Acid Deposition

1. DEFINITION

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. In New Hampshire, vehicles generate 51% of nitrogen oxide emissions, while power plants generate 90% of sulfur oxide emissions and 39% of nitrogen emissions. However, much of the acid deposition comes from industrial areas in the midwestern and southwestern United States (NH Comparative Risk Project 1997). The estimated acidity (pH) of rainfall in 1997 for the Northeast ranged from 4.3-4.7 (Driscoll et al. 2001); 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.

2. EXPERT OPINION

Acid deposition may have critical effects on species and habitats of conservation concern in New Hampshire (Table 4-4). 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.

TABLE 4-4. Number of habitats and species at highest risk due to acid deposition. See Table 4-5 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	0
3	3	1
2	5	9
1	11	4

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Aquatic ecosystems

Low pH affects nearly all levels of the aquatic food web—including bacteria, fungi, algae, zooplankton, invertebrates, fish, and birds. At the individual level, chronic acidity affects embryonic development, growth, metabolism, respiration, reproduction, and survival. Community-level effects include shifts in species composition, community structure, and predator-prey interactions. Ecosystem processes such as decomposition of organic matter, primary productivity, and secondary production are strongly affected by pH (Haines 1981, Schindler et al. 1985).

Many species of aquatic organisms are sensitive to changes in pH. Aquatic insect diversity and abundance often declines in acidified lakes and streams (Haines 1981, Okland and Okland 1986). Crustaceans and molluscs 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 mortal-

TABLE 4-5. Habitats and species at highest risk from effects of acid deposition, in descending order by Rank. Eastern brook trout is the only fish shown because of the volume of information available. Assessments for other species are currently being reviewed. See Appendix A and B for additional information on specific risk factors and rankings.

Species	Habitat	Ranking Scores* 1	2	3	4	5	Rank	Class
SPECIES								
Jefferson Salamander	Vernal Pools	4	3	4	2	4	2.92	3
Eastern Brook Trout	Aquatic	4	3	2	3	4	2.63	2
White Mountain Arctic	Alpine	4	3	2	2	4	2.33	2
White Mountain Fritillary	Alpine	4	3	2	2	4	2.33	2
Rusty Blackbird	Lowland Spruce-Fir Forest	3	3	4	2.5	2	2.13	2
American Marten	High Elevation Spruce-Fir Forest	4	3	1	3	3	2.04	2
Spruce Grouse	Lowland Spruce-Fir Forest	4	3	1	3	3	2.04	2
Bicknell's Thrush	High Elevation Spruce-Fir Forest	4	2	2	3	3	2.00	2
Common Loon	Aquatic	2	4	2	2	4	2.00	2
Three-toed Woodpecker	Lowland Spruce-Fir Forest	4	2	2	3	3	2.00	2
HABITATS								
	Alpine	4	3	2	3	4	2.63	3
	High Elevation Spruce-Fir Forest	4	3	2	3	4	2.63	3
	Northern Hardwood-Conifer Forest	4	3	2	3	4	2.63	3
	Montane Watersheds	4	3	1	3	4	2.33	2
	Talus Slopes and Rocky Ridges	4	3	2	2	4	2.33	2
	Vernal Pools	4	3	4	2	2	2.33	2
	Hemlock-Hardwood-Pine Forest	4	2	2	3	4	2.25	2
	Lowland Spruce Fir Forest	4	2	2	3	4	2.25	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

ity (Haines 1981, Schindler 1988, Baker et al. 1996).

Through reduction in aquatic community diversity and biomass as discussed above, organisms at higher trophic levels may not be able to forage or reproduce effectively in acidified water bodies. Diet and foraging efficiency of some fish species may be affected by acid-induced changes in zooplankton community structure. Waterfowl and other birds that forage on aquatic invertebrates or fish might also be affected, including American bittern, common loon, American black duck, and rusty blackbird (Longcore et al. 1987, Rattner et al. 1987).

(B) Terrestrial ecosystems

Terrestrial plant productivity and health can be severely affected by acid deposition. Vegetation in high-elevation spruce-fir forests, alpine habitats, talus slope/rocky ridge habitats, and cliffs 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 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. Nitrogen saturation is one impact of acid deposition that may have cascading effects within New Hampshire's terrestrial ecosystems on plant communities and wildlife habitat.

(C) Mobilization of heavy metals

An indirect effect of acidification may be increased bioavailability of toxic metals including mercury, aluminum, cadmium, and lead (Haines 1981, Schindler 1988, Spry and Weiner 1991). Mercury methylation is enhanced under acidic conditions, and methylmercury is one of the more pervasive and acute threats in New Hampshire. Acidity mobilizes aluminum that damages roots and contributes to soil infertility. Aluminum is acutely toxic to aquatic invertebrates and fish.

4. RESEARCH NEEDS

Given that the effects of acid deposition on species and habitats are generally well documented, relatively few research needs have been identified. On the broad scale, examples of potential topics include shifts in alpine community composition, while more focused studies could include investigation of prey availability for rusty blackbirds. Additional research may be relevant to determine the efficacy of any proposed mitigation measures.

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Agriculture

1. DEFINITION

Wildlife that depend on grassland habitats existed in pre-settlement New England in low numbers and increased as early settlers cleared the land for farming. Natural processes—such as fire, beaver activity, and flooding—maintained grassy areas prior to human settlement. As some natural disturbances have declined in the last 150 years, grassland species have become more reliant on remaining agricultural lands making them increasingly vulnerable to commonly used agricultural practices and loss of active farms.

Currently there are 101,175 ha of farmland in New Hampshire (United States Department of Agriculture 2004), mainly in Grafton, Merrimack, and Coos Counties. Wildlife species that use agricultural fields are vulnerable to mowing for hay, and converting fields to developments. Mowing can result in significant mortality to grassland birds (eggs and chicks), snakes, and turtles.

