities	H
Northern Long-eared Bat	Work & other activities	M
Peregrine Falcon	Work & other activities	M

Peregrine Falcon	Recreational activities	M
Piping Plover	Recreational activities	H
Red Knot	Recreational activities	M
Ruddy Turnstone	Recreational activities	M
Sanderling	Recreational activities	M
Semipalmated Sandpiper	Recreational activities	M
Softshell Clam	Not specified	M
Timber Rattlesnake	Recreational activities	M
Tri-colored Bat	Recreational activities	H
Tri-colored Bat	Work & other activities	M
Whimbrel	Recreational activities	M
White Mountain Arctic	Recreational activities	M
White Mountain Fritillary	Recreational activities	M
Willet	Recreational activities	M

Literature Cited

Banks, P. B., and J. V. Bryant. 2007. Four-legged friend or foe? Dog walking displaces native birds from natural areas. Biology Letters 3: 611–613. doi:10.1098/rsbl.2007.0374

Bowles, A. E. 1995. Responses of wildlife to noise. In R. L. Knight and K. J. Gutzwiller, editors. Wildlife and recreationists: coexistence through management and research. Island Press, Washington D.C., USA.

Boyle, S. A. and F. B. Samson. 1985. Effects of nonconsumptive recreation on wildlife: a review. Wildlife Society Bulletin 13:110-116.

Burger, J. 1991. Foraging behavior and the effect of human disturbance on the piping plover (*Charadrius melodus*). Journal of Coastal Research 7:39-52

Camp, R. J. and Knight, R. L., 1998. Effects of rock climbing on cliff plant communities at Joshua Tree National Park, California. Conservation Biology 12:1302-1306.

Christenson, B. L. 1981. Reproductive ecology of and response to disturbance by Common Loons in Maine. Thesis, University of Maine, Orono, Maine, USA.

Cole, D. N. 1995. Res. Note INT-RN-425. Intermountain Research Station, US Forest Service, Ogden, Utah, USA.

Cole, D. N. and P. B. Landres 1995. In R. L. Knight and K. J. Gutzwiller, editors. Wildlife and recreationists: coexistence through management and research. Island Press, Washington D.C., USA.

Cole, D. N. and C. A. Monz. 2002. Trampling disturbance of high-elevation, Wind River Mountains, Wyoming, USA. Arctic, Antarctic, and Alpine Research 34:365-376.

Flather, C. H. and H. K. Cordell.1995. In R. L. Knight and K. J. Gutzwiller. Outdoor recreation: historical and anticipated trends. Wildlife and recreationists: coexistence through management and research. Island Press, Washington D.C., USA.

Garber, S. D., and J. Burger. 1995. A twenty year study documenting the relationship between turtle decline and human recreation. Ecological Applications 5:1151-1162.

Grade, T.J. 2011. Effects of lead fishing tackle on common loons (*Gavia immer*) in New Hampshire, 1989-2010. Thesis, University of Wisconsin-Madison, 73 p.

Harrington, B., and N. Drilling. 1996. Investigations of effects of disturbance to migratory shorebirds at migration stopover sites on the U.S. Atlantic coast. Report to U.S. Fish and Wildlife Service. Manomet Observatory, Manomet, MA.

Keddy, P. A, A. J. Spavold and C.J. Keddy. 1979. Snowmobile impact on old field and marsh vegetation in Nova Scotia, Canada: an experimental study. Environmental Management 3:409-415.

Knight, R.L. and D. N. Cole 1995. Wildlife responses to recreationists. In R. L. Knight and K. J. Gutzwiller, editors. Wildlife and recreationists: coexistence through management and research. Island Press, Washington D.C., USA.

Knight, R. L. and D. N. Cole 1995. Factors that influence wildlife responses to recreationists. In R. L. Knight and K. J. Gutzwiller, editors. Wildlife and Recreationists: Coexistence Through Management and Research. Island Press, Washington D.C., USA.

McCarthy, K. P. 2010. Evaluation of disturbance factors and their effect on breeding common loons at Lake Umbagog National Wildlife Refuge, New Hampshire and Maine. Thesis, University of Massachusetts, Amherst. 171 p.

McMillan, M. A. and D. W. Larson. 2002. Effects of rock climbing on the vegetation of the Niagara Escarpment in southern Ontario, Canada. Conservation Biology 16:389-398.

Miconi, R., M. Pokras, and K. Taylor. 2000. Mortality in breeding Common Loons: How significant is trauma? Pages 19-24 in J. McIntyre and D. C. Evers, editors. Loons: old history and new findings. Proceedings of a Symposium from the 1997 meeting, American Ornithologists' Union. North American Loon Fund, Holderness, New Hampshire, USA.

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

Nuemann, P. W. and H. G. Merriam. 1972. Ecological effects of snowmobiles. Canadian Field Journal. 86:207-212.

New Hampshire Office of State Planning. 2003. New Hampshire Outdoors: Statewide Comprehensive Outdoor Recreation Plan. Concord, New Hampshire, USA.

Snetsinger, S.D. and K. White. 2009. Recreation and Trail Impacts on Wildlife Species of Interest in Mount Spokane State Park. Pacific Biodiversity Institute, Winthrop, Washington. 60 p.

Sperduto, D. D. and C. V. Cogbill. 1999. Alpine and subalpine vegetation of the White Mountains, New Hampshire. New Hampshire Natural Heritage Inventory, Concord, New Hampshire, USA.

Staine, K. J. and J. Burger. 1994. The nocturnal foraging behavior of breeding piping plover *Charadrius melodus* in New Jersey. Auk 111:579-587.

Steven, R., C. Pickering, and J.G. Castley. 2011. A review of the impacts of nature based recreation on birds. Journal of Environmental Management 92:2287-2294.

Thomas, D. W. 1995. Hibernating bats are sensitive to nontactile human disturbance. Journal of Mammalogy 76:940-946.

United States Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; determination of threatened status for the Puritan tiger beetle and the northeastern beach tiger United States Fish and Wildlife Service. 1994. Island ethics: recognizing and protecting colonial nesting seabird and waterbird islands in the Gulf of Maine. Brochure.

United States Fish and Wildlife Service. 1996. Piping Plover (Charadrius melodus), Atlantic Coast Population, Revised Recovery Plan. Hadley, Massachusetts. 258 pp.

White, C. M., N. J. Clum, T. J. Cade, and W. G. Hunt. 2002. Peregrine falcon (*Falco peregrinus*). In A. Poole and F. Gill, editor. The birds of North America, No 660. The Birds of North America, Inc, Philadelphia, Pennsylvania, USA.

Invasive and Other Problematic Species, Genes and Diseases

The threat category ‘invasive and other problematic species, genes and diseases’ (IUCN 8) includes both native and non-native plants, animals, pathogens, microbes, and genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread and/or increase in abundance. This definition encompasses a broad array of organisms, and the types of impacts to native species and habitats are equally variable. It includes invasive species that were not present in New Hampshire prior to European settlement, and have been directly or indirectly introduced and spread into the state by human activities.

A variety of wildlife species are vulnerable to increased predation from both native and non-native animals. Many species are also affected by diseases and parasites, including white-nose syndrome in bats, fungal pathogens in reptiles, and ticks and nematodes in moose. Native and non-native insects act as forest pests, damaging or killing native tree species and causing significant changes to wildlife habitats. Native tree species can also be affected by non-native fungal pathogens. Invasive plants can compete with native species for nutrients, water and light, and can change the physical environment by altering soil chemistry.

Risk Assessment Summary

Invasive species affect all 24 habitats and 106 SGCN. This is second only to pollution in the number of species affected. The majority of threat assessment scores were ranked as low (n=116, 51%), followed by moderate (n = 83, 37%) and high (n = 26, 12%). Only the moderate and high-ranking threats are summarized for each category in Table 4-17.

Non-native species and diseases affected the most species and habitats. This includes invasive animals, plants and diseases. Some of these have the potential to have dramatic effects on a species, as White-Nose Syndrome in bats has proven by reducing the populations of three species of bats by 90% and others by 50-90%.

An overpopulation of native species and disease also affects multiple species. In particular the increase of generalist predators such as foxes due to increased food sources in suburban neighborhoods can increase predation on other native species. Disease and parasite outbreaks are also causing mortality in some species, such as moose.

Known Wildlife Exposure Pathways

Avian & Mammalian Predators

Introduced and native predators (cats, raccoons, foxes, gulls, etc.) can have serious impacts on ground-nesting birds, particularly Piping Plover, Common Nighthawk, Common Tern, Least Tern, and Roseate Tern. Island-nesting birds such as Common and Roseate Terns also face competition from gulls for nesting sites. In freshwater habitats, introduced species such as bass can impact populations of native fish such as redbelly dace and bridle shiner. Changes in fish communities can also adversely impact some freshwater mussel species by reducing the number of available host fish species.

Some species of gulls have increased exponentially along the northeastern coast resulting from a combination of factors including the protection of all seabirds, changes in human land use along coastal islands, a rise in the fishing industry, and the use of open landfills. Herring gulls began nesting on the Isles of Shoals in the 1920s, and the population peaked at 5,000 pairs in the late 1970s. Great black-backed gulls began nesting on the Islands in the 1950s and have steadily been replacing herring gulls (numbers compiled from Drury 1973, Borror and Holmes 1990, United States Fish and Wildlife Service (USFWS) Colonial Waterbird Survey 1994). These larger, more aggressive birds compete with terns for nesting sites and can prey directly on tern eggs and chicks (Goodale 2000, Donehower 2003). Data suggest that lobster bait is the primary food of herring gull chicks in Penobscot Bay. The frequency of lobster bait in the herring gull chick diet on five study islands was 56% in 1999 (n=251) and 41% in 2000 (n=605) (Goodale 2000).

Increased development and human use of coastal areas have allowed for an abundance of potential tern and plover predators (USFWS 1998, Kress and Hall 2004). Mammalian predators such as feral cats, rats, raccoons, mink, skunk, and fox that gain access to breeding habitats can devastate some local bird populations. Additionally, avian predators such as Great Horned Owls and Black-crowned Night-Herons feed on tern chicks and adults. Predation is a proximate mortality factor for New England cottontails, particularly those that occupy small habitat patches (Barbour and Litvaitis 1993, Brown and Litvaitis 1995, Villafuerte et al. 1997).

Diseases and Parasites
Diseases have affected a number of wildlife species, most notably white-nose syndrome, which has already decimated bat populations in New Hampshire. Timber rattlesnakes and other snake species are threatened by snake fungal disease. Moose populations are declining apparently as a result of a combination of brain worm and winter tick parasites. Soft-shell clams are being affected by transmissible cancer cells. Some diseases, such as white-nose syndrome, are brought to new places by attaching to the clothing and gear of outdoor recreationists, farm tourists and other travelers. Others come in shipments of goods from other countries, including pets, plants and livestock. Others may be transmitted between species as ranges expand.

White-Nose Syndrome is a disease affecting a variety of native bat species, caused by a non-native fungal pathogen (Lorch et al. 2011). The fungus infects overwintering bats in their hibernacula, damaging tissues and disrupting hibernation, leading to starvation and death. The fungus impacts all bat species in New Hampshire hibernacula, including northern long-eared bat, little brown bat, eastern small-footed bat, and tri-colored bat. In 2010, White-Nose Syndrome was first identified in New Hampshire hibernacula, and since that time, a mortality rate of affected bat species has been documented at almost 99%.

Snake fungal disease (SFD) is an emerging threat that has been documented in a number of native snake species (NEPARC 2013). The fungal pathogen *Ophidiomyces ophiodiicola* has been implicated as the primary cause of the disease, although this has yet to be definitively proven. The disease has been observed across most of the eastern U.S., has been confirmed in eight species of snakes, and is suspected in several others. In New Hampshire, mortality due at least in part to SFD is a particular threat for timber rattlesnakes, which are already highly vulnerable due to the small population size.

Amphibian populations are vulnerable to several established diseases such as *Chytrid* fungus and Ranavirus with concern for additional emerging diseases such as salamander *Chytrid* (*Batrachochytrium salamandrivorans)* currently known in Europe but not the United States.

Fish populations are also vulnerable to disease and parasites, although there is very little baseline data available to evaluate the risk that they pose to native fish populations. Diseases or parasites may impact populations indirectly. The swim bladder nematode *(Anguillicoloides crassus)*, introduced to the American eel from Japanese eel populations, does not kill eels directly, but it may affect the mature eel's ability to migrate to its spawning grounds in the Sargasso Sea (Palstra et al. 2007). Migratory fish populations may be exposed to disease as they encounter fish farming operations in the ocean (Bakke and Harris 1998). Commercially raised live bait used by anglers along with other fish culture operations are another potential source of introduced diseases, such as Viral Hemorrhagic Septicemia (VHS) (AFS 2005).

New Hampshire's moose population is in severe decline, apparently as a result of two different parasites. In northern New Hampshire, moose are preyed upon by winter ticks (*Dermacentor albipictus*). In bad years, these parasites can attack moose in huge numbers, with some individuals carrying 50,000 to 100,000 ticks. Heavily infested animals suffer loss of blood, hair, and overall body mass, often leading to hypothermia and starvation (Musante et al. 2007). In southern New Hampshire, moose are at risk from a nematode known as brain worm (*Parelaphostrongylus tenuis*). This neuroparasite is common in white-tailed deer, which apparently rarely suffer impacts from infection. In moose, however, animals exhibit symptoms such as loss of coordination, general weakness, impaired vision, fearlessness, and walking in circles (Anderson 1964). In moose, infection by brain worms as almost always fatal. In areas where deer populations have increased, infections of brain worm in moose have become more prevalent. In Minnesota, which has seen a similar decline in the moose population, 45% of moose autopsied where found to carry the brain worm parasite (Wunschman et al. 2015).

Along the north Atlantic coast from New York to Prince Edward Island, soft shell clams are experiencing mortality due a leukemia-like cancer. Studies on infected animals have shown that the cancer cells are genetically distinct from the host clams, while being nearly identical to one another (Metzger et al. 2015). It is speculated that these tumor cells developed in a single animal, and then somehow began translocating to other individuals. How these cells have spread over large distances is uncertain.

Forest Insect Pests

Insect pests have the potential to significantly impact wildlife habitats. Hemlock woolly adelgid is widespread in southern and central New Hampshire, and has the potential to cause extensive tree mortality. Native ash species are at risk from emerald ash borer, which has recently arrived in the state. In northern New Hampshire, spruce – fir forests are vulnerable to widespread mortality as a result of non-native balsam woolly adelgid and native spruce budworm.