2. EXPERT OPINION

Most of the grasslands in New Hampshire are the direct result of the positive influence that agriculture has had on grassland-dependent species by clearing forested areas and maintaining them in an open state. At the same time, because of the limited distribution of these habitats, some agricultural practices pose a threat to these grassland species. Mowing practices, such as haying before July 15 (which we acknowledge is necessary to maximize forage quality), are in use throughout the state and present a threat to grassland nesting species such as the upland sandpiper and northern harrier. Collisions with mowing equipment can cause mortality for black racer, smooth green snake, wood turtle, Blanding's turtle, and spotted turtle, though impacts to populations are poorly documented. In a very localized area, mowing of salt marshes is a serious, short-term threat to Nelson's sharp-tailed sparrow, salt marsh sharp-tailed sparrow, seaside sparrow, and willet. Reductions of populations of grassland-dependent species is possible in the next 1 to 5 years. Run-off of herbicides, pesticides and fertilizers from agricultural lands in the Connecticut River watershed may pose a threat to aquatic habitat (Francis and Mulligan 1997).

TABLE 4-6. Number of habitats and species at highest risk due to agriculture. See Table 4-7 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	1	0
3	1	0
2	0	2
1	8	11

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Hay Cropping

Hay cropping can kill grassland birds, turtles, and snakes. Reproduction in grassland birds 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). Farmers mow their hayfields 2 to 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. Direct mortality of wood turtles caused by collision with farm machinery has been documented in agricultural fields where turtles seek exposed soils for nesting (Saumure and Bider 1998).

(B) Habitat Conversion

The conversion of agricultural fields to development has been significant. For instance, active agricultural land acreage dropped by 50% in Rockingham and

TABLE 4-7. Habitats and species at highest risk from effects of agriculture, in descending order by Rank. See Appendix A and B for additional information on specific threats and rankings.

Species	Habitat	Ranking Scores* 1	2	3	4	5	Rank	Class
SPECIES								
Upland Sandpiper	Shrublands	3	3	3	3	4	2.50	2
Grasshopper Sparrow	Grasslands	3	3	3	3	4	2.50	2
HABITATS								
	Grasslands	4	4	4	4	4	4.00	4
	Connecticut River Mainstem Watersheds	3	3	4	3	4	2.75	3

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

Strafford Counties between 1962 and 1998 (*see Development*). Historical conversion of floodplains for agriculture also has been significant. However, it is unlikely that floodplain habitat will be lost to agriculture in the future, and there are many opportunities to restore floodplains. The loss of agriculture to other non-grassland habitat uses reduces the amount of potential quality habitat available to grassland-dependent species.

(C) Pesticides and Runoff

See Non-point Source Pollution.

4. RESEARCH NEEDS

- Demographic studies to determine causes of grassland wildlife population declines
- Assess which extensive grasslands are important to grassland nesting birds and other priority wildlife species, and which of these species is harmed by early mowing. This likely requires more field surveys of nesting birds and other wildlife in large grasslands
- Collect data on species distribution (e.g., upland sandpipers, northern harriers, grasshopper sparrows) and land use, including frequency and timing of mowing, rates of habitat loss to development, and overall changes to landscape composition (including field size distributions). Such data could be useful in determining the potential for re-colonization of historic breeding sites where appropriate management could be implemented
- Identify and assess threats (e.g., land use practices in agricultural areas) to specific wood turtle populations.
- Determine value of Farm Bill programs in conservation of grassland wildlife

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Altered Hydrology

1. DEFINITION

The frequency and intensity of floods or droughts strongly influences the physical and biological characteristics of aquatic ecosystems (Poff et al. 1997). Plants and wildlife in riparian areas have adapted to natural variation in flows and water levels. Periodic flooding provides fish and amphibians with access to spawning areas, causes an influx of organic matter to streams, and prevents the encroachment of upland plant species into wetland habitats (Poff et al. 1997). Impoundments and water level fluctuation above and below dams, restricted tidal flows, water withdrawal for irrigation and other uses, increased impervious surface area, and seasonal lake drawdowns alter natural hydrology (Richter et al. 1996). Hydrologic alteration can profoundly affect stream connectivity and the ability of fish and wildlife to migrate freely along a stream corridor.

2. EXPERT OPINION

Altered hydrology affects species and habitats throughout New Hampshire. Impacts can be serious and immediate, especially for relatively small populations or habitats (e.g. tiger cobblestone beetles and salt marshes). In general, more densely populated, lower elevation watersheds are more affected by altered hydrology than are high elevation and northern watersheds. While the overall effects of altered hydrology on aquatic ecosystems are well documented, species-specific impacts are poorly understood.

TABLE 4-8. Number of habitats and species at highest risk due to altered hydrology. See Table 4-9 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	1
3	1	5
2	7	4
1	9	11

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Man-made Dams

Dams cause changes in water temperature, transparency, substrate composition, and flow, all of which influence biological communities. Increased flows below impoundments may result in high sediment loads, suffocating fish and invertebrates and altering spawning substrates (Baxter and Glaude 1980). The leaching of plant nutrients and toxic substances (e.g. mercury) from flooded soils upstream of dams 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 near the dam (Baxter and Glaude 1980). Fluctuating water levels upstream and downstream from dams on the Connecticut River pose a threat to cobblestone tiger beetles by inundating their habitat more frequently than natural flooding events (Nothnagle 1993). Water level management for hydropower or flood control on high order rivers may decrease the frequency and intensity of flooding events needed to maintain floodplain forest communities (Bornette and Amoros 1996; see Altered Natural Disturbance Regime). Dams restrict the movements of aquatic species, especially anadromous fish, which migrate upstream to spawn, and freshwater mussels, which depend on fish for dispersal and development.