Based on FIA plot data, hemlock is the second most abundant tree species in New Hampshire (Morin & Pugh 2014), with the greatest concentration in the hemlock - hardwood - pine forest habitat. The hemlock wooly adelgid sucks sap from young hemlock twigs, resulting in needle drop, twig die-back, growth reduction, and tree mortality over the course of several years (Havill et al. 2014). In terms of wildlife habitat, hemlock provides valuable wintering areas for white-tailed deer, and is an important cover species for ruffed grouse, turkey, and snowshoe hare (Jordan & Sharp 1967). Hemlock is also used as a food source or nesting site for a large number of bird species (Lapin 1994). Widespread mortality of this species could have significant consequences for a wide variety of wildlife in New Hampshire.

Emerald ash borer (EAB) is an insect pest that feeds on and kills native ash (*Fraxinus* spp.) species. This non-native beetle was first identified in North America in Michigan in 2002 (USDA 2008). It has since spread to 24 states and two Canadian provinces, killing tens of millions of ash trees. It was first discovered in New Hampshire in 2013 in Concord, and has since been found in nine other towns. All three of New Hampshire's native ash species are vulnerable to attack by EAB, but white ash (*Fraxinus americana*) is by far the most abundant species, making up a significant component of the northern hardwood – conifer forest. The loss of ash in this habitat could have significant impact on forest structure, creating large openings and potentially altering soil composition. There are also at least 43 species of arthropods known to feed exclusive on ash species, all of which could face a threat of extinction with the loss of these trees (Gandhi & Herms 2010).

In northern New Hampshire, spruce – fir forests are vulnerable to attack from a combination of insect pests. The first, balsam woolly adelgid, is a non-native insect that attacks balsam fir (and other fir species), feeding on twigs and stems. Although cold temperatures appear to be preventing it from surviving at elevations above 2,200', balsam fir at lower elevations may be eliminated from most areas of the state. The other major insect pest in this habitat is spruce budworm. This is a native moth that, despite its name, feeds primarily on balsam fir, although it will also attack spruces, particularly during significant outbreaks. Historically, budworm and spruce bark beetle outbreaks were important disturbance agents that regenerated spruce-fir forests and maintained a diversity of age classes on the landscape. They primarily target mature forests, and result in regeneration of stands with essentially the same species composition. There has not been a significant outbreak of spruce budworm in recent decades, but recent surveys indicate that budworm concentrations are increasing. A major outbreak in conjunction with balsam woolly adelgid damage could devastate balsam fir by causing the outbreak to be more serious than historical outbreaks. Although regeneration of balsam fir forests is important for healthy forests, a serious outbreak could impact wildlife that rely on those habitats, such as Bicknell's thrush, American marten, and lynx, particularly if the regenerating forest differs form the spruce-fir type.

Invasive Plant and Animal Species

Invasive plants can displace native plant species and alter ecosystem processes. Invasive species such as Japanese barberry (*Berberis thunbergii*), burning bush (*Euonymus alatus*), and glossy buckthorn (*Frangula alnus*) can invade forests, particularly in areas that have been fragmented by development.

Horticulture has been responsible for the introduction and spread of a number of exotic plants. In fact, the majority of woody invasive plants in the U.S. (85%) were introduced for horticultural purposes including landscaping, gardening, mitigation of soil erosion, and improving wildlife habitat (Reichard 1997 as cited in Reichard and White 2001). In accordance with the Invasive Species Act (1258-FN), there are 27 species listed as invasive in New Hampshire, including Japanese knotweed (*Fallopia japonica*), Norway maple (*Acer platanoides*), Japanese barberry, glossy buckthorn, and others. According to the law, "No person shall collect, transport, import, export, move, buy, sell, distribute, propagate or transplant any living and viable portion of any plant species, which includes all of their cultivars and varieties," listed in the Act. These and other invasive exotic plants may decrease plant species diversity, produce allelopathic chemicals that retard other species, modify disturbance regimes, and significantly modify the species' composition and structure of vegetation (Silander and Klepeis 2001). These mechanisms may inhibit forest regeneration and degrade wildlife habitat.

In New Hampshire, there are several exotic plants that are particularly problematic in floodplain habitats, where the combination of rich soils and frequent disturbance are well-suited to non-native invasives. Common invasive plants in floodplains include Asian bittersweet (*Celastrus orbiculatus*), Japanese knotweed, and black swallowwort (*Cynanchum louiseae*) (ISI 2005). Asian bittersweet can completely envelop both hardwoods and conifers, leading to mortality of the trees they use for support. Although research into specific effects of invasive plants on wildlife has been limited, studies have shown that Japanese knotweed (Maerz et al. 2005) and European buckthorn (*Rhamnus cathartica*) can have measurable negative impacts on amphibians. Additionally, climate change may exacerbate the invasive species threat. Increased stress, new deposits of mineral soil, eroded surfaces and edge habitat may lead to increases in invasive species which specialize in disturbed edge habitats. More intense flooding events may also disperse invasive species into new areas.

Invasive aquatic species, including Eurasian milfoil (*Myriophyllum spicatum*)and water chestnut (*Trapa natans*), are gradually increasing their range in New Hampshire (NHDES 2008). These species have the potential to change the composition of native aquatic plant communities, especially in smaller, shallow waterbodies. Invasive plant species are often spread by recreational boaters and their establishment is aided by dredging and other disturbance of native plant communities. Large scale efforts to control invasive aquatic plants using techniques such as herbicide application, mechanical harvesters, or hand pulling, reduce the range of the plant in the short term, but are difficult to sustain over the long term (Roley and Newman 2008). The NH Lake Host Program has been effective at slowing the spread of aquatic invasive species by staffing boat ramps with trained personnel who both educate boaters and inspect boats for invasive species before they are launched.

In aquatic settings, zebra mussels have a high potential to significantly affect the state's freshwater mussels, especially the state endangered dwarf wedgemussel. After their discovery in Lake Saint Clair (in the Great Lakes Region) in 1988, zebra mussels quickly spread throughout many regions of the United States and parts of Canada. Adult zebra mussels are transported to waterbodies while attached to boats, and larvae may be transported in bilge and bait bucket water. Zebra mussels compete with native freshwater mussels for food and may reduce food concentration to levels that cannot support native species (Strayer 1999). The Connecticut River is at high to serious risk of zebra mussel colonization (Michelle Babione, Silvio O. Conte National Wildlife Refuge, personal communication).

The invasive Asian Clam (*Corbicula fluminea*) has been introduced to the Merrimack River watershed and has expanded its range. Like the zebra mussel, the Asian clam has the potential to alter freshwater ecosystems by out competing native fauna and impacting the food web by consuming large quantities of zooplankton (Souza et al. 2008). Introduced fish species can also have major impacts on native aquatic species. Largemouth bass, introduced throughout the northeast due to its popularity with anglers, have contributed to significant declines in native minnow diversity (Whittier et al. 1997). The northern snakehead, a voracious predator native to northeast Asia, was introduced to a pond in Maryland in 2002 and has since expanded its range throughout the Potomac River watershed. Fish introductions, whether by anglers or aquarists, are difficult to prevent without effective public information campaigns and law enforcement.

Research Needs

- Evaluate predator control techniques to protect common, roseate, and arctic terns and piping plovers.

- Determine ecology of gull populations at Isle of Shoals, including sources and importance of human-subsidized food.
- Evaluate modifications to fishing and aquaculture practices to minimize subsidization of gulls and other predators.
- Evaluate effect of landfills on predator abundance, impacts to at-risk species, and modifications to reduce impacts.
- Evaluate locations and extent of human food supplements for predators in rare species habitats.
- Assess the impacts of predation by introduced fish species on native fish species and other fauna (e.g. freshwater mussels).
- Assess threats from diseases to species of concern in New Hampshire.
- Assist health officials with understanding interactions of wildlife diseases and human health.
- Evaluate the long term impacts of invasive plants and animals on aquatic ecosystems along with the impacts and effectiveness of different control practices to help inform management strategies.
- Identify and monitor existing and potential transport mechanisms for invasive species
- Research and evaluate forms of invasive plant and animal control.
- Collect data on invasive species abundance and distribution to identify current threat areas.
- Identify species and sites for invasive species management, which can be combined with existing efforts (e.g., Invasive Plant Atlas of New England and New Hampshire’s Estuarine and Freshwater Working Group).
- Research effects of introduced species on at-risk wildlife and associated habitats
- Assess habitat characteristics that facilitate invasions by exotic plants.

Table 4-17. Habitats and species at highest risk from the effects of invasive & other problematic species, genes & diseases (threats ranked as *Low* not included here). Some habitats and species were evaluated for multiple specific threats separately and therefore listed multiple times below. See Appendix E for additional information on specific threats and rankings.

Habitat	**IUCN Level 2**	**Overall Threat Score**
Appalachian Oak Pine Forest	Invasive non-native/alien species/diseases	M
Appalachian Oak Pine Forest	Problematic native species/diseases	M
Coastal Islands	Problematic native species/diseases	H
Dunes	Invasive non-native/alien species/diseases	M
Estuarine	Invasive non-native/alien species/diseases	M
Estuarine	Not Specified	H
Floodplain Forests	Invasive non-native/alien species/diseases	M
Grasslands	Invasive non-native/alien species/diseases	M

Hemlock-Hardwood-Pine Forest	Invasive non-native/alien species/diseases	H
High Elevation Spruce-Fir Forest	Invasive non-native/alien species/diseases	H
Large warmwater rivers	Not Specified	M
Lowland Spruce-Fir Forest	Problematic native species/diseases	H
Marine	Invasive non-native/alien species/diseases	M
Northern Hardwood-Conifer Forest	Not Specified	H
Salt Marsh	Invasive non-native/alien species/diseases	M
Shrublands	Invasive non-native/alien species/diseases	M
Shrublands	Problematic native species/diseases	M
Temperate Swamp	Invasive non-native/alien species/diseases	H
Vernal Pools	Invasive non-native/alien species/diseases	M
Warmwater lakes and ponds	Not Specified	M

Common Name	**IUCN Level 2**	**Overall Threat Score**
American Black Duck	Introduced genetic material	M
American Eel	Invasive non-native/alien species/diseases	M
American Kestrel	Problematic native species/diseases	M
American Marten	problematic native species/diseases	H
American Oysters	Invasive non-native/alien species/diseases	M
American Shad	Problematic native species/diseases	M
Atlantic Sea Scallop	Invasive non-native/alien species/diseases	M
Bald Eagle	Problematic native species/diseases	M
Banded Sunfish	Invasive non-native/alien species/diseases	M
Bicknell's Thrush	Not Specified	M
Big Brown Bat	Invasive non-native/alien species/diseases	M

Black-billed Cuckoo	Invasive non-native/alien species/diseases	M
Blueback Herring	Problematic native species/diseases	M
Blue-winged Warbler	Invasive non-native/alien species/diseases	M
Blue-winged Warbler	Problematic native species/diseases	M
Bobolink	Invasive non-native/alien species/diseases	M
Bridle Shiner	Invasive non-native/alien species/diseases	M
Brook Trout	Not Specified	M
Brown Thrasher	Invasive non-native/alien species/diseases	M
Brown Thrasher	Problematic native species/diseases	M
Canada Warbler	Invasive non-native/alien species/diseases	M
Canada Warbler	Not Specified	M
Cerulean Warbler	Invasive non-native/alien species/diseases	M
Cerulean Warbler	Not Specified	M
Common Gallinule	Invasive non-native/alien species/diseases	M
Common Nighthawk	Problematic native species/diseases	H
Common Tern	Problematic native species/diseases	H
Dwarf Wedgemussel	Invasive non-native/alien species/diseases	M
Eastern Meadowlark	Invasive non-native/alien species/diseases	M
Eastern Small-footed Bat	Invasive non-native/alien species/diseases	H
Eastern Towhee	Invasive non-native/alien species/diseases	M
Eastern Towhee	Problematic native species/diseases	M
Eastern Whip-poor Will	Not Specified	M
Field Sparrow	Invasive non-native/alien species/diseases	M
Field Sparrow	Problematic native species/diseases	M
Finescale Dace	Invasive non-native/alien species/diseases	H

Frosted Elfin	Invasive non-native/alien species/diseases	M
Golden-winged Warbler	Invasive non-native/alien species/diseases	M
Golden-winged Warbler	Problematic native species/diseases	M
Hognose Snake	Diseases of unknown cause	M
Horseshoe Crab	Invasive non-native/alien species/diseases	M
Jefferson/Blue-Spotted Salamander Complex	Introduced genetic material	M
Karner Blue Butterfly	Invasive non-native/alien species/diseases	M
Least Bittern	Invasive non-native/alien species/diseases	M
Least Terns	Problematic native species/diseases	H
Little Brown Bat	Invasive non-native/alien species/diseases	H
Lynx	Problematic native species/diseases	H
Marsh Wren	Invasive non-native/alien species/diseases	M
Monarch	Invasive non-native/alien species/diseases	M
Monarch	Problematic native species/diseases	M
Moose	Problematic native species/diseases	H
New England Cottontail	Problematic native species/diseases	M
Northern black racer	Diseases of unknown cause	M
Northern myotis (Northern Long-eared Bat)	Invasive non-native/alien species/diseases	H
Northern Redbelly Dace	Invasive non-native/alien species/diseases	H
Northern Shrimp	Invasive non-native/alien species/diseases	M
Peregrine Falcon	Problematic native species/diseases	M
Pied-billed Grebe	Invasive non-native/alien species/diseases	M
Piping Plover	Problematic native species/diseases	H
Prairie Warbler	Invasive non-native/alien species/diseases	M
Prairie Warbler	Problematic native species/diseases	M

Purple Finch	Invasive non-native/alien species/diseases	M
Purple Martin	Invasive non-native/alien species/diseases	M
Ribbon snake	Diseases of unknown cause	M
Roseate Tern	Problematic native species/diseases	H
Round Whitefish	Invasive non-native/alien species/diseases	M
Scarlet Tanager	Invasive non-native/alien species/diseases	M
Scarlet Tanager	Not Specified	M
Sedge Wren	Invasive non-native/alien species/diseases	M
Softshell Clam	Invasive non-native/alien species/diseases	M
Softshell Clam	Not Specified	H
Sora	Invasive non-native/alien species/diseases	M
Spruce Grouse	Problematic native species/diseases	H
Timber Rattlesnake	Diseases of unknown cause	H
Tri-colored Bat	Invasive non-native/alien species/diseases	H
Upland Sandpiper	Not Specified	M
Veery	Invasive non-native/alien species/diseases	M
Veery	Not Specified	M
Vesper Sparrow	Invasive non-native/alien species/diseases	M
Wood Thrush	Invasive non-native/alien species/diseases	M
Wood Thrush	Not Specified	M
Wood Turtle	Problematic native species/diseases	M

Literature Cited

American Fisheries Society (AFS) (2005) *Suggested Procedures for the Detection and Identification of Certain Finfish and Shellfish Pathogens.* American Fisheries Society, Bethesda, MD.

Anderson, R.C. 1964. Neurologic disease in moose infected experimentally with *Pneumostrongylus tenuis* from white-tailed deer. Pathologica Veterinaria. 289- 322.

Bakke, T. A. and P. D. Harris. 1998. Diseases and parasites in wild Atlantic salmon (*Salmo salar*) populations. Canadian Journal of Fisheries and Aquatic Sciences 55(Suppl. 1):247-266.

Barbour, M.S., and J.A. Litvaitis. 1993. Niche dimensions of New England cottontails in relation to habitat patch size. Oecologia 95:321-327.

Borror, A.C., and D.W. Holmes. 1990. Breeding Birds of the Isles of Shoals. Shoals Marine Laboratory, New York. 76pp.

Brown, A.L., and J.A. Litvaitis. 1995. Habitat features associated with predation of New England cottontails: what scale is appropriate? Canadian Journal of Zoology 73:1005-1011.

Donehower, C. 2003. Predation rate and predatory behavior of large gulls on Eastern Egg Rock. Unpublished Report. National Audubon Society.

Drury, W.H. 1973. Population changes in New England seabirds. Bird-Banding 44:267-313.

Gandhi, K.J.K, and D.A. Herms. 2010. North American arthropods at risk due to widespread *Fraxinus* mortality caused by the alien emerald ash borer. Biological Invasions 12:1839–1846.

Goodale, W. 2000. The importance of lobster bait in Penobscot Bay gull diet. Unpublished Report. College of the Atlantic.

Havill, N.P., L.C. Vieira, and S.M. Salom. 2014. Biology and Control of Hemlock Woolly Adelgid. FHTET-2014-05. USDA Forest Service. 21 p.

Invasive Species Initiative. 2005. http://tncweeds.ucdavis.edu/index.html.Jordan, J.S., and W.M. Sharp. 1967. Seeding and planting hemlock for ruffed grouse cover. Res. Pap. NE-83. USDA Forest Service. 17 p.

Kress, S.W., and C.S. Hall. 2004. Tern Management Handbook – Coastal Northeastern United States and Atlantic Canada. U.S. Department of Interior, Fish and Wildlife Service, Hadley Massachusetts, USA.

Lapin. B. 1994. The impact of hemlock woolly adelgid on resources in the Lower Connecticut River Valley. Report for the NE Center for Forest Health Research. Hamden, CT: USDA Forest Service. 45 p.

Lorch, J.M., C.U. Meteyer, M.J. Behr, J.G. Boyles, P.M. Cryan, A.C. Hicks, A.E. Ballmann, J.T.H. Coleman, D.N. Redell, D.M. Reeder, and D.S. Blehert. 2011. Experimental infection of bats with *Geomyces destructans* causes white-nose syndrome. Nature 480:376–378.

Maerz, J. C., B. Blossey, and V. Nuzzo. 2005. Green frogs show reduced foraging success in habitats invaded by Japanese knotweed. Biodiversity and Conservation 14: 2901-2911.

Metzger, M.J., C. Reinisch, J. Sherry, and S.P. Goff. 2015. Horizontal transmission of clonal cancer cells causes leukemia in soft-shell clams. Cell. 161:255-263.

Morin, R.S. and S.A. Pugh. 2014. Forests of New Hampshire 2013. Resource Update FS-29. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 4 p.

Musante, A.R., P.J. Pekins, and D.L. Scarpitti. 2007. Metabolic impacts of winter tick infestations on calf moose. Alces 43:101-110.

New Hampshire Department of Envronmental Services (NHDES). 2008. Report of the New Hampshire Exotic Aquatic Species Program 2006-2008. Report #: R-WD-09-08. Retrieved from: http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-09-08.pdf.

Palstra, A. P.; Heppener, D. F. M.; van Ginneken, V. J. T.; Sze´kely, C.; van den Thillart, G. E. E. J. M., 2007: Swimming performance of silver eels is severely impaired by the swim-bladder parasite Anguillicola crassus. J. Exp. Mar. Biol. Ecol. 352, 244–256.

NEPARC. 2013. Snake Fungal Disease: Frequently Asked Questions. NEPARC publication 2013-02.

Roley, S.S**.** and R.M. Newman. 2008. Predicting Eurasian watermilfoil invasions in Minnesota. Lake and Reservoir Management. 24: 361-369.Reichard, S.H., and P. White. 2001. Horticulture as a pathway of invasive plant introductions in the United States. BioScience 51:103-113.

Sacerdote-Velat, A. and King, R. 2014. Direct Effects of an Invasive European Buckthorn Metabolite on Embryo Survival and Development in Xenopus laevis and Pseudoacris triseriata. Journal of Herpetology Vol. 48 (1):51-58.

Silander, J.A., Jr., and D.M. Klepeis. 2001. The invasion ecology of Japanese barberry (Berberis thunbergii) in the New England landscape. Biological Invasions 1:189-201.

Sousa, R., C. Antunes, and L. Guilhermino. 2008. Ecology of the invasive Asian clam *Corbicula fluminea* (Müller, 1774) in aquatic ecosystems: an overview. International Journal of Limnology 44(2):85-94.

Strayer, D.L. 1999. Effects of alien species on freshwater mollusks in North America. Journal of the North American Benthological Society 18: 74-98.

USDA Forest Service. 2008. Emerald Ash Borer Pest Alert NA-PR-02-04. Northeastern Area, State and Private Forestry.Newtown Square, PA.

United States Fish and Wildlife Service. 1994. Island ethics: recognizing and protecting colonial nesting seabird and waterbird islands in the Gulf of Maine. Brochure.

United States Fish and Wildlife Service. 1998. Roseate Tern Recovery Plan –Northeastern Population, First Update. Hadley, MA, USA.

Villafuerte R., J.A. Litvaitis, and D.F. Smith. 1997. Physiological responses by lagomorphs to resource limitations imposed by habitat fragmentation: implications to condition-sensitive predation. Canadian Journal of Zoology 75:148-151.

Whittier, T. R. et al. 1997. Cyprinid Distributions in Northeast U.S.A. Lakes: Evidence of Regional-Scale Minnow Biodiversity Losses. Canadian Journal of Fisheries and Aquatic Sciences 54: 1593-1607.

Wunschman, A, A.G. Armien, E. Butler, M. Schrage, B. Stromberg, J.B. Bender, A.M. Firshman, and M. Carstensen. 2015. Necropsy findings in 62 opportunistically collected free-ranging moose (*Alces alces*) from Minnesota, USA (2003-13). Journal of Wildlife Diseases. 51(1):157-165.

Natural System Modifications

The ‘natural system modifications’ threat category (IUCN 7) covers a wide range of activities that convert or degrade habitats largely as a result of human management. Often the goal of such management is to improve conditions for human activities, including recreation, energy generation, navigation, and general safety. Also included here are threats resulting from the lack of management in habitats that historically rely on disturbance to persist on the landscape. Most threats in the latter category apply to terrestrial systems, in particular the suppression of fire in pine barrens and cessation of management in grasslands and shrublands. In aquatic systems, the dominant threat in this category is dams, which fragment river systems, alter flows and sedimentation patterns, and cause mortality in aquatic organisms. Other natural systems modifications identified as important in New Hampshire include water withdrawals (both surface and subsurface), bank stabilization along rivers, and ditching and tidal restrictions in coastal habitats.

Risk Assessment Summary

In New Hampshire, this threat category was used for 242 threat-target combinations, with 99 of these ranked as high or medium threats (41%, with 38 high and 61 medium – see table 4-18). The high and medium threats are evenly divided between two broad pathways (see below): “absent or inappropriate habitat management” (47 targets, primarily in terrestrial systems) and “altered hydrology” (43 targets, aquatic and wetland systems).

The management category includes fire suppression (19 targets, primarily in pine barrens), lack of management in early successional habitats (22 targets, grasslands and shrublands), and natural succession in wetlands and dunes (5 targets). A higher proportion of threats in this pathway are ranked medium (55% of all M/H threats) than high (31%). The effects of dams were ranked as medium or high threats for 32 targets (17 high, 15 medium), with these targets including most aquatic habitats and the fish and mussels that live in them. Water withdrawals were identified as a medium threat for four aquatic habitats, and tidal restrictions for two coastal habitats and four salt marsh bird species. Channelization or stabilization of river banks was identified as a threat to five species that depend on these habitats.

Known Wildlife Exposure Pathways

Fire and Fire Suppression
Fire suppression alters the vegetative structure of habitats by inhibiting the establishment of fire tolerant plant species (e.g., pitch pine, scrub oak, and a variety of grasses and forbs, among others). In the absence of fire, habitats eventually succeed to dense canopied forest dominated by white pine and/or hardwoods (e.g., oak, red maple, and/aspen) with little or no grass and forb cover. This renders the habitat unusable by a number of rare and declining wildlife species, particularly those specialized in pine barrens habitats. Of particular concern are several Lepidoptera with specialized host plant requirements, including the Karner blue butterfly, frosted elfin, wild indigo duskywing, and others (Grundel et al. 1998, VanLuven 1994).

For instance, a lack of fire in the Concord pine barrens has caused the characteristic mosaic of grassy openings, heath barrens, scrub oak thickets, and pitch pine woodlands to be replaced by white pine and hardwood forest (VanLuven 1994). Similar shifts in vegetation structure and composition have been implicated in the decline of Karner blue butterflies at many locales (Grundel et al. 1998). Similarly, white pine and fire-intolerant hardwoods have substantially increased over the last 50 years in the Ossipee Pine Barrens and are predicted to soon be the dominant canopy species (Howard et al 2005).

Although not solely dependent on fire to provide suitable habitat, many species of wildlife typical of early successional forests and shrublands often reach their highest densities in fire-adapted habitats. Historically, New England Cottontails likely occupied native shrublands that were created and maintained via fire and other means (Litvaitis 2001). Similarly, the highest known densities of Eastern Whip-poor-wills and Eastern Towhees in New Hampshire occur in the remaining patches of pine barrens in the towns of Concord and Ossipee (Hunt 2013a, b).

Fire suppression also leads to an accumulation of highly flammable fuels (pine needles, leaf litter, and dead wood). As such, the potential increases for a catastrophic wildfire that would severely impact remaining patches of pine barrens habitat and populations of associated wildlife species. Wildlife mortality rates under this scenario may be too high to sustain wildlife populations in the long term (Howard et al. 2005).

Lack of Management

Like fire-adapted systems, grasslands and shrublands require periodic disturbance if they are to persist on the landscape. In the absence of management (e.g., mowing, selective harvest, herbicide), these habitats will revert to a forested condition in relatively short time spans, and are no longer suitable for most early successional wildlife species.

Long term timber harvesting in New England has resulted in a forest with altered size and age class distributions. When adequate structural conditions associated with different seral stages of forest development are not represented on the landscape, associated wildlife species cannot find the structure needed to reproduce and occupy the landscape. For example, lynx are dependent on large areas with high snowshoe hare densities. Clearcutting and other silvicultural methods that produce high snowshoe hare densities are important to consider in forest management.

Dams and Water Management/Use

Impoundments above dams cause changes in water temperature, turbidity, substrate composition, and flow, all of which influence biological communities. Increased flows below impoundments result in high sediment loads, suffocating fish and invertebrates and altering fish spawning substrates (Baxter and Glaude 1980, Moser 1993). The leaching of plant nutrients and toxic substances (e.g. mercury) from flooded soils upstream of impoundments can lead to algal blooms and accumulated toxins in fish tissue (Baxter and Glaude 1980). Increased biological oxygen demand from the decomposition of flooded soil and vegetation may cause lower dissolved oxygen levels, typically in the deep water adjacent to the dam (Baxter and Glaude 1980). Periodic flooding of shoreline and wetland habitats has been shown to increase mercury methylation in lakes and ponds with water levels controlled by a dam (Simonin et al. 2008). Fluctuating water levels upstream and downstream from dams pose a threat to Cobblestone Tiger Beetles by potentially inundating their habitat more frequently than natural flooding events (Nothnagle 1993). Water level management for hydropower or flood control may decrease the frequency and intensity of flooding events needed to maintain floodplain forest communities (Bornette and Amoros 1996). Water level drawdowns, especially during the winter months, impact invertebrate and plant communities in the littoral zone and may influence nutrient cycling in a waterbody (Zohary and Ostrovsky 2011). Changes in fish communities that result from artificial flow manipulation involve a shift to habitat generalist fish species (Kanno and Vokoun 2010).

Dams restrict the movements of aquatic species, especially diadromous fish, which migrate upstream to spawn, and freshwater mussels, which depend on larval transport by host fish for dispersal (Waters 1996). Widespread dam construction throughout the northeast has resulted in dramatic declines in migratory fish populations (Limburg and Waldman 2009). Fish passage construction has improved access to spawning habitat in some rivers, but migratory delays and mortality during downstream migration continue to limit the recovery of diadromous fish populations (Castro-Santos and Letcher 2010).

Although not always directly related to water management, alteration of stream banks through channelization can impact flows, sedimentation, and the species that depend on them.
River bank stabilization restricts the dynamic nature of a river and often causes erosion problems downstream, and eliminates habitats used by Bank Swallows and emerging dragonflies. Bank stabilization removes habitat features, including undercut banks and fallen trees, which are important to native fish species such as Brook Trout. Dams, ditches, and road crossings in tidal systems have hydrologic effects on estuaries and salt marshes, usually through reductions in tidal flooding. Without tidal influence, typical salt marsh vegetation is replaced with invasive reeds and grasses (Sinicrope et al. 1990).
Water withdrawal for irrigation, municipal water supplies, snow making, or industrial uses can decrease water levels and flows in aquatic habitats. An estimated 320 million gallons of water is withdrawn daily from the Merrimack River during the summer (Merrimack River Watershed Council 2001). In addition to impeding the movements of aquatic species, low flows can create higher water temperatures and stagnant conditions that encourage algal blooms. Water withdrawn for irrigation may re-enter aquatic systems, containing increased nutrient levels (Baxter and Glaude 1980). Low summer flows modify invertebrate and fish communities, favoring generalist species. A study of streams impacted by water withdrawal in Connecticut documented a significant decrease in fluvial dependent fish species (Kanno and Vokoun 2010). Unusually low summer flows due to groundwater withdrawal in the Ipswich River (Massachusetts) resulted in a significant decrease in fluvial dependent fish species the species composition (Armstrong et al. 2001).