(B) Development

Flow regimes are altered by channelization, stream bank stabilization, construction fill, and road or railroad crossings. The effects are most obvious in coastal salt marshes where development and drainage ditches

TABLE 4-9. Habitats and species at highest risk from effects of altered hydrology, in descending order by Rank. Atlantic salmon is the only fish shown because of the volume of information available and recent initiatives to restore the species. Assessments for other species are currently being reviewed. See Appendix A and B for additional information on specific risk factors and rankings.

Species	Habitat	Ranking Scores* 1	2	3	4	5	Rank	Class
SPECIES								
Atlantic Salmon	Aquatic	4	4	4	4	4	4.00	4
Dwarf Wedgemussel	Aquatic	3	3	4	4	4	3.00	3
Nelson's Sharp-tailed Sparrow	Salt Marshes	3	3	4	4	4	3.00	3
Saltmarsh Sharp-tailed Sparrow	Salt Marshes	3	3	4	4	4	3.00	3
Seaside Sparrow	Salt Marshes	3	3	4	4	4	3.00	3
Willet	Salt Marshes	3	3	4	4	4	3.00	3
Brook Floater	Aquatic	2	3	4	4	4	2.50	2
Blandings Turtle	Marsh and Shrub Wetlands	2	3	4	3	3	2.08	2
Cobblestone Tiger Beetle	Aquatic	4	4	2	2	2	2.00	2
Pied-billed Grebe	Marsh and Shrub Wetlands	2	3	4	2	3	1.88	2
HABITATS								
	Salt Marshes	3	3	4	4	4	3.00	3
	Tidal Coastal Watersheds	3	3	4	3	3	2.50	2
	Non-Tidal Coastal Watersheds	3	3	4	3	3	2.50	2
	Connecticut River Mainstem Watersheds	3	3	2	4	4	2.50	2
	Coastal Transitional Watersheds	3	3	4	3	3	2.50	2
	Floodplain Forests	4	3	2	3	3	2.33	2
	Southern Upland Watersheds	2	3	4	3	3	2.08	2
	Peatlands	2	3	3	3	3	1.88	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

have restricted tidal flooding. Without tidal influence, typical salt marsh vegetation is replaced with invasive reeds and grasses (Sinicrope et al. 1990). River bank stabilization restricts the dynamic nature of a river and often causes erosion problems downstream. Culverts at road crossings also alter natural hydrological patterns by constricting and channeling flow. Culverts reduce stream connectivity, acting as dispersal barriers to fish, amphibians, and some invertebrates (Watters 1996, Warren and Pardew 1999).

(C) Seasonal draw-down

Water levels in some New Hampshire lakes and ponds are reduced in the fall to prevent ice damage and reduce spring flooding. Drawdowns ranging from 1 to 10 feet occurred in 53 lakes and ponds in the fall of 2004 (New Hampshire Department of Environmental Services 2003). Artificially low water levels subject shoreline communities to freezing temperatures and interfere with the spring spawning activity of fish and amphibians. Reduced water levels decrease the habitat available to reef spawning fish, and lowering water levels after spawning may expose eggs to desiccation (Anras et al.1999). Significant changes in water level during the breeding season of shoreline nesting birds may flood nests or increase predation risk.

(D) Impervious surfaces

A landscape with a significant area of impervious surfaces can cause shorter, more intense flood periods, which alter stream morphology and potentially kill or inhibit the movement of some species (United States

Environmental Protection Agency 2003). Impervious surfaces prevent rainwater from replenishing groundwater, which is the primary source of water for small streams and wetlands during the summer.

(E) Water withdrawal

Water withdrawal for irrigation, municipal water supplies, or industry 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 reenter aquatic systems, containing increased nutrient levels (Baxter and Glaude 1980). Low summer flows modify invertebrate and fish communities to favor generalist species. Unusually low summer flows in the Ipswich River in Massachusetts have resulted in a high proportion of generalist fish species (Massachusetts Executive Office of Environmental Affairs 2004).

4. 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 drawdowns on species diversity in aquatic habitats
- Investigate the potential correlation between drawdown and methyl mercury production

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Altered Natural Disturbance Regime

1. DEFINITION

Before European settlement, forested habitats were continuously altered by disturbances such as wildfire, beaver impoundments, Native American burning, agriculture, flooding, erosion and deposition, insect outbreaks, hurricanes, and openings created by massive passenger pigeon breeding colonies. Now, the effects of some of these natural agents of forest disturbance are substantially lessened (DeGraaf et al. 2005).

Centuries of land use and reduction of many natural disturbances have created a landscape of relatively homogenous, middle-aged to mature forest of similar size and structure amidst cities, suburbs, and highways and relatively little grassland, shrubland, or young forest habitat (DeGraaf et al. 2005). Pitch pine barrens, a critical habitat that supports a large number of rare and declining species, and Appalachian oak-pine forests are particularly vulnerable to altered natural disturbance regimes. To maintain the native diversity of wildlife on the New Hampshire landscape, including at-risk and rare species, habitat management and restoration are needed (DeGraaf et al. 2005).

2. EXPERT OPINION

Altered natural disturbance regimes critically impact pine barrens, Appalachian oak pine forests, and shrubland habitats and related species (e.g., Karner blue butterfly) and seriously affect species dependant on young forest habitats including American woodcock and ruffed grouse. To a lesser degree they also affect grasslands habitat and associated species (e.g., northern harrier, upland sandpiper, and grasshopper sparrow), as well as Blanding's and spotted turtles that use both grassland and shrubland habitats for nesting.

TABLE 4-10. Number of habitats and species at highest risk due to altered natural disturbance regimes. See Table 4-11 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	1	0
3	4	1
2	2	4
1	2	14

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Mechanical ecological processes

Fire, beaver, and passenger pigeon roosting are among the mechanical ecological processes that once had a significant impact on New Hampshire's landscape. The decline, and in some cases the cessation of these natural disturbances, combined with habitat loss due to development, is reducing some critical habitats to levels at or below historical levels (e.g., grasslands, shrublands, young forests, pine barrens, and Appalachian oak-pine forests) (Brooks 2003, Litvaitis 2003).

For instance, fire suppression may alter the community structure of fire-adapted habitats by reducing the establishment of seeds that prefer bare mineral soil, and by increasing competition with fire tolerant species. Fire suppression has led to the succession of most of New Hampshire's remaining pine barrens to dense canopied forest that are becoming dominated by white pine and/or hardwoods (e.g., oak, red maple, and aspen). These conditions are ill suited for a large suite of rare and declining species (e.g., Karner blue butterfly, Persius duskywing skippers, and Fowler's toad) (Grundel 1998, VanLuven 1994). Fire suppression also can allow a dangerous accumulation of fuel load (duff, litter, dead wood), and subsequent fires can be intense enough to kill large number of animals and significantly threaten human safety.

The passenger pigeon, considered to have been

TABLE 4-11. Habitats and species at highest risk from effects of altered natural disturbance regimes, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores*					Rank	Class
		1	2	3	4	5		
SPECIES								
Karner Blue Butterfly	Pine Barrens	4	3	3	3	4	2.92	3
American Woodcock	Shrublands	3	3	3	3	4	2.50	2
Ruffed Grouse	Shrublands	3	3	3	3	4	2.50	2
Racer	Pine Barrens	4	4	2	3	1	2.00	2
Whip-poor Will	Pine Barrens	3	2	3	3	3	1.88	2
HABITATS								
	Pine Barrens	4	4	4	3	4	3.67	4
	Appalachian Oak Pine Forest	4	3	4	3	3	2.92	3
	Hemlock-Hardwood-Pine Forest	3	3	4	3	4	2.75	3
	Lowland Spruce Fir Forest	4	3	3	3	3.4	2.74	3
	Shrublands	3	4	3	3	3	2.63	3
	Northern Hardwood-Conifer Forest	2	3	4	3	3	2.08	2
	Talus Slopes and Rocky Ridges	4	3	1	3	3	2.04	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

North America's most abundant land bird in historical times (e.g. flocks of 1 to 2 billion birds), also occurred in high numbers in New Hampshire (Foss 1994). High densities of roosting pigeons toppled small trees and broke off branches, increasing the amount of sunlight reaching the forest floor and perhaps exacerbating wildfires (Ellsworth and McComb 2003). Both conditions would have favored the maintenance of Appalachian oak-pine forest, pine barrens, grasslands, and shrublands, all of which were more abundant historically than they are today (Brooks 2003, Ellsworth and McComb 2003). Based on recent research, 2-6% of the state may have been affected annually (Ellsworth and McComb 2003).

(B) Chemical ecological processes

Fire and flooding events result in chemical processes that alter species composition in a variety of ways. Fire generates readily available nutrients, creates a blackened ground surface that increases soil temperatures and enhances nutrient cycling, and reduces competition with other plants (Brown and Smith 2000). These factors, coupled with pitch pine's post-fire ability to re-sprout and drop seeds, aids in the maintenance of pine barrens communities (Brown and Smith 2000).

Flooding provides a regular source of nutrients for floodplain areas (Osgood 1996, Wistendahl 1958). Floodplain soils tend to be rich in nutrients and have been targeted throughout history as excellent lands for agriculture (Nichols et al. 2000). With nearly 5,000 man-made dams in New Hampshire, many floodplains now do not benefit from these added nutrients.

(C) Hydrological processes

Seasonal flooding and flooding by beavers are hydrological processes that also had a more significant impact historically than today. Seasonal flooding of high order or high gradient rivers was a regular natural disturbance. This disturbance maintained the conditions suited to many types of floodplain forests (Bornette and Amoros 1996). Today, there are nearly 5,000 man-made dams in New Hampshire. Many of these dams inhibit the frequency and intensity of floods on high-order or high-gradient rivers (Nislow and Magilligan 2000), resulting in reduced species and structural diversity of floodplain vegetation and reduced diversity of wildlife using floodplain areas (Nilsson et al. 1997).

Unlike man-made dams, beaver dams are generally constructed on low order or low gradient streams. This form of natural disturbance creates marshes, meadows, and shrublands beneficial to many species of wildlife. After a beaver dam degrades and becomes breeched after abandonment, the previously ponded area succeeds to a meadow and without further disturbance will succeed into shrubland, and eventually back to forest (Naiman et al. 1988). However, areas available for damming by beavers has declined significantly. An analysis of wet flats in New Hampshire (the floodplain that would be affected by beavers) shows that nearly 30% (267 out of 961) are affected by agriculture. Another 17% (165 out of 961) are affected by development (CSRC 2002, TNC 2003).

4. RESEARCH NEEDS

- 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 and relative abundance and distribution of pine barrens, grasslands, and shrublands
- Investigate impacts of beaver population level changes on natural communities and habitat distribution

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Climate Change

1. DEFINITION

Natural variations in global climate occur over very long periods. Human activities influence the global climate by increasing atmospheric concentrations of carbon dioxide, methane, CFCs, and nitrous oxide that trap heat at the earth's surface (Firor 1990, Gates 1993). Human induced climate change is likely to profoundly affect the climatology, ecosystems, and native biodiversity of New Hampshire and the region (IPCC 2001, New England Regional Assessment (NERA) 2001, Nedeau 2004).