Research Needs

- Research the impacts of water level fluctuation on natural communities.
- Expand the impervious surfaces assessment done in the coastal watershed to other watersheds in New Hampshire.
- Continue to monitor the results of salt marsh restoration projects on the coast.
- Investigate the quantitative effects of seasonal draw-downs on species diversity in aquatic habitats.
- Compare vegetation composition and structure, nutrient loading, and soil chemistry along impounded and free-flowing rivers in New Hampshire.
- Assess interactive impacts of fire suppression, land use history, ecological history, microclimate alterations, and habitat patch isolation on vegetation structure and composition of pine barrens, grasslands, and shrublands.

- Investigate impacts of beaver population changes on natural communities and habitat distribution.
- Monitor the response of diadromous fish populations to improvements in fish passage and dam removals.
- Research the influence of diadromous fish populations on freshwater and marine food webs.

Table 4-18. Habitats and species at highest risk from the effects of natural system modifications (threats ranked as *Low* not included here). IUCN Level 2 provided if evaluated to that level (if not evaluated to level 2, text reads *not specified*). Some habitats and species were evaluated for multiple specific threats separately and therefore listed multiple times below. See Appendix E for additional information on specific threats and rankings.

Habitat	IUCN Level 2	Overall Threat Score
Coldwater rivers and streams	Dams & water management/use	M
Coldwater rivers and streams	Not Specified	M
Estuarine	Other ecosystem modifications	M
Floodplain Forests	Dams & water management/use	H
Grasslands	Other ecosystem modifications	M
Hemlock-Hardwood-Pine Forest	Not Specified	M
Lakes and ponds with coldwater habitat	Dams & water management/use	H
Large warmwater rivers	Dams & water management/use	H
Lowland Spruce-Fir Forest	Not Specified	H
Peatlands	Not Specified	M
Pine Barrens	Not Specified	M
Salt Marsh	Not Specified	M
Salt Marsh	Other ecosystem modifications	H
Shrublands	Not Specified	M
Shrublands	Other ecosystem modifications	H
Warmwater lakes and ponds	Dams & water management/use	H
Warmwater lakes and ponds	Not Specified	M
Warmwater rivers and streams	Dams & water management/use	H
Warmwater rivers and streams	Not Specified	M

Common Name	IUCN Level 2	Overall Threat Score
Alewife	Dams & water management/use	H
Alewife Floater	Dams & water management/use	H
Alewife Floater	Other ecosystem modifications	H
American Brook Lamprey	Dams & water management/use	M
American Eel	Dams & water management/use	H
American Kestrel	Not Specified	H
American Shad	Dams & water management/use	H
American Shad	Dams & water management/use	M
American Woodcock	Not Specified	M

Banded Sunfish	Dams & water management/use	M
Bank Swallow	Not Specified	H
Black-billed Cuckoo	Not Specified	M
Black-billed Cuckoo	Other ecosystem modifications	H
Blandings Turtle	Dams & water management/use	M
Blueback Herring	Dams & water management/use	H
Blue-winged Warbler	Not Specified	M
Blue-winged Warbler	Other ecosystem modifications	H
Bobolink	Other ecosystem modifications	M
Bridle Shiner	Dams & water management/use	H
Brook Floater	Dams & water management/use	H
Brook Floater	Other ecosystem modifications	M
Brook Trout	Dams & water management/use	M
Brook Trout	Other ecosystem modifications	M
Brown Thrasher	Fire & fire suppression	M
Brown Thrasher	Not Specified	M
Brown Thrasher	Other ecosystem modifications	H
Common Gallinule	Not Specified	M
Common Nighthawk	Fire & fire suppression	M
Common Nighthawk	Other ecosystem modifications	M
Creeper (Mussel)	Dams & water management/use	M
Dwarf Wedgemussel	Dams & water management/use	H
Dwarf Wedgemussel	Other ecosystem modifications	H
Eastern Meadowlark	Other ecosystem modifications	M
Eastern Pondmussel	Dams & water management/use	H
Eastern Towhee	Fire & fire suppression	M
Eastern Towhee	Not Specified	M
Eastern Towhee	Other ecosystem modifications	H
Eastern Whip-poor Will	Fire & fire suppression	M
Eastern Whip-poor Will	Other ecosystem modifications	M
Field Sparrow	Fire & fire suppression	M
Field Sparrow	Not Specified	M
Field Sparrow	Other ecosystem modifications	H
Frosted Elfin	Not Specified	H
Golden-winged Warbler	Not Specified	M
Golden-winged Warbler	Other ecosystem modifications	H
Grasshopper Sparrow	Other ecosystem modifications	M
Horned Lark	Other ecosystem modifications	M
Karner Blue Butterfly	Not Specified	H
Lake Trout	Dams & water management/use	M
Lake Whitefish	Dams & water management/use	M
Least Terns	Other ecosystem modifications	M
Nelson's Sparrow	Other ecosystem modifications	H
New England Cottontail	Other ecosystem modifications	H
Northern black racer	Other ecosystem modifications	M
Northern Harrier	Other ecosystem modifications	M
Pied-billed Grebe	Not Specified	M

Pine Barrens Lepidoptera	Not Specified	M
Piping Plover	Other ecosystem modifications	M
Prairie Warbler	Fire & fire suppression	M
Prairie Warbler	Not Specified	M
Prairie Warbler	Other ecosystem modifications	H
Puritan Tiger Beetle	Not Specified	M
Purple Martin	Other ecosystem modifications	M
Rapids Clubtail	Dams & water management/use	M
Rapids Clubtail	Not Specified	M
Redfin Pickerel	Dams & water management/use	M
Round Whitefish	Dams & water management/use	H
Ruffed Grouse	Not Specified	M
Saltmarsh Sparrow	Other ecosystem modifications	H
Sea Lamprey	Dams & water management/use	H
Seaside Sparrow	Other ecosystem modifications	H
Shortnose Sturgeon	Dams & water management/use	M
Skillet Clubtail	Dams & water management/use	M
Skillet Clubtail	Not Specified	M
Sleepy duskywing	Not Specified	M
Sora	Not Specified	M
Spotted Turtle	Dams & water management/use	M
Triangle Floater	Dams & water management/use	M
Vesper Sparrow	Fire & fire suppression	M
Vesper Sparrow	Other ecosystem modifications	M
Willet	Other ecosystem modifications	H
Wood Turtle	Dams & water management/use	H

Literature Cited

Armstrong, D.S., Richards, T.A., and Parker, G.W., 2001, Assessment of Habitat, Fish Communities, and Streamflow Requirements for Habitat Protection, Ipswich River, Massachusetts, 1998-99: U.S. Geological Survey Water-Resources Investigations Report 01-4161, 72 p.

Baxter, R., and P. Glaude. 1980. Environmental Effects of Dams and Impoundments in Canada: Experience and Prospects. Canadian Bulletin of Fisheries and Aquatic Sciences No. 205. 34p.

Bornette, G., and C. Amoros. 1996. Disturbance regimes and vegetation dynamics: role of floods in riverine wetlands. Journal of Vegetation Science 7:615-622.

Castro-Santos, T. and Letcher, B. 2010. Modeling migratory energetics of Connecticut River American shad (Alosa sapidissima): implications for the conservation of an iteroparous anadromous fish. Canadian Journal of Fisheries and Aquatic Sciences, 67:806-830.

Grundel, R., N. B. Pavlovic, and C. L. Sulzman. 1998b. Habitat use by the endangered Karner blue butterfly in oak woodlands: the influence of canopy cover. Biological Conservation 85:47-53.

Howard, L. F., J. A. Litvaitis, T. D. Lee, and M. J. Ducey. 2005. Reconciling the Effects of Historic Land Use and Disturbance on Conservation of Biodiversity in Managed Forests in the

Northeastern United States: part 1—pine barrens. National Commission on Science for Sustainable Forestry. Washington, DC, USA.

Hunt, P.D. 2013a. Bird use of pine barrens and other shrubland habitats in New Hampshire: 2010-2012. Report to NH Fish and Game Department, Nongame and Endangered Species Program. New Hampshire Audubon, Concord.

Hunt, P.D. 2013b. Habitat use by the Eastern Whip-poor-will (*Antrostomus vociferus*) in New Hampshire, with recommendations for management. Report to the NH Fish and Game Department, Nongame and Endangered Wildlife Program. Audubon Society of New Hampshire, Concord.

Kanno, Y., and J.C. Vokoun. 2010. Evaluating effects of water withdrawals and impoundments on fish assemblages in southern New England streams, USA. Fisheries Management and Ecology 17: 272-283.

Limburg K.E., Waldman J.R. 2009. Dramatic declines in North Atlantic diadromous fishes. BioScience 59:955–965.

Litvaitis, J.A. 2001. Importance of early successional habitats to mammals in eastern forests. Wildlife Society Bulletin 29:466-473.

Merrimack River Watershed Council [MRCW]. 2001. Water demand analysis on the Merrimack River watershed: Data and literature on the water use of the Merrimack River watershed. Prepared for the Merrimack Watershed Team

Moser G. 1993. Dwarf Wedge Mussel (**Alasmidonta heterodon)** Recovery Plan. United States Fish and Wildlife Service, Northeast Region. 48p.

Nothnagle, P. 1993. Status survey of New Hampshire/Vermont populations of the cobblestone tiger beetle (*Cicindela marginipennis*). Report submitted to the U. S. Fish and Wildlife Service, Concord, New Hampshire, USA.

Sinicrope, T. L., P. G. Hine, R. S. Warren, and W. A. Niering. 1990. Restoration of an impounded salt marsh in New England. Estuaries 13:25-30.

Simonin, H.A., J.L. Jefferey, L.C. Skinner, K.M. Roy. 2008. Lake variability: Key factors controlling mercury concentrations in New York State fish. Environmental Pollution 154:107–115.

VanLuven, D. E. 1994. Site conservation plan for the Concord Pine Barrens, Concord New Hampshire. The Nature Conservancy, Concord, New Hampshire, USA.

Watters G. 1996. Small Dams as Barriers to Freshwater Mussels (Bivalvia and Unionoida) and Their Hosts. Biological Conservation. Elsevier Science Limited. 75:79-85.

Pollution

Pollution is a very broad category within the IUCN classification (IUCN 9), and includes any threat involving the addition of materials or energy into a natural system where they would not normally occur. For the purposes of the New Hampshire Wildlife Action Plan, pollution has been sub-divided into more specific "**Exposure Pathways**" as listed below:

Domestic and urban wastewater addresses issues related to water-borne sewage and non-point runoff from housing and urban areas that include nutrients, toxic chemicals and sediments. This includes chemicals and next generation pollutants (caffeine or pharmaceuticals) in household waste streams. Technically, sewage from a pipe is "point-source" whereas a leaking septic system is "nonpoint-source."

Threats to wildlife and habitats under the heading of **Agricultural & Forestry Effluents** include the following exposure pathways:

> **Nutrient loads** from agricultural practices focuses on water-borne pollutants from agricultural, silvicultural and aquaculture systems. This includes nutrients and toxic chemicals, and the effects of these pollutants on the site where they are applied.
>
> **Herbicides and Insecticides** can enter an ecosystem through agricultural run-off and can have impacts to both species and habitats.
>
> **Sedimentation** inputs may come from agricultural practices, or may come from domestic and urban wastewater run-off.

Persistent organic contaminants include a range of toxic or potentially toxic chemicals unrelated to pesticides. Many of these are byproducts of industrial processes or may come from agricultural sources, chemicals from disease control or from manufacturing. Examples of emerging chemicals of concern include flame retardants and components of plastics that mimic or disrupt hormones. Various contaminants can be transported by air, water or soil, making this group of pollutants widespread and often hard to track.

Oil spills, under the category of **Industrial and military effluents** (IUCN category 9.2), can directly cause injury or death to species, and can have lasting impacts on effected habitats. Examples include leakage from fuel tanks, oil spills from pipelines and ships, or polychlorinated biphenyls (PCBs) in river sediments.

Mercury and **Acid Deposition** are forms of airborne pollutants, which include all atmospheric pollutants from point and non-point sources. It is often difficult to determine the sources of many atmospheric pollutants – and thus hard to take action to counter them.

Excess energy includes all inputs of heat, sound or light that disturb wildlife or ecosystems. The most common examples of this are light pollution (such as lamps that attract insects) and thermal pollution (such as heated water from power plants).

Risk Assessment Summary

Pollution affects all 24 habitats and 112 SGCN. This is the greatest number of species affected by any single threat category. The majority of threat assessment scores were ranked as low (n=221, 63%), followed by moderate (n = 105, 30%) and high (n = 25, 7%). Only the moderate and high ranking threats are summarized for each category in Table 4-19.

Because pollution operates in many ways, and often on broad spatial scales, it was the most common threat evaluated during species and habitat threat assessment. All terrestrial, wetland, aquatic, and marine habitats experience at least one pollution-related threat (Table 4-19). Aquatic systems (rivers and lakes) had the most threats as a group, with wetland and coastal habitats occupying an intermediate position. Most terrestrial habitats had only a few threats identified, and some had none. Along the same lines, more threats were identified for coastal and aquatic species, and relatively few for wetland and terrestrial ones. A significant exception to the latter was a large number of birds and insects for which pesticides were identified as a threat.

When specific threat pathways were identified, pesticides were the most common threat with 92 instances across species and habitats (Table 4-19). This threat pathway operated across a wide range of species and habitats, and was even listed for migratory species on their winter grounds. However, pesticide-related threats were often ranked low, usually because of limited information on their impacts. Atmospheric pollutants were a close second, including 42 instances of mercury and 40 of acid deposition. Mercury and acid deposition were also noted across a wide range of habitat types. General pollution from runoff was listed in 48 cases, with specific runoff pollutants of sediment and nutrients listed 11 and 38 times, respectively. Almost all instances of these three runoff related threats apply to non-terrestrial species and habitats. Oil spills were listed 26 times, almost entirely for coastal species and habitats.