The greatest effects of climate change will be on regional air and water temperatures, precipitation patterns, storm intensity, and sea levels. These types of changes have been well documented already (NERA 2001, Wake and Markham 2005), and global climate models are in general agreement that trends will continue and even accelerate in the next century (IPCC 2001). The ten hottest years of the last millennium have all occurred since 1983 (NERA 2001), and regional climate change models predict a 6.0-10.0 F temperature increase in the next century in New England, which would make our climate comparable to portions of the southeastern United States.

Because of their complex nature, broad patterns of change are still difficult to predict. Climatic changes have been linked to local ecological changes, including range shifts and asynchrony with seasonal habitat requirements. Not every species is obviously threatened by climate change. But no ecosystem can sustain the breadth of changes likely to result from climate change without harm to many taxa.

TABLE 4-12. Number of habitats and species at highest risk due to climate change. See Table 4-13 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	0
3	1	2
2	7	7
1	3	6

2. EXPERT OPINION

Climate change will broadly affect every species and habitat of conservation concern in New Hampshire. Impacts will likely be most severe for habitats with narrow temperature and water level regimes, such as alpine, high and low elevation spruce-fir forests, coastal islands, vernal pools, and aquatic habitats. For some animals, changing snow depths (e.g., American marten and lynx) and high altitude seasonal timing (e.g., alpine butterflies) may begin to have impacts during the next decade. Thermal habitat of New Hampshire's native fishes will likely decline substantially. Invasive species, diseases, and pathogens will likely become more problematic, as warmer regional temperatures facilitate their introduction and proliferation. High altitude and coastal impacts are fairly well documented.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) 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). 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). Snow depth and frequency are important factors affecting distribution of American marten (Krohn et al. 1995, Raine 1983) and lynx (Hoving et al. 2005). Changes to lake ice duration and surface water temperatures will strongly affect primary productivity, dissolved

TABLE 4-13. Habitats and species at highest risk from effects of climate change, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores* 1	2	3	4	5	Rank	Class
SPECIES								
White Mountain Arctic	Alpine	4	3	2	3	4	2.63	3
White Mountain Fritillary	Alpine	4	3	2	3	4	2.63	3
Lynx	Upland Forests	4	4	2	2	3	2.33	2
American Marten	High Elevation Spruce-Fir Forest	4	3	2	3	3	2.33	2
Common Tern	Coastal Islands	4	3	2	3	2	2.04	2
Piping Plover	Dunes	4	3	2	3	2	2.04	2
Roseate Tern	Coastal Islands	4	3	2	3	2	2.04	2
Spruce Grouse	Lowland Spruce-Fir Forest	4	3	1	3	3	2.04	2
Common Loon	Aquatic	4	4	1	3	2	2.00	2
HABITATS								
	Alpine	4	4	2	3	4	3.00	3
	High Elevation Spruce-Fir Forest	4	4	1	3	3	2.33	2
	Hemlock-Hardwood-Pine Forest	4	3	1	3	4	2.33	2
	Northern Hardwood-Conifer Forest	4	3	1	3	4	2.33	2
	Talus Slopes and Rocky Ridges	4	3	2	2	4	2.33	2
	Coastal Islands	4	3	1	3	3	2.04	2
	Dunes	4	3	1	3	3	2.04	2
	Lowland Spruce Fir Forest	4	3	1	3	3	2.04	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

oxygen, thermal habitat, and invertebrate and fish communities.

(B) Seasonality

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). 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).

(C) Shifts in forest communities and wildlife

The southern range of cold-adapted forest trees—such as spruce, fir, aspen, and sugar maple—will likely retreat northward, dramatically altering the composition of New Hampshire's northern and high-elevation forests and dependant wildlife species. Forest damage—resulting from increased storm intensity, warmer periods, droughts, and damaging ozone—will stress many forest communities.

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. Alpine herbaceous communities are strongly affected by climate change (Walker et al. 1995, Kimball and Weihrauch 2000, Lessica and McCune 2004, Sperduto and Nichols 2004). Walther (2002) has documented climate-related elevation shift of alpine plants, rising tree line, and northward range shifts of 39 butterfly species. For *Boloria titania montinus* and *Oeneis melissa semidea*, the combination of climate change and isolation will likely result in local extirpation without a northward range shift (e.g., extinction).

(D) 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 cold-water fish will be replaced by warm-water 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. Marine productivity—and thus marine fisheries—may be affected by changes in thermohaline circulation of coastal waters, a changing thermal regime, and reduced oxygen availability.

(E) Climate volatility and storms

Climate models predict an increase in the frequency and intensity of coastal storms. Besides fundamentally changing the climate of important habitats, storm cycles can introduce new threats to animals. Inclement weather can disrupt bird migrations and make breeding and nesting sites inhospitable, forcing birds into marginal habitats. Similarly, storms batter coastal ecosystems, disrupting dunes, salt marshes, and estuaries, and bringing additional stress to species living there (Michener et al. 1997). Nesting plovers, saltmarsh birds, and colonial seabirds are highly susceptible to storms.

(F) Rising sea level

Sea level in the United States is rising 2.5 to 3.0 mm/yr. Global warming could raise the sea level 15 cm by 2050 and 34 cm by 2100 (Titus and Narayanan 1995, Titus 1990). Under this scenario, low elevation coastal habitats will likely be flooded or overwashed more frequently by storm surges (Gulf of Maine Council Habitat Restoration Subcommittee 2004). These 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). Sea level rise will destroy dunes, salt marshes, and their associated species, negating any current protection efforts (Simas et al. 2001).

(G) 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 Portsmouth, New Hampshire. Loss of hemlock would have dramatic effects on forest composition, wildlife habitat, and ecosystem processes in terrestrial and aquatic ecosystems. 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.