Threats can also be compared based on the proportion of targets for which a threat was ranked relatively highly. Under this approach, oil spills would be considered the most important threat, since 30% of all targets assessed received a medium or high rank. Again, the greatest risk from this threat is in coastal habitats. Pesticides rank second with 12% of targets receiving a medium or high threat score. Most affected were insects and insectivorous birds, with additional impacts on some aquatic organisms. Threats associated with runoff accounted for 7.8%, and 5.3% associated with nutrients received a medium or high score, with mussels, fish, and aquatic habitats being the primary targets. The only other threat to receive medium or high scores was acid deposition at 2.5%, where the main targets were species and habitats associated with cold water, high elevation, or forest.

Known Wildlife Exposure Pathways

Domestic and urban wastewater

Pollutants from developed areas affect many species and habitats of concern in New Hampshire, primarily in wetlands and aquatic systems. Although the severity of wastewater pollution varies by habitat, experts reported that most habitats are already being impacted. Severity decreases as one moves north and away from densely populated areas. Coldwater rivers and streams, especially at higher elevations, are the least impacted by wastewater pollution, but possibly the most vulnerable. Associated pollutants can alter water chemistry, trophic state, and organisms' physiology. Direct impacts to specific aquatic species warrant further investigation, but it is predicted that the degree of ecological change caused by runoff pollution is substantial. Pollutants vary in the extent to which their impacts have been documented, with more research on nutrients and road salt and less on emerging threats such as pharmaceuticals.

Water-borne sewage and non-point runoff from housing and urban areas introduces a wide variety of pollutants into wetland and aquatic systems, including nutrients, toxic chemicals, road salt, and pharmaceuticals. Also included in such runoff are sediments and pesticides, but because of more specific interest in these pollutants, they are being treated separately (see *Pesticides* paragraph). Note that nutrient runoff from agriculture is a separate exposure pathway.

In New Hampshire, over 90% of water pollution issues are attributed to stormwater runoff (NHDES 2015). Runoff from faulty septic systems, industry, landscaping activities, roads, golf courses, landfills, junkyards, and wastewater treatment facilities can affect aquatic systems by contributing excessive nutrients (e.g., phosphorus and nitrogen) and other pollutants (e.g., heavy metals, organic compounds, and sediment) (Richter et al. 1997, NHDES 1999, Francis and Mulligan 1997). Introduced nutrients from fertilizers entering aquatic systems can change plant composition in wetland communities and cause algal blooms, reducing dissolved oxygen concentrations enough to kill or displace fish and invertebrates (Carpenter et al. 1998).

Stormwater runoff from impervious surfaces (e.g., roofs, roads, and parking lots) often flows directly into aquatic systems. These surfaces accumulate a variety of contaminants including petroleum products, lead, PCBs, road salt, sand, pesticides, and fertilizers (United States Environmental Protection Agency 2005). The decline in aquatic species diversity as watersheds become more urbanized is well documented (Weaver and Garman 1994, Richter et al. 1997). In a Massachusetts fen community, species richness, evenness, and the abundance of individual species were adversely impacted by high sodium and chloride concentrations along a turnpike (Richburg et al. 2001). Roadside vernal pools in New Hampshire had higher levels of both sodium and chloride and lower embryonic survival of spotted salamander larvae when compared to woodland vernal pools (Turtle 2000).

Combined Sewer Overflows (CSOs), which allow wastewater treatment plants to release untreated wastewater into water bodies during heavy rain, increase nutrient and turbidity levels and prolong the presence of persistent toxins in riverine habitats. New Hampshire currently has 33 identified CSOs in six communities (NHDES 2012). These communities are working with NHDES and the USEPA to reduce their CSO discharges.

Nutrient loads from agriculture

Excessive nutrient inputs into wetland and aquatic systems have long been recognized as a significant threat. Impacts are generally greater in the major river valleys where agriculture predominates, and hence on large river habitats, floodplains, and their embedded wetlands.

Fertilizers applied to farmlands that are not taken up by crops eventually wash into water bodies or wetlands. Such runoff can affect aquatic systems by contributing excessive nutrients (e.g., phosphorus and nitrogen) (Richter et al. 1997, NHDES 1999, Francis and Mulligan 1997). Introduced nutrients from fertilizers entering aquatic systems can change plant composition in wetland communities and cause algal blooms, reducing dissolved oxygen concentrations enough to kill or displace fish and invertebrates (Carpenter et al. 1998).

Sedimentation

According to expert opinion, problematic land uses near waterbodies can result in excessive erosion, sediment deposition, increased turbidity, and the introduction of contaminants. Marsh and shrub wetlands, temperate swamps, large warmwater rivers, and aquatic habitats appear to be the most impacted. Some aquatic species are directly impacted, particularly freshwater mussels and aquatic insects, while others are indirectly impacted by habitat changes caused by excessive sedimentation.

Excess sediment can enter wetlands and aquatic systems in a variety of ways, most typically in runoff from agriculture or impervious surfaces. This category also includes altered sedimentation patterns in aquatic systems that result from altered hydrology in lotic waters (e.g., dams, bank stabilization).

Sedimentation can alter natural community composition and reduce population sizes of fish, amphibians, and benthic invertebrates by increasing turbidity and burying cobble, gravel, and boulder substrates (Hedrick et al. 2005). Soil particles entering wetlands can affect hydrology and vegetation (Mahaney et al. 2004). In estuarine and nearshore marine systems, sedimentation can limit aquatic plant growth and cause direct physical impact to sessile species such as oyster beds. Conversely, an adequate sediment supply is vital to build salt marsh habitat, particularly in regions of rising sea level.

Bank erosion and sediment deposition are natural processes that can be accelerated by human activity. Dense impervious surfaces, road upgrades, poor forestry practices, residential development, wetland filling, dredging and filling, mining, water level fluctuations, recreational vehicles, riparian zone alterations, channelization, and boat wakes increase bank erosion (Alexander and Hansen 1983, Connecticut River Joint Commission (CRJC) 2002, Francis and Mulligan 1997, Zankel 2004). Shoreline stabilization projects may reduce erosion at a specific location, but negatively affect downstream locations (CRJC 2002). A survey of 1,300 landowners along the Connecticut River indicated bank erosion as their primary concern (NHDES 1999).

Pesticides

Pesticides have long been known to negatively affect wildlife beyond their intended targets, and many of the more dangerous and broad-spectrum insecticides are no longer in widespread use as a result. However, new classes of pesticides, which often have a much narrower mode of action, have been documented to have both direct (e.g., mortality) or indirect (e.g., on food supply) effects on non-target organisms. Experts identified 31 Species of Greatest Conservation Need and nine critical habitats that are impacted by pesticide use in New Hampshire. Overall, pesticide exposure was evaluated as a low threat to most species and habitats, but experts agree that this threat is poorly understood because data is often insufficient, and the response of many species to pesticide exposure needs further study.

The pesticide category includes insecticides and herbicides intentionally or unintentionally released into the environment. Sources include agricultural uses, domestic and urban waste water that carries excess pesticides, and those pesticides used to control problematic species outbreaks or unwanted plant species.

Pesticides generally act in one of two ways: through direct toxicity or by altering food supplies and/or habitat, and more specific pathways within both these modes of action are discussed below. Toxic effects of pesticides involve the bioaccumulation of toxins within fat tissue. At high doses, exposure can result in acute toxicity and death.

Historically pesticides were usually broad-spectrum chemicals such as chlorinated hydrocarbons (e.g., DDT) that affect a variety of plant or insect species. In the case of insecticides, many non-target species were presumably killed through use of broad-spectrum pesticides, and these have been implicated in local extirpations of some insects (e.g., tiger beetles, Leonard and Bell 1998). Toxic effects of such pesticides on vertebrates include eggshell thinning in raptors (from DDT) and direct mortality (e.g., monocrotophos, Goldstein et al. 1999). Although DDT has been banned in the U.S., it is still used in parts of Latin America where some New Hampshire species migrate. Because of these extensive non-target effects, DDT and many other chemicals have been banned in many areas, and – at least in the case of DDT – the species affected by them have largely recovered. In their stead, more target-specific insecticides were developed, particularly related to control of disease-bearing Diptera. There is at present limited evidence of toxic effects of these chemicals on other species, although they are implicated in altered food availability (e.g., Evans et al. 2007, Nocera et al. 2012).

Neonicitinoids are a new class of systemic broad-spectrum insecticide that are directly applied to seeds to prevent insect damage to the growing plant. Introduced in 1994, they are now the most widely used class of insecticide in the US (Cresswell 2014). Neonicitinoiods have been implicated in declines in bee and butterfly populations (e.g. Jepsen et al 2015, Hatfield et al 2012), and toxic effects are increasingly being documented in vertebrates as well (Gibbons et al. 2015). A recent study in Europe also linked them to declines in several widespread bird declines (Hallman et al. 2014). These chemicals may act both directly (e.g., on pollinators) or indirectly through suppression of food supplies (e.g., for birds, Ghilain and Bélisle 2008, Paquette et al. 2013).

Broad-spectrum chemical herbicides and insecticides applied to forests to control hardwood regeneration and outbreaks of forest pests can enter stream systems soon after application, affecting wildlife, aquatic habitats, and human health (Miller 1982, Rashin and Graber 1993). Developed resistance from insecticides by individual species (such as spruce budworms) makes chemical applications less effective (Natural Resources Canada 1997). Even at low concentrations, the combined effect of multiple pesticides and herbicides can impact the resilience of aquatic organisms (Hua and Relyea 2014).

Persistent organic contaminants

This broad category includes a range of toxic or potential toxic chemicals other than pesticides, many of which have been detected in habitats or species of greatest conservation need. Examples of persistent organic contaminants include dioxins, PCBs, plastics and their derivative products, and flame retardants, although new types are continually being identified. In addition, there are unmonitored and unregulated inputs such as antibacterial products and pharmaceuticals that may have effects on wildlife that have yet to be determined.

Some of these contaminants can result in toxic effects, involving the bioaccumulation of toxins within fat tissue. At high doses, exposure can result in acute toxicity and death. At lower doses, toxins may be released during periods of negative energy balance such as hibernation or lactation in species such as bats (Kunz et al. 1977). Organic compounds may accumulate and persist in the sediment and in the tissue of fish and benthic invertebrates (NHDES 1999).

Oil Spills

The effect of oil spills may be very localized or very extensive depending on the source and timing of the contamination and the affected species or habitat. Impacts could be serious for sand dunes, salt marshes, estuarine habitats, coastal islands and associated species (i.e., Roseate and Common Terns, Piping Plovers, American oysters) either immediately or in the long term. The effects of oil spills on dunes and coastal islands are well documented.

Most significant oil spills originate from pipelines, power plants, trains, or tankers, and it is this class of spill that is considered here. Small amounts of oil that enter waterways in developed areas (e.g., from roads) are considered under "domestic and urban waste water."

Wildlife exposed to oil can be directly poisoned if they ingest it, or physiologically compromised if it coats their fur or feathers. Birds and mammals so coated lose their ability to thermoregulate and are at high risk of dying from exposure. Oil is of particular concern in this regard when a spill occurs in an area where sensitive species congregate (e.g., nesting or rafting seabirds, fish spawning beds, or seal haulout areas). Aquatic fish and invertebrates are impacted by oil through direct exposure, ingestion or absorption. Oil can cause significant mortality especially to eggs and larvae of many species and to sessile organisms such as oysters and other shellfish beds. Physiological impacts such as fin erosion, enlarged livers and increased heart rates have been documented in fish after exposure to oil. Because oil can persist for long periods of time in the environment, habitats may remain impaired long after an initial oil spill response, and clean-up efforts themselves can lead to unintended ecosystem damage.

Mercury

The primary source of mercury as a pollutant is fossil fuel combustion (particularly coal-fired power plants), with smaller amounts also coming from incineration of municipal and hospital waste. Airborne mercury precipitates into the environment, and becomes methylated in environments with anoxic conditions and high concentrations of organic carbon. Methylmercury is readily taken up by organisms, and is then biomagnified at higher trophic levels. The effects of mercury on wildlife are varied, but generally involve neurological impairment that can lead to behavioral, reproductive, and/or physiological impacts. Such effects are generally more pronounced in longer-lived species at the top of food chains, which have a greater likelihood of accumulating mercury to toxic concentrations.

While the presence of mercury is well documented, the actual effects on most wildlife species have been fairly minor. Long-lived predator species are one exception to this. Because of a process called biomagnification, species such as loons that feed at high trophic levels have higher levels of mercury in their blood than those that species that feed at lower trophic levels (Evers et al 2012).

Methylmercury availability greatly affects species and habitats of conservation concern in New Hampshire, though habitat and species sensitivity varies. Impacts will likely be serious in salt marshes, marsh and shrub wetlands, and floodplain forests. Mercury will likely have a serious effect on aquatic and high-elevation habitats in the short-term. Methylmercury is well documented in aquatic habitats, somewhat documented in salt marsh, marsh and shrub wetlands, and high-elevation habitats, and weakly or undocumented in alpine and peatlands.

Because mercury is more likely to be biologically available in wetland and aquatic systems, most work to date has been done with wildlife that occupy these habitats, particularly those that feed primarily on fish (Evers and Clairs 2005a). For example, 14% of Common Loons in southeastern New Hampshire have blood mercury levels high enough to cause impairment (Evers et al. 1998), and lower Bald Eagle productivity in Maine is significantly correlated to chick blood mercury levels (DeSorbo and Evers 2005). Insectivorous species can also accumulate relatively high mercury levels (e.g., salt marsh sparrows, Lane and Evers 2005; Bicknell's Thrush, Rimmer et al. 2005), although to date impacts have not been documented in these species. It is possible that these smaller songbirds – in contrast to longer lived loons and eagles – do not live long enough for the toxic effects of mercury to manifest, and even studies in highly contaminated sites have obtained variable results (e.g., Brasso and Cristol 2008, Hallinger et al. 2010). In addition, mercury availability may increase in systems impacted by acid deposition, particularly high elevation habitats (e.g,. Bicknell's Thrush, above) and peatlands (Evers et al. 2005).

Acid Deposition

Acid deposition may have critical effects on species and habitats of conservation concern in New Hampshire. Impacts are expected to be critical for alpine habitats, high elevation spruce-fir forests, and northern hardwood-conifer forests. Effects are expected to be serious for montane watersheds, vernal pools, talus slopes and rocky ridges, lowland spruce-fir forests, and hemlock-hardwood-pine forests. For most habitats, these effects are possible in the near term, although such effects could be immediate in the case of vernal pools. With the exception of vernal pools, the impacts of acid deposition on these habitats are well documented.

Combustion in vehicle engines, power plants, and other industrial processes generates nitrogen oxides and sulfur oxides, which enter the atmosphere and are transformed into acids. These chemicals can travel for hundreds of miles in the upper atmosphere before falling as acid precipitation or dry deposition, at which point they can lower the pH of water bodies, damage plant tissues, or alter mineral availability in the soil. The estimated acidity (pH) of rainfall in 2010 for the Northeast ranged from 4.9 to 5.1 (USEPA 2014); normal pH for rainfall is approximately 5.5. Although surface waters in New Hampshire are naturally acidic due to low acid-neutralizing capacity of its bedrock, anthropogenic acidification has stressed most natural communities. Acidic precipitation can alter terrestrial and aquatic ecosystems in the Northeast (Driscoll et al. 2001), and may have additive or synergistic effects with other ecosystem stressors.

In aquatic systems, low pH can affect embryonic development, growth, metabolism, respiration, reproduction, and survival. Many species of aquatic organisms are sensitive to changes in pH, and aquatic insect diversity and abundance often declines in acidified lakes and streams (Haines 1981, Okland and Okland 1986). Crustaceans and mollusks are sensitive to acid deposition because it interferes with calcium uptake, and the state-endangered Dwarf Wedgemussel and Brook Floater may be affected by chronic acidity. Amphibians experience high mortality or reduced productivity in acidic environments via reduced abundance of egg masses, decreased hatching success, increased larval mortality, and inhibited development (Pough 1976, Rowe et al. 1992, Horne and Dunson 1994, Kiesecker 1996). Impacts to fish include reduced growth, reproductive failure, skeletal deformities, and mortality (Haines 1981, Schindler 1988, Baker et al. 1996). Brook trout have been shown to seek refuge downstream during pulses of acid deposition (Baker et al. 1996), and aluminum concentrations may reach toxic levels in streams where calcium has been leached away by acid rain (Baker and Schofield 1982). Wildlife at higher trophic levels may be compromised if their preys (e.g. fish) are less available (Longcore et al. 1987).

In terrestrial systems, plant productivity and health can be severely affected by acid deposition. This is particularly true in high-elevation habitats (e.g. high-elevation spruce-fir forest, alpine), where plants may suffer direct foliar damage from contact with acid fog and mist, which often has a much higher acidity than rain. Acidophilic plants will replace calciphilic plants due to chronic acidification, and some of New Hampshire's rarest alpine and cliff communities may be at risk (Rusek 1993). Acidity also leaches nutrients from foliage and mobilizes aluminum, which damages roots and contributes to soil infertility. Acid deposition works in concert with cold temperatures to cause winter injury, a proximate cause of widespread red spruce decline in the Northeast. At the same time, acidic precipitation is known to leach metals such as calcium from upper soil layers, making it less available to terrestrial invertebrates (snails, arthropods) which require it for exoskeleton development. Declines in these invertebrates may have bottom-up effects on their predators, particularly ground-foraging birds (e.g., Wood Thrush, Hames et al. 2002).

Excess Energy
The overall impacts of light pollution on New Hampshire wildlife are quite small in comparison to other threats. This threat is likely only important in large urban areas, and even there its magnitude is poorly known.

Human activity is increasingly responsible for inputs of excess energy into the environment. These inputs can take the form of light, heat, or sound, all of which have documented effects on wildlife and their habitats.

Outdoor lighting by streetlights, parking lot lights, and illumination associated with buildings has sharply increased over the last half century (Frank 1988, Cinzano et al. 2000). Light pollution has adverse effects on many species of insects, particularly nocturnal taxa such as moths. Lepidopterists have long attributed moth population declines, especially those of northeastern saturniids, to increasing artificial light pollution (Frank 1988). Artificial lighting disturbs flight, navigation, vision, migration, dispersal, oviposition, mating, feeding, and crypsis in some moths (Frank 1988). It also increases their susceptibility to predation by birds, bats, and spiders (Frank 1988). Heavily lit urban areas can attract nocturnally migrating birds (e.g., many songbirds, cuckoos, owls, rails), which become disoriented and may suffer mortality from collisions with buildings or other structures (Klem 1989). Disoriented birds, in turn, may be more susceptible to predation, or may find themselves in inhospitable environments with limited foraging opportunities. Recent analysis suggests that between 365 and 988 million birds (median of 599 million) are killed as a result of window collisions each year (Loss et al. 2014), although not all of these are related to light pollution.

Thermal pollution is generally associated with outflows of heated water from power plants, and can have strongly negative, albeit local, effects on aquatic fauna (Stewart et al. 2013). In addition to altering habitat for resident species, heated discharge may influence the spawning success of migratory fish species, including American shad. One of the largest contributors of heated discharge to the Connecticut River, the Vermont Yankee Nuclear Power Plant, was decommissioned in 2014. There are still active power plants with heated discharge in coastal New Hampshire and in the Merrimack River.

There is increasing evidence that noise pollution can alter the behavior of birds, and presumably other animals that communicate with vocalizations. Such effects may be most significant along busy roadways, but have also been proposed in far less noisy situations such as along recreational trails. Noise pollution was not identified as a specific threat in the 2015 NH WAP, but it could be considered under IUCN 6 as a sub-category of human disturbance.

Research Needs

Run-off

- Expand water quality monitoring to include a greater variety of aquatic habitats
- Compare areas known to be receiving polluted runoff with areas that are relatively pristine
- Conduct research on prevalence and impacts of emerging pollutants on wildlife (e.g., pharmaceuticals, hormone disruptors, plastics).

Nutrients

- Monitor sensitive freshwater indicator species (such as bridle shiners and freshwater mussels) for signs of nutrient impacts.

Sediment

- Gather more complete information on how sedimentation acts on species and habitats, and determine ecological responses to high nutrient inputs.
- Determine the severity of sedimentation in key habitats and investigate the severity posed to SGCN.

Pesticides

- Determine neonicitinoid levels in New Hampshire habitats and assess their potential effects on local insect populations.
- Monitor the long-term effects of pesticides on the reproductive fitness of avian predators.
- Monitor sublethal effects of aquatic herbicide applications on wildlife and aquatic plants.

Oil Spills

- Assess potential impacts of an oil spill near threatened and endangered species breeding grounds (i.e., Seavey Island, Hampton Beach State Park and Seabrook Town Beach).
- Conduct long-term assessments and biodiversity surveys of coastal islands, dunes, and salt marshes before and after oil spills to determine effects.
- Identify appropriate mitigation for loss of wildlife due to oil spills.

Mercury

- Initiate a steering committee of state agencies (NHFG and NHDES) to work with federal agencies (USEPA, USFWS, USDA, and USGS), industry, universities, and non-profit organizations that will facilitate operations of the National Mercury Monitoring Network. Process should follow the successful mercury network by BRI with the Northeastern Ecosystem Research Cooperative.
- Conduct a risk assessment for habitats and their species assemblages.
- Continue to monitor mercury levels in species of concern across a variety of habitats.
- Determine the effects of varying mercury loads on species of concern, particularly those known to have relatively high concentrations (e.g., Bicknell's Thrush, Saltmarsh Sparrow).

Acid Deposition

- Are there potential effects of acid deposition on alpine communities, and how do these interact with the effects of climate change?
- How has acidification affected prey availability for non-forest species like the Rusty Blackbird?
- Additional research may be relevant to determine the efficacy of any proposed mitigation measures based on research conducted at Hubbard Brook Experimental Forest.

Table 4-19. Habitats and species at highest risk from the effects of pollution (threats ranked as *Low* not included here). IUCN Level 3 provided if evaluated to that level (if not evaluated to level 2 or level 3, text reads *not specified*). Some habitats and species were evaluated for multiple specific threats separately and therefore listed multiple times below. See Appendix E for additional information on specific threats and rankings

Habitat	IUCN Level 2	IUCN Level 3	Overall Threat Score
Alpine	Air-borne pollutants	Acid rain	M
Alpine	Air-borne pollutants	Mercury	M
Alpine	Air-borne pollutants	Ozone	M
Coastal Islands	Industrial & military effluents	Oil spills	H
Coldwater rivers and streams	Agricultural & forestry effluents	Not Specified	M
Coldwater rivers and streams	Air-borne pollutants	Acid rain	M
Coldwater rivers and streams	Domestic & urban waste water	Run-off	M
Coldwater rivers and streams	Not Specified	Not Specified	M
Dunes	Industrial & military effluents	Not Specified	M
Dunes	Industrial & military effluents	Oil spills	H
Estuarine	Domestic & urban waste water	Run-off	M
Estuarine	Industrial & military effluents	Oil spills	H
Estuarine	Not Specified	Nutrient loads	M
Floodplain Forests	Not Specified	Not Specified	M
Grassland (Cropland)	Agricultural & forestry effluents	Herbicides & pesticides	M
Lakes and ponds with coldwater habitat	Agricultural & forestry effluents	Not Specified	M
Lakes and ponds with coldwater habitat	Air-borne pollutants	Acid rain	M
Lakes and ponds with coldwater habitat	Not Specified	Not Specified	M
Large warmwater rivers	Agricultural & forestry effluents	Herbicides & pesticides	M
Large warmwater rivers	Domestic & urban waste water	Run-off	M
Large warmwater rivers	Excess energy	Thermal pollution	M
Large warmwater rivers	Not Specified	Not Specified	M
Marine	Air-borne pollutants	Mercury	M
Marine	Industrial & military effluents	Oil spills	M
Marsh and Shrub Wetlands	Not Specified	Not Specified	M
Peatlands	Domestic & urban waste water	Run-off	M
Peatlands	Not Specified	Not Specified	M
Salt Marsh	Domestic & urban waste water	Run-off	M

Salt Marsh	Industrial & military effluents	Oil spills	H
Salt Marsh	Not Specified	Not Specified	M
Temperate Swamp	Not Specified	Not Specified	M
Vernal Pools	Not Specified	Not Specified	H
Warmwater lakes and ponds	Agricultural & forestry effluents	Not Specified	M
Warmwater lakes and ponds	Domestic & urban waste water	Run-off	M
Warmwater lakes and ponds	Domestic & urban waste water	Sewage	M
Warmwater lakes and ponds	Not Specified	Not Specified	M
Warmwater rivers and streams	Agricultural & forestry effluents	Not Specified	M
Warmwater rivers and streams	Domestic & urban waste water	Run-off	H
Warmwater rivers and streams	Domestic & urban waste water	Run-off	M
Warmwater rivers and streams	Not Specified	Not Specified	M

Common Name	**IUCN Level 2**	**IUCN Level 3**	**Overall Threat Score**
American Brook Lamprey	Domestic & urban waste water	Run-off	M
American Bumble Bee	Agricultural & forestry effluents	Herbicides & pesticides	H
American Kestrel	Not Specified	Not Specified	M
American Oysters	Agricultural & forestry effluents	Nutrient loads	M
American Oysters	Domestic & urban waste water	Not Specified	M
American Oysters	Industrial & military effluents	Oil spills	H
Atlantic Sea Scallop	Air-borne pollutants	Mercury	M
Atlantic Sea Scallop	Industrial & military effluents	Oil spills	M
Bald Eagle	Not Specified	Not Specified	M
Banded Sunfish	Domestic & urban waste water	Run-off	M
Banded Sunfish	Not Specified	Not Specified	H
Bank Swallow	Agricultural & forestry effluents	Herbicides & pesticides	M
Bicknell's Thrush	Air-borne pollutants	Acid rain	M
Bobolink	Agricultural & forestry effluents	Herbicides & pesticides	M
Bridle Shiner	Domestic & urban waste water	Run-off	M
Bridle Shiner	Not Specified	Not Specified	H
Brook Floater	Not Specified	Not Specified	H
Brook Trout	Air-borne pollutants	Acid rain	H

Brook Trout	Domestic & urban waste water	Run-off	M
Chimney Swift	Agricultural & forestry effluents	Herbicides & pesticides	M
Cliff Swallow	Agricultural & forestry effluents	Herbicides & pesticides	M
Common Loon	Air-borne pollutants	Mercury	M
Common Tern	Industrial & military effluents	Oil spills	H
Dwarf Wedgemussel	Not Specified	Not Specified	H
Eastern Pondmussel	Domestic & urban waste water	Not Specified	M
Eastern Whip-poor Will	Not Specified	Not Specified	M
Golden Eagle	Not Specified	Not Specified	M
Horseshoe Crab	Agricultural & forestry effluents	Nutrient loads	M
Horseshoe Crab	Air-borne pollutants	Mercury	M
Horseshoe Crab	Domestic & urban waste water	Not Specified	M
Horseshoe Crab	Domestic & urban waste water	Run-off	M
Horseshoe Crab	Industrial & military effluents	Oil spills	M
Jefferson/Blue-Spotted Salamander Complex	Air-borne pollutants	Acid rain	M
Margined Tiger Beetle	Not Specified	Not Specified	H
Monarch	Agricultural & forestry effluents	Herbicides & pesticides	H
Monarch	Agricultural & forestry effluents	Not Specified	M
Nelson's Sparrow	Air-borne pollutants	Mercury	M
Nelson's Sparrow	Not Specified	Not Specified	M
Northern Leopard Frog	Agricultural & forestry effluents	Herbicides & pesticides	M
Northern Shrimp	Air-borne pollutants	Mercury	M
Northern Shrimp	Industrial & military effluents	Oil spills	M
Peregrine Falcon	Not Specified	Not Specified	M
Piping Plover	Industrial & military effluents	Not Specified	M
Piping Plover	Industrial & military effluents	Oil spills	H
Purple Martin	Agricultural & forestry effluents	Herbicides & pesticides	M
Rainbow Smelt (diadromous)	Not Specified	Not Specified	M
Rainbow Smelt (landlocked)	Domestic & urban waste water	Run-off	M
Roseate Tern	Industrial & military effluents	Oil spills	H
Round Whitefish	Agricultural & forestry effluents	Not Specified	M
Rusty-patched Bumble Bee	Agricultural & forestry effluents	Herbicides & pesticides	H

Saltmarsh Sparrow	Air-borne pollutants	Mercury	M
Saltmarsh Sparrow	Not Specified	Not Specified	M
Scarlet Tanager	Air-borne pollutants	Acid rain	M
Seaside Sparrow	Air-borne pollutants	Mercury	M
Seaside Sparrow	Not Specified	Not Specified	M
Softshell Clam	Agricultural & forestry effluents	Nutrient loads	M
Softshell Clam	Air-borne pollutants	Mercury	M
Softshell Clam	Domestic & urban waste water	Run-off	M
Softshell Clam	Industrial & military effluents	Oil spills	M
Swamp Darter	Domestic & urban waste water	Run-off	M
Swamp Darter	Not Specified	Not Specified	M
Veery	Air-borne pollutants	Acid rain	M
Willet	Air-borne pollutants	Mercury	M
Wood Thrush	Air-borne pollutants	Acid rain	M
Yellow Bumble Bee	Agricultural & forestry effluents	Herbicides & pesticides	H
Yellowbanded Bumble Bee	Agricultural & forestry effluents	Herbicides & pesticides	H

Literature Cited

Alexander, G., and E. Hansen. 1983. Sand Sediment in a Michigan Trout Stream Part II. Effects of Reducing Sand Bedload on a Trout Population. North American Journal of Fisheries Management. American Fisheries Society. 3:365-372.