4. RESEARCH NEEDS

- Monitor indicators of range shifts of alpine lepidoptera and habitat plants
- Monitor impacts of decreased snow depth on marten and lynx
- Study impacts of early ice release on aquatic communities
- Monitor effect of storms and rising sea levels on coastal habitats, such as dunes, salt marshes, and lower tidal watersheds, as well as on their associated species

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Development

1. DEFINITION

Development includes residential, commercial, and industrial construction, mining extraction operations, and recreational areas (e.g., ski areas, athletic fields). Human population growth, property values, and local land planning vary between towns and regions. Activities associated with development often result in the loss or fragmentation of wildlife habitats and direct wildlife mortality during or after construction. Some effects are subtle; light pollution can distract or disorient moths, or expose terrestrial animals to predation. Indirect effects of development, including altered hydrology, introduced species, pollutants, non-point source pollution, transportation infrastructure, recreational use, and predation are discussed independently.

2. EXPERT OPINION

All habitats and species are affected by development to varying degrees. New Hampshire's human population is rapidly expanding, especially in the south, and those species restricted to southern New Hampshire are at immediate risk.

Development is a widespread threat to wetland and terrestrial habitats and species. Species or habitats with a limited distribution, restricted habitat requirements, and/or low population sizes are at greatest risk. Effects can be extensive and critical for some species (e.g., timber rattlesnake, New England cottontail, Karner blue butterfly, Blanding's and spotted turtles, common loon, Jefferson salamander, and salt marsh birds). Development of uplands surrounding salt marshes, freshwater marshes, shrub wetlands, and vernal pools is likely to be extensive and critical. Impacts will be chronic or serious for forest habitats, watersheds, and area-sensitive species. Impacts are generally well documented.

TABLE 4-14. Number of habitats and species at highest risk due to development. See Table 4-15 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	9	10
3	3	17
2	9	7
1	10	22

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Rapid population growth

New Hampshire's population grew by 17% between 1990 and 2004, twice the rate of other New England states (Society for the Protection of New Hampshire Forests 2005). Previously undeveloped land is being subdivided and developed to meet growing demands for housing and services at a rate of nearly 6,900 ha per year.

Rising land values contribute to development, since high property values limit the amount of land that can be protected with existing funds. Currently, 28% of New Hampshire's land area is protected, and only 25% of protected land area is in the southern half of the state, where development is most intense and land values are highest (Society for the Protection of New Hampshire Forests 2005). Southern New Hampshire also harbors the greatest diversity of the state's wildlife, including many rare or endangered species. At the current rate of protection and development, many more species will likely become rare, and several species may become extirpated. Some species are at greater risk due to limited distribution, low population densities (e.g., Karner blue butterfly, timber rattlesnake), life history characteristics (e.g., high adult survivorship, late age of maturity, large home ranges), or ease of development (e.g., pitch-pine barrens).

TABLE 4-15. Habitats and species at highest risk from effects of development, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

		Ranking Scores*						
Species	Habitat	1	2	3	4	5	Rank	Class
SPECIES								
Common Loon	Aquatic	4	4	4	4	4	4.00	4
Karner Blue Butterfly	Pine Barrens	4	4	4	4	4	4.00	4
Nelson's Sharp-tailed Sparrow	Salt Marshes	4	4	4	4	4	4.00	4
Northern Leopard Frog	Grasslands	4	4	4	4	4	4.00	4
Saltmarsh Sharp-tailed Sparrow	Salt Marshes	4	4	4	4	4	4.00	4
Seaside Sparrow	Salt Marshes	4	4	4	4	4	4.00	4
Willet	Salt Marshes	4	4	4	4	4	4.00	4
New England Cottontail	Shrublands	4	4	3	4	4	3.67	4
Jefferson Salamander	Vernal Pools	4	3	4	4	4	3.50	4
Timber Rattlesnake	Appalachian Oak Pine Forest	4	4	3	3	4	3.33	4
Fowlers Toad	Pine Barrens	4	3	3	4	4	3.21	3
Blandings Turtle	Marsh and Shrub Wetlands	4	4	3	3	3	3.00	3
Brook Floater	Aquatic	3	3	4	4	4	3.00	3
Common Tern	Coastal Islands	4	4	4	1	4	3.00	3
Dwarf Wedgemussel	Aquatic	3	3	4	4	4	3.00	3
Roseate Tern	Coastal Islands	4	4	4	1	4	3.00	3
Spotted Turtle	Marsh and Shrub Wetlands	4	4	2	3	4	3.00	3
Spruce Grouse	Lowland Spruce-Fir Forest	2	4	4	4	4	3.00	3
Wood Turtle	Floodplain Forests	4	4	2	3	4	3.00	3
American Marten	High Elevation Spruce-Fir Forest	3	4	3	4	3	2.92	3
Eastern Pondmussel	Aquatic	4	3	4	4	2	2.92	3
Whip-poor Will	Pine Barrens	4	3	4	3	3	2.92	3
Bald Eagle	Aquatic	3	3	4	3	4	2.75	3
Racer	Pine Barrens	4	4	2	3	3	2.67	3
American Woodcock	Shrublands	3	4	3	3	3	2.63	3
Hognose Snake	Pine Barrens	4	3	3	3	3	2.63	3
Non-breeding Birds		4	3	3	3	3	2.63	3
Ruffed Grouse	Shrublands	3	4	3	3	3	2.63	3
American Bittern	Marsh and Shrub Wetlands	1	4	4	4	4	2.50	2
Osprey	Marsh and Shrub Wetlands	3	3	4	3	3	2.50	2
Ringed Boghaunter	Peatlands	1	4	4	4	4	2.50	2
Sedge Wren	Marsh and Shrub Wetlands	1	4	4	4	4	2.50	2
Common Nighthawk	Pine Barrens	4	3	3	2	3	2.33	2
Northern Goshawk	Upland Forests	4	3	2	3	3	2.33	2
Piping Plover	Dunes	4	3	1	4	3	2.33	2
Red-shouldered Hawk	Floodplain Forests	3	2	4	3	4	2.29	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