Baker, J. P. and Schofield, C. L. 1982. Aluminium toxicity to fish in acidic waters. Water, Air Soil Poll. 18:289-309.

Baker, J.P., J.Van Sickle, C.J. Gagen, D.R. DeWalle, W.E. Sharpe, R.F. Carline, B.P. Baldigo, P.S. Murdoch, D.W. Bath, W.A. Kretser, H.A. Simonin, and P.J. Wigington. 1996. Episodic acidification of small streams in the northeastern United States: effects on fish populations. Ecological Applications 6:422-437.

Brasso, R.L., and D.A. Cristol. 2008. Effects of mercury exposure on the reproductive success of tree swallows (Tachycineta bicolor). Ecotoxicology 17:133-141.

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley and V.H. Smith. 1998. Non-point pollution of surface waters with phosphorous and nitrogen. Ecological Applications 8:559-568.

Cinzano, P., F. Falchi, and C.D. Elvidge. 2000. The light pollution problem: a global assessment. Abstract *in* Program of the 32nd annual meeting of the Division of Planetary Sciences, American Astronomical Society, Pasadena, CA. Bulletin of the American Astronomical Society 32(3). http://www.aas.org/publications/baas/v32n3/dps2000/142.htm

Connecticut River Joint Commission (CRJC). 2002. River Dynamics and Erosion. River Banks and Buffers No. 1. Available http://www.crjc.org/pdffiles/rivdynero.pdf. (Accessed May 2005).

Cresswell, J. 2014. On the natural history of neonicotinoids and bees. Functional Ecology 28:1311-1312.

DeSorbo, C.R., and D.C. Evers. 2005. Evaluating exposure of Maine's Bald Eagle population to Mercury: assessing impacts on productivity and spatial exposure patterns. Report BRI 2005-08. BioDiversity Research Institute, Gorham, Maine.

Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001. Acidic deposition in the northeastern United States: Sources and inputs, ecosystem effects, and management strategies. Bioscience 51:180-198.

USEPA. 2014. United States Environmental Protection Agency: Acid Rain in New England. National Atmospheric Deposition Program/National Trends Network. http://www.epa.gov/region1/eco/acidrain/intro.html. Accessed June 1, 2015.

Evans, K.L., J.D. Wilson, and R.B. Bradbury. 2007. Effects of crop type and aerial invertebrate abundance on foraging barn swallows *Hirundo rustica.* Ag. Ecosystems and Mgmt. doi: 10.1016/j.agee.2007.01.015

Evers, D.C. 2005. Mercury Connections: The extent and effects of mercury pollution in northeastern North America. BioDiversity Research Institute, Gorham, Maine.

Evers, D.C., A.K. Jackson, T.H. Tear and C.E. Osborne. 2012. Hidden Risk: Mercury in Terrestrial Ecosystems of the Northeast. Biodiversity Research Institute. Gorham, Maine. BRI Report 2012-07. 33 pages.

Evers, D.C., and T.A. Clair. 2005a. Biogeographical patterns of environmental mercury in northeastern North America. Ecotoxicology 14. 296pp.

Evers, D.C., J.D. Kaplan, M.W. Meyer, P.S. Reaman, A. Major, N. Burgess, and W.E. Braselton. 1998. Bioavailability of environmental mercury measured in Common Loon feathers and blood across North American. Environmental Toxicology and Chemistry 17:173-183.

Evers, D.C., N. Burgess, L. Champoux, B. Hoskins, A. Major, W. Goodale, R. Taylor, R. Poppenga, and T. Daigle. 2005. Patterns and interpretation of mercury exposure in freshwater avian communities in northeastern North America. Ecotoxicology 14:193-222.

Evers, D.C., Y-J. Han, C.T. Driscoll, N.C. Kamman, M.W. Goodale, K.F. Lambert, T.M. Holsen, C.Y. Chen, T.A. Clair, and T. Butler. 2007. Biological mercury hotspots in the northeastern United States and southeastern Canada. Bioscience 57: 29-43.

Francis, F., and A. Mulligan. 1997. Connecticut River Corridor Management Plan. Connecticut River Joint Commission. Charlestown, New Hampshire, USA.

Frank, K.D. 1988. Impact of outdoor lighting on moths: an assessment. Journal of the Lepidopterists' Society. 42:63-93.

Ghilain, A. and M. Bélisle. 2008. Breeding success of Tree Swallows along a gradient of agricultural intensification. Ecol. Appl. 18:1140-1154.

Gibbons, D., Morrissey, C., and Mineau, P. 2015. A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife. Environmental Science and Pollution Research 22:103-118.

Goldstein, M.I., T.E. Lacher, B. Woodbridge, M.J. Bechard, S.B. Canavelli, M.E. Zaccagnini, G.P. Cobb, E.J. Scollon, R. Tribolet, M.J. Hopper. 1999. Monocrotophos-induced mass mortality of Swainson's Hawks in Argentina, 1995–96. Ecotoxicology 8:201-214.

Haines, T.A. 1981. Acidic precipitation and its consequences for aquatic ecosystems: a review. Transactions of the American Fisheries Society 110:669-707.

Hallinger, K.K., D.J. Zabransky, K.A. Kazmer, and D.A. Cristol. 2010. Birdsong differs between mercury-polluted and reference sites. *The Auk* 127:156-161.

Hallman, C.A., R.P.B. Foppen, C.A.M. van Turnhout, H. de Kroon, and E. Jongejans. 2014. Declines in insectivorous birds are associated with high neonicotinoid concentrations. Nature. doi: 10.1038/nature13531

Hames, R.S., K.V. Rosenberg, J.D. Lowe, S.E. Barker, and A.A. Dhondt. 2002. Adverse effects of acid rain on the distribution of the Wood Thrush Hylocichla mustelina in North America. Proceedings of the National Academy of Sciences of the United States of America 99:11235-11240.

Hatfield, R., Jepsen, S., Mader, E., Black, S. H., & Shepherd, M. 2012. Conserving Bumble Bees. Guide-lines for Creating and Managing Habitat for America's Declining Pollinators. The Xerces Society for Invertebrate Conservation, USA. 32pp.

Hedrick L., S. Welsh, and J. Hedrick. 2005. A New Sampler Design for Measuring Sedimentation in Streams. North American Journal of Fisheries Management. American Fisheries Society 25:238-244.

Horne, M.T., and W.A. Dunson. 1994. Exclusion of the Jefferson salamander, Ambystoma jeffersonia-num, from some potential breeding ponds in Pennsylvania: effects of pH, temperature, and metals on embryonic development. Archives of Environmental Contamination and Toxicology 27:323-300.

Jepsen, S., D. F. Schweitzer, B. Young, N. Sears, M. Ormes, and S. H. Black. 2015. Conservation Status and Ecology of Monarchs in the United States. NatureServe, Arlington, Virginia and the Xerces Society for Invertebrate Conservation, Portland Oregon. 36pp.

Kiesecker, J.M. 1996. pH induced growth reduction and its effects on predator-prey interactions be-tween Ambystoma tigrinum and Pseudacris triseriata. Ecological Applications 6:1325-1331.

Klem, D., Jr. 1989. Bird-window collisions. Wilson Bulletin 101: 606-620.

Kunz, T.H., E.L.P. Anthony, and W.T. Rumage. 1977. Mortality of little brown bats following multiple pesticide applications. Journal of Wildlife Management 41:476-483.

Lane, O.P., and D.C. Evers. 2005. Developing a geographic exposure profile of methylmercury availability in salt marshes of New England. Report BRI 2005-04. BioDiversity Research Institute, Gorham, Maine.

Leonard, J.G., and R.T. Bell. 1999. Northeastern Tiger Beetles: A field guide to tiger beetles of New England and eastern Canada. CRC Press, Boca Raton, FL.

Longcore, J.R., R.K. Ross, and K.L. Fisher. 1987. Wildlife resources at risk through acidification of wetlands. Transactions of the 52nd North American Wildlife and Natural Resources Conference, pages 608-618.

Scott R. Loss, S.R., T. Will, S.S. Loss, and P.P. Marra. 2014. Bird–building collisions in the United States: Estimates of annual mortality and species vulnerability. Condor 116: 8–23. DOI: 10.1650/CONDOR-13-090.1

Mahaney W., D. Wardrop, and J. Bishop. 2004. Impacts of Sedimentation and Nitrogen Enrichment on Wetland Plant Community Development. Plant Ecology 175(2):227-243.

Miller, J. 1982. Hardwood Control Using Pelleted Herbicides and Burning. Proceedings, 35th Annual Meeting Southern Weed Science Society; 1982 January 19-21; Atlanta, GA. Southern Weed Science Society. 210-215.

Natural Resources Canada. 1997. Genetically Engineered Baculoviruses for Forest Insect Management Applications. A Canadian Forest Service Discussion Paper. Science Branch. Ottawa, Ontario.

New Hampshire Department of Environmental Services. 1999. New Hampshire Non-point Source Management Plan. Concord, New Hampshire, USA.

New Hampshire Department of Environmental Services. 2012. Combined Sewage Overflows (CSOs). Environmental Fact Sheet WD-WEB-09. Available http://des.nh.gov/organization/commissioner/pip/factsheets/wwt/documents/web-9.pdf. (Accessed June 2015).

New Hampshire Department of Environmental Services. 2015. New Hampshire Department of Environmental Services Soak Up the Rain NH: About SOAK. http://soaknh.org/about/. Accessed June 19, 2015.

Nocera, J.J., J.M. Blais, D.V. Beresford, L.K. Finity, C. Grooms, L.E. Kimpe, K. Kyser, N. Michelutti, M.W. Reudink, and J.P. Smol. 2012. Historical pesticide applications coincided with an altered diet of aerially foraging insectivorous Chimney Swifts. Proc. Royal Soc. B. doi: 10.1098/rspb.2012.0445.

Okland, J. and K.A. Okland. 1986. The effects of acid deposition ion benthic animals in lakes and streams. Experientia 42:471.

Paquette, S.R., D. Garant, F. Pelletier, and M. Bélisle. 2013. Seasonal patterns in Tree Swallow prey (Diptera) abundance are affected by agricultural intensification. Ecological Applications 23:122-133.

Pough, F.H. 1976. Acid precipitation and embryonic mortality of spotted salamanders, Ambystoma maculatum. Science. 192:68-70.

Rashin, E., and C. Graber. 1993. Effectiveness of Best Management Practices for Aerial Application of Forest Pesticides. Washington State Department of Ecology. Ecology Publication No. 93-81.

Hua, J., and R. A. Relyea. 2014. Chemical cocktails in aquatic ecosystems: Pesticide effects on resistance and resilience. Environmental Pollution 189:18-26.

Richburg, J.A., W. Patterson, and F. Lowenstein. 2001. Effect of road salt and Phragmites australis invasion on the vegetation of a western Massachusetts calcareous lakebasin fen. Wetlands 21:247-255.

Richter B., D. Braun, M. Mendelson, and L. Master. 1997. Threats to Imperiled Freshwater Fauna. Conservation Biology 2:1081-1093.

Rimmer, C., K. McFarland, D.C. Evers, E.K. Miller, Y. Aubry, D. Busby, and R. Taylor. 2005. Mercury levels in Bicknell's Thrush and other insectivorous passerine birds in montane forests of northeastern United States and Canada. Ecotoxicology 14:223-240.

Rowe, C.L., W.J. Sadinski, and W.A. Dunson. 1992. Effects of acute and chronic acidification on three larval amphibians that breed in temporary ponds. Archives of Environmental Contamination and Toxicology 23:339-350.

Rusek, J. 1993. Air-pollution-mediated changes in alpine ecosystems and ecotones. Ecological Applications 3:409-416.

Schindler, D.W., K.H. Mills, D.F. Malley, S. Findlay, J.A. Shearer, I.J. Davies, M.A. Turner, G.A. Lindsey, and D.R. Cruikshank. 1985. Long-term ecosystem stress: Effects of years of experimental acidification. Canadian Journal of Fisheries and Aquatic Sciences 37:342-354.

Schindler, D.W. 1988. Effects of acid rain on freshwater ecosystems. Science 239:149-157.

Stewart, R.J., W.M. Wollheim, A. Miara, C.J. Vorosmarty, B. Fekete, R. Lammers, and B. Rosenzweig. 2013. Horizontal cooling towers: Riverine ecosystem services and the fate of thermoelectric heat in the contemporary Northeast. *Environmental Research Letters*, 8:025010

Turtle, S.L. 2000. Embryonic survivorship of the spotted salamander (Ambystoma maculatum) in roadside and woodland vernal pools in southeastern New Hampshire. Journal of Herpetology 34:60-67.

United States Environmental Protection Agency (USEPA). Draft 2005. National Management Measures to Control Non-point Source Pollution from Urban Areas. Management Measure 7 – Bridges and Highways. Available: http://www.epa.gov/owow/nps/urbanmm/index.html. (Accessed May 2005).

Weaver, L.A., and G.C. Garman. 1994. Urbanization of a watershed and historical changes in a stream fish assemblage. Transactions of the American Fisheries Society 123:162-172.