TABLE 4-15. (continued)

Species	Habitat	Ranking Scores*					Rank	Class
		1	2	3	4	5		
HABITATS								
	Pine Barrens	4	4	4	4	4	4.00	4
	Salt Marshes	4	4	4	4	4	4.00	4
	Dunes	4	3	4	4	4	3.50	4
	Hemlock-Hardwood-Pine Forest	4	3	4	4	4	3.50	4
	Lowland Spruce Fir Forest	4	3	4	4	4	3.50	4
	Non-Tidal Coastal Watersheds	4	3	4	4	4	3.50	4
	Tidal Coastal Watersheds	4	3	4	4	4	3.50	4
	Vernal Pools	4	3	4	4	4	3.50	4
	Appalachian Oak Pine Forest	4	4	3	3	4	3.33	4
	Floodplain Forests	3	4	4	3	4	3.21	3
	Northern Hardwood-Conifer Forest	4	3	3	4	4	3.21	3
	Coastal Transitional Watersheds	3	3	4	3	3	2.50	2
	Connecticut River Mainstem Watersheds	3	3	2	4	4	2.50	2
	Marsh and Shrub Wetlands	1	4	4	4	4	2.50	2
	Peatlands	1	4	4	4	4	2.50	2
	Grasslands	4	4	2	2	3	2.33	2
	High Elevation Spruce-Fir Forest	1	4	4	3	4	2.29	2
	SShrublands	3	3	3	3	3	2.25	2
	Coastal Islands	3	3	3	2	4	2.25	2
	Southern Upland Watersheds	2	3	2	4	4	2.08	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

(B) Wetland draining and filling

Filling of freshwater or estuarine wetlands can cause immediate severe harm to local flora and fauna. New Hampshire still has the majority of its historic freshwater wetlands (Dahl 1990, 2000), whereas impacts to salt marshes in the region have been more extensive (Shriver et al. 2004). Currently, freshwater wetlands (see Marsh and Shrub Wetlands and Peatlands profiles), salt marshes, rivers, and streams are regulated by the New Hampshire Department of Environmental Services (NHDES) (RSA 482-A and Wetlands Bureau Administrative Rules). Vernal pools, although regulated by RSA 482-A, are vulnerable to filling because of their small size, ephemeral hydroperiod, and overlooked wildlife value. Landowners may remove beaver dams 'to protect private property' with little regulatory oversight.

The greatest threat to wetland habitats in New Hampshire is the development of surrounding uplands. Many wetland species require an intact upland buffer for nesting (e.g., American black duck, turtles), foraging (e.g., Jefferson salamander, Fowler's toad, odonates), dispersal (e.g., Blanding's and spotted turtles), and hibernation (e.g., Jefferson salamander) (Semlitsch and Bodie 2003). Current state regulations do not require development setbacks from wetlands, unless designated as a Prime wetland by the town. Town zoning and wetland regulations vary considerably.

Shoreline development reduces habitat quality for wildlife through vegetative modification or removal, pollution, creation of structures in close proximity to nesting or wintering sites, increased predator densities and human activity, and, potentially, declines in reproductive success and local population numbers (Alvo 1981, Dahmer 1986, McIntyre 1988, Buehler 2000). The Comprehensive Shoreland Protection Act (RSA 483-B) regulates shoreline cutting and development of major rivers and large surface bodies (larger than 10 ac); however, most of the smaller perennial tributaries receive no upland protection. Sites favored by nesting common loons and wintering and nesting bald eagles often are of prime development value and/or receive intense recreational use (K. Taylor, Loon Preservation Committee; C. Martin, NHA, personal communications). Removal of riparian vegetation reduces the habitat quality for wood turtles (Tuttle and Carroll 1997) and makes them more vulnerable to collection and predation.

(C) Unregulated upland development

Development of terrestrial habitats is largely unregulated by the state. Site-specific permits are required by the NHDES for impacts exceeding 0.93 ha, but this review is focused on storm water discharge, with little or no review of wildlife or rare natural community impacts. Approximately 7,000 ha of forestland have been lost annually in New Hampshire since the mid-1980s, largely because of development (Society for the Protection of New Hampshire Forests 2005). Among matrix forests, Appalachian oak pine forests and hemlock-hardwood forests appear to be at greatest risk. Ninety-five percent of predicted Appalachian oak pine forests occurred in Cheshire, Hillsborough, Rockingham, and Strafford Counties (New Hampshire Fish and Game GIS; C. Foss, NHA, personal communication), all areas experiencing heavy human population growth (SPNHF 2005). Pine barrens are at particular risk because of their limited distribution and because the soils they occur on are favorable for development. Early successional shrublands in southern New Hampshire are ephemeral but are rapidly being developed, leaving the New England cottontail at serious risk.

(D) Fragmentation

Habitat is fragmented when it is subdivided into increasingly smaller patches that are segregated from one another. Fragmentation of habitat has numerous and widespread impacts on wildlife populations and habitats, both aquatic and terrestrial (Saunders et al. 1991). As forests in New Hampshire are subdivided, ecological processes may be disrupted and edge effects may increase. Most pitch pine-scrub oak woodland communities have been fragmented into relatively small habitat patches (Howard et al. 2005), reducing the potential for large natural disturbances (especially fire) of sufficient frequency, intensity, and extent to maintain natural ecological processes (Wagner et al. 2003). Population level impacts from fragmentation are serious or critical for species requiring large areas of habitat (e.g., American marten, bobcat, lynx, timber rattlesnake, Blanding's turtle). Wetlands, including vernal pools, are becoming increasingly fragmented by development, especially in southern New Hampshire, making wetland dependent organisms vulnerable. Where these species must disperse through inhospitable habitat, local populations are vulnerable to reduced gene flow or extirpation (Semlitsch and Bodie 1998, Marsh and Trenham 2001).