Transportation and Service Corridors

The 'transportation and service corridors' category (IUCN 4) includes threats from a variety of vehicles operating on land, water and air, and the infrastructure and management that they require to operate, as well as utility and service lines used to transport energy and resources. For the purposes of the New Hampshire Wildlife Action Plan, threats in this category were often evaluated under the following specific sub-categories:

- Roads & railroads - surface transport on roadways and dedicated tracks
- Utility & service lines - transport of energy & resources
- Shipping lanes - transport on and in freshwater and ocean waterways and associated dredging and dumping of dredged materials
- Flight paths - air transport
- Airports - management of grassland areas surrounding runways at airports

Several related threats are known and summarized under other threat summaries (e.g., Residential and Commercial Development, IUCN 1; Pollution, IUCN 9).

Risk Assessment Summary

The transportation & service corridor threat was evaluated for 114 unique threats across 20 habitats and 77 species (Table 4-20). The majority of threat assessment scores were ranked as low (n=67, 59%), followed by moderate (n = 37, 32%) and high ranking threats (n = 10, 9%).

Roads and railroads were the primary type of transportation identified in habitat and species risk assessment (Table 4-20). Roads were identified as a high threat category for four habitat types, all of which were either wetlands or aquatic habitat types. Roads were identified as a moderate threat category for three habitat types. Roads were identified as a high threat category for four species, three of which were turtles. Roads were identified as a moderate threat category for 14 species and ranged from species that are fully aquatic to primarily terrestrial. Removal of roosting habitat for roadway expansion or creation was a low ranking threat for seven bat species, primarily due to a low predicted spatial extent score and some lack of certainty.

Utility and service lines was identified as a moderate threat for northern black racers. The primary threat identified for black racers was associated with management of utility lines, particularly mortality to individual snakes from machinery or compaction of underground den sites. Nesting turtles, New England cottontails, and birds associated with grasslands and shrublands could also be impacted by some vegetative management along utility lines, but these species were not included in assessments. Removal of roosting habitat for utility right of way expansion or creation was a low ranking threat for seven bat species, primarily due to a low predicted spatial extent score and some lack of certainty.

Shipping lanes, and associated dredging and dumping of dredged materials, was evaluated for 15 species and five habitats, all occurring on the coast. Shipping lanes ranked as a moderate threat for marine and dune habitats and several species including fin whale and softshell clam. Shipping lands and associated dredging and dumping of dredged materials ranked as a low ranking threat for 13 of 20 (65%) species and habitats evaluated which was largely influenced by a localized (i.e., low ranking) spatial extent score. Stressors identified for this threat ranged from species disturbance and mortality to ecosystem degradation.

Management of airports was a moderate to high ranking threat for grasslands and associated grassland birds including upland sandpipers, eastern meadowlarks, grasshopper sparrows, horned lark, and vesper sparrow. Airport management was also a threat for pine barrens lepidoptera including Karner blue butterfly and frosted elfin.

Flight paths were evaluated only for peregrine falcons, and was ranked as a low ranking threat. Disturbance from planes or helicopters near nests could be a localized concern to evaluate in future.

Known Wildlife Exposure Pathways

Mortality and collision on roadways and shipping lanes

Mortality can affect the dispersal and viability of isolated populations, and eventually cause local extirpation (Trombulak and Frissell 2000, Forman et al. 2003). At greatest risk are slow-moving species (e.g., reptiles and amphibians), species that depend on high adult survivorship (turtles), species that are long range dispersers (bobcat, American marten, wolves), or species with scarce populations (timber rattlesnake) (Fahrig and Rytwinski 2009). Low population densities and skewed age and sex ratios have raised concerns about the effect of road mortality on the viability of some turtle populations in the region (e.g., Marchand and Litvaitis 2004, Gibbs and Steen 2005, Patrick and Gibbs 2010). Turtles are attracted to the bare soil and open canopy of road shoulders and utility corridors, but adults and hatchlings are at risk from vehicles. Snakes may be attracted to roads to bask on warm pavement surfaces (Trombulak and Frissell 2000). Wide-ranging mammals such as bobcat, lynx, American marten, and wolves are likely to encounter and cross roads. As traffic volume increases, vehicle collisions become increasingly probable, reducing local population abundances and decreasing the likelihood and frequency of dispersal to unoccupied or low-density habitats (Litvaitis, University of New Hampshire, personal communication). Large mammals crossing roadways (e.g., black bear, moose, and deer), although not likely to be a population viability concern, cause safety concerns for motorists. Whales and other marine mammals may be vulnerable to collision with boats in marine habitats (Jensen and Silber 2004).

Habitat loss and fragmentation

New Hampshire's human population density and associated development continues to increase, especially in the southern counties (Johnson 2012, Society for Protection of New Hampshire Forests 2005). Increasing human population density leads to increasing road densities, road widening, and higher traffic volume (see Development threat). The construction of roads, railroads and airports results in a considerable loss of habitat (Trombulak and Frissell 2000). Furthermore, areas bisected by roads result in smaller, fragmented blocks of habitat, with more isolated local populations potentially at a higher risk of localized extinction (Saunders et al. 1991 (Fahrig 2002)).

Wildlife is affected well beyond the scope of the actual physical disturbance (Forman and Deblinger 2000, Jones et al. 2000); while roadways are estimated to cover ~1% of the land area of the United States, up to 19% of this area has been projected to be ecologically affected by roads (Forman 2000). For example, effects of roadway noise may extend hundreds of meters from a heavily traveled road, reducing species occupation (e.g., forest interior birds) and altering behavior (Forman and Deblinger 2000, Forman et al. 2003). Roads can affect aquatic habitats by increasing contaminated runoff and increasing water temperatures (see Pollution summary).

Dispersal
The effects of roads and utility corridors as barriers to wildlife movement are widespread (Andrews 1990, Forman et al. 2003, Trombulak and Frissell 2000). Roads that bisect seasonal or annual wildlife migration routes are of particular concern, especially for rare amphibians and reptiles that migrate between wetlands and uplands or between wetland complexes (Fahrig et al. 1995, Trombulak and Frissell 2003). New England cottontails may be reluctant to cross a wide road because of the break in dense cover that they prefer (J. Litvaitis, University of New Hampshire, personal communication). Lepidoptera may be impeded from crossing roads by vehicular wind (S. Fuller, NHFG, personal communication). Road design can block wildlife; Jersey barriers and steep-sloping granite curbs can trap small organisms on roadways and increase mortality risk (Klemens 2000; M. Marchand, NHFG, personal observation). Underpasses (e.g., culverts) at stream crossings, especially those that are undersized or perched, may be ineffective for passage of aquatic organisms (Jackson 2003). Identifying optimal locations to place mitigation strategies such as crossing structures can also be difficult (Beaudry et al. 2008, Patrick et al. 2012).

Mortality and habitat loss from vegetation management
Areas surrounding airport runways and roadsides often are cleared of native vegetation and are maintained as homogenous mowed habitat, largely due to safety concerns (Forman et al. 2003). Mowing and shrub/tree management during critical times can have serious effects on local populations of plants or wildlife (e.g., Karner blue butterfly, frosted elfin butterfly, northern black racer, grasshopper sparrow, upland sandpiper, and New England cottontail). Utility and service corridors can provide suitable habitat for species dependent on shrubland habitats (Askins et al. 2012). However, management of these areas can result in loss or degradation of habitat and direct mortality of animals, depending on the timing of management and practices employed. For example, removal of dense shrublands occupied by New England cottontail removes important structure used as habitat and exposes individual rabbits to predators. Removal of vegetation during winter is particularly problematic because alternative cover (grasses, forbs, stick piles) is typically reduced from snowfall and seasonal dieback. Conversely, wood turtles hibernate underwater in streams during winter and therefore are not typically adversely impacted by management in the uplands during this time. During spring through fall, wood turtles use dense shrublands and grasslands and are vulnerable to crushing from management equipment.

Dredging of Shipping Lanes
Dredging harbors (e.g., Hampton harbor) and shipping lanes can adversely affect local populations of benthic invertebrates such as softshell clams by removing substrate used as habitat and resulting in mortality of individuals (Boyd et al. 2005, Thrush and Dayton 2002) and disturbance to foraging areas for certain fish. Placement of dredged spoils can impact dune habitats.

Research Needs

- Identify specific areas of the landscape where connectivity is limited by a road and identify options for increasing safe passage of wildlife
- Identify significant travel corridors for species of concern to provide guidance to transportation planners

- Monitor (e.g., with radio-telemetry, remote cameras, or mark-recapture) wildlife populations in areas where underpass systems have been installed or are proposed, to evaluate success
- Expand collection of road-killed data. Currently, the only species monitored are deer, bear, moose and turkey. Data collection could make use of volunteers (e.g., Reptile and Amphibian Reporting Program) and those likely to encounter road kill (New Hampshire Department of Transportation road agents).
- Evaluate road design, roadside habitat management and road placement so that it is least detrimental to significant natural resources.
- Identify populations of SGCN (e.g., reptiles, New England cottontail) occupying utility and service corridors to inform management.

Table 4-20. Habitats and species at highest risk from the effects of transportation & service corridors (threats ranking as *Low* not included here). IUCN Level 2 provided if evaluated to that level. Some habitats and species were evaluated for multiple specific threats separately and therefore listed multiple times below. Airport management was not listed as option during threat assessment so these were included as 'Not Specified'. See Appendix E for additional information on specific threats and rankings.

Habitat	IUCN Level 2	Overall Threat Score
Appalachian Oak Pine Forest	Roads & railroads	M
Coldwater rivers and streams	Roads & railroads	H
Dunes	Shipping lanes	M
Estuarine	Shipping lanes	M
Floodplain Forests	Roads & railroads	M
Grasslands	Not Specified	M
Marine	Shipping lanes	M
Marsh and Shrub Wetlands	Roads & railroads	H
Temperate Swamp	Roads & railroads	M
Vernal Pools	Roads & railroads	H
Warmwater rivers and streams	Roads & railroads	H

Common Name	IUCN Level 2	Overall Threat Score
American Brook Lamprey	Roads & railroads	H
Bald Eagle	Roads & railroads	M
Blanding's Turtle	Roads & railroads	H
Box Turtle	Roads & railroads	M
Brook Trout	Roads & railroads	M
Cerulean Warbler	Roads & railroads	M
Eastern Meadowlark	Not Specified	M
Fin Whale	Shipping lanes	M
Fowlers Toad	Roads & railroads	M
Frosted Elfin	Not Specified	M
Grasshopper Sparrow	Not Specified	M
Hognose Snake	Roads & railroads	M
Horned Lark	Not Specified	M
Humpback whale	Shipping lanes	M

Jefferson/Blue-Spotted Salamander Complex	Roads & railroads	M
Karner Blue Butterfly	Not Specified	M
Karner Blue Butterfly	Roads & railroads	M
Marbled Salamander	Roads & railroads	M
North Atlantic Right Whale	Shipping lanes	M
Northern black racer	Roads & railroads	M
Northern black racer	Utility & service lines	M
Northern Leopard Frog	Roads & railroads	M
Redfin Pickerel	Roads & railroads	M
Ribbon snake	Roads & railroads	M
Softshell Clam	Shipping lanes	M
Spotted Turtle	Roads & railroads	H
Timber Rattlesnake	Roads & railroads	M
Upland Sandpiper	Not Specified	H
Vesper Sparrow	Not Specified	M
Wood Turtle	Roads & railroads	H

Literature Cited

Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: a review. Australian Zoologist 26:130-141.

Askins, R. A., C. M. Folsom-O'Keefe, and M. C. Hardy. 2012. Effects of vegetation, corridor width and regional land use on early successional birds on powerline corridors. PLoS ONE.

Beaudry, F., P. G. deMaynadier, and M. L. Hunter Jr. 2008. Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. Biological Conservation 141:2550-2583.

Boyd, S. E., D. S. Limpenny, H. L. Rees, and K. M. Cooper. 2005. The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging). ICES Journal of Marine Science: Journal du Conseil 62:145-162.

Fahrig, L., J.H. Pedlar, S.E. Pope, P.D. Taylor, and J.F. Wenger. 1995. Effect of road traffic on amphibian density. Biological Conservation 73:177-182.

Fahrig, L. 2002. Effect of habitat fragmentation on the extinction threshold: a synthesis. Ecological Applications 12:346-353.

Fahrig, L. and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Pages 1-20 Ecology and Society.

Forman, R.T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology. 14:31-35.

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

Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P. Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R. France, R. France, C.R. Goldman, K. Heanue, J.A. Jones, F.J. Swanson, T. Turrentine, and T.C. Winter. 2003. Road Ecology Science and Solutions. Island Press, Washington, D.C., USA.

Gibbs, J.P., and D.A. Steen. 2005. Trends in sex ratios of turtles in the United States: Implications of road mortality. Conservation Biology 19:552-556.

Jackson, S.D. 2003. Ecological considerations in the design of river and stream crossings. In 2003 Proceedings of the International Conference on Ecology and Transportation, edited by C. L. Irwin, P. Garrett, and K. P. McDermott. Raleigh, North Carolina: Center for transportation and the environment, North Carolina State University, North Carolina, USA.

Jensen, A. S. and G. K. Silber. 2004. Large whale ship strike database. US Department of Commerce, National Oceanic and Atmospheric Administration.

Johnson, K. M. 2012. New Hampshire Demographic Trends in the Twenty-First Century. Carsey Institute, University of New Hampshire.

Jones, J.A., F.J. Swanson, B.C. Wemple, and K.U. Snyder. 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. Conservation Biology 14:76-85.

Klemens, M.W. 2000. Turtle Conservation. Smithsonian Institution Press, Washington, D.C., USA.

Marchand, M.N. and J.A. Litvaitis. 2004. Effects of habitat features and landscape composition on the population structure of a common aquatic turtle in a region undergoing rapid development. Conservation Biology 18:758-767.

Patrick, D. A. and J. P. Gibbs. 2010. Population structure and movements of freshwater turtles across a road-density gradient. Landscape Ecology 25:791-801.

Patrick, D. A., J. P. Gibbs, V. D. Popescu, and D. A. Nelson. 2012. Multi-scale habitat-resistance models for predicting road mortality "hotspots" for turtles and amphibians. Herpetological Conservation and Biology 7:407-426.

Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5:18-32.

Society for the Protection of New Hampshire Forests. 2005. New Hampshire's Changing Landscape. Population growth and land use changes: what they mean for the Granite State. Executive Summary. Concord, New Hampshire, USA.

Thrush, S. F. and P. K. Dayton. 2002. Disturbance to marine benthic habitats by trawling and dredging: implications for marine biodiversity. Annual Review of Ecology and Systemtics 33:449-473.

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.