(E) Light Pollution

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. Some researchers estimate that upwards of 100 million birds are killed annually in this manner in North America.

(F) Commercial extraction

Commercial extraction removes vegetation and abiotic resources used by wildlife. In addition, large machinery may be a source of direct mortality. Commercial extraction of sand and gravel is a threat to timber rattlesnakes, eastern hognose snakes, and wood turtles. Abandoned gravel pits may be valuable habitat for some wildlife (e.g., early successional obligates such as New England cottontail and nesting turtles). However, following extraction of abiotic resources, properties often are sold for development, permanently altering the site for wildlife.

4. RESEARCH NEEDS

- Identify priority areas for protection, restoration, and management among all critical habitat types
- Identify landscape connections for protection and restoration
- Identify critical habitat needs of species at greatest risk through monitoring
- Identify land planning that is least likely to affect significant natural resources

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Diseases and Pathogens

1. DEFINITION

Wildlife diseases are most commonly bacterial but can also be viral or fungal. Diseases are transmitted or enhanced by the poultry industry, unsanitary birdhouses, mosquitoes, and chemical applications and often are persistent. Great improvements in the speed and efficiency of international commerce have facilitated the spread of diseases that were once isolated to certain regions. The threat of disease to wildlife populations in New Hampshire is likely to increase with the expansion of global trade. Diseases can have dramatic affects on fish and wildlife populations due to widespread mortality in infected areas. In addition, wildlife diseases also can pose risks to human health.

2. EXPERT OPINION

Diseases may locally affect fish, wildlife, and plants that comprise habitats of conservation concern in New Hampshire. Impacts will likely be serious for several species over the short and long-term. Impacts on vernal pool species, fish, purple martins, a variety of raptors and corvids, and coastal bird species such as the common and roseate tern, can be at extreme risk due to large magnitudes of mortality associated with diseases. Impacts are well documented for coastal island birds, fish, purple martins, and raptors and are poorly documented for vernal pool habitats.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

Chronic wasting disease (CWD) appears to be transmitted via abnormal proteins called prions. Transmission is through physical contact or through infected feed. Infected prions are most concentrated in the nervous system tissue such as the brain or lymphatic tissue. CWD is a contagious neurological disease that is fatal to ungulates (primarily deer and elk). It is considered a transmissible spongiform encephalopathy or TSE that attacks the brains of infected animals. As a result, the animal becomes emaciated, exhibits abnormal behavior, and eventually dies (Animal and Plant Health Inspection Services 2005).

TABLE 4-16. Number of habitats and species at highest risk due to diseases and pathogens. See Table 4-17 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	0
3	0	0
2	1	0
1	2	3

Avian cholera is an increasing threat to seabirds (USFWS 1998) and may be linked to contamination by the poultry industry. Avian cholera is a highly infectious disease caused by the bacterium *Pasteurella multocida* that is quickly lethal and can kill entire colonies if not contained.

Avian botulism is also carried through a bacterium that is transmitted through the discharge of sewage or buildup of organic matter. The botulism bacterium accumulates in dead birds and scavengers are vulnerable to transmission. The source and transmission of salmonella in birds is not well understood.

In 1988, 37 common terns were found dead on Eastern Egg Rock in Maine from avian cholera. This resulted in complete abandonment of the colony with only 37% recolonizing later in the season (Kress 1997). In 1991, large numbers of terns and laughing gulls died from avian botulism on Eastern Egg Rock after a massive menhaden die-off in Muscongus Bay. Avian cholera has been identified as the bacterium that killed terns, gulls, and eiders on seabird islands in Maine. In 2004, close to 2000 common tern chicks were found dead on the nests at Monomoy Island,

TABLE 4-17. Habitats and species at highest risk from effects of diseases and pathogens, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores*					Rank	Class
		1	2	3	4	5		
HABITATS								
	Appalachian Oak Pine Forest	4	3	1	3	3	2.04	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

Massachusetts with no evidence of external trauma. Salmonella was determined to be the cause of death.

Diseases spread by various pathogens (e.g., viruses, bacteria, parasites) can harm fish populations in New Hampshire. While diseases in wild fish populations are natural, more widespread incidents of disease are present under adverse environmental conditions. Fish pathogens are more likely to occur in areas with crowded conditions (aquaculture facilities) and poor water quality. Studies on the transmission of diseases from hatchery fish stocks to wild fish populations are inconclusive. Whirling disease, infectious pancreatic necrosis, bacterial kidney disease, and gas bubble disease are examples of salmonid diseases known to have occurred in NHFG fish culture facilities.

West Nile Virus (WNV) is carried in birds and spread through the bite of infected mosquitoes, often causing encephalitis or meningitis. It was first detected in the United States in 1999 and is now found in all of the lower 48 states. Corvids and raptors appear to be particularly susceptible to the disease (Gancz et al. 2002). The New Hampshire Department of Health and Human Services has limited their collection of dead birds for WNV testing to crows and blue jays, so it is difficult to determine whether other species in New Hampshire have been exposed to WNV.

By September 2005, 51 birds, representing 22 species, tested positive for eastern equine encephalitis. It is not known if there are population level effects from this disease.

International trade in wildlife, especially amphibians, is a major pathway for the potential introduction of foreign diseases to native wildlife populations in the United States (Daszag et al. 1999, Mazzoni et al. 2003). Over one million bullfrogs are imported into the United States each year. Many of these frogs are raised on farms in South America where they may become carriers for diseases that could potentially spread to wild populations (Mazzoni et al. 2003).

4. RESEARCH NEEDS

- Establish rapid diagnostic techniques for ungulates potentially infected with CWD
- Assess threats from diseases to species of concern in New Hampshire
- Assist health officials with understanding interactions of wildlife diseases and human health

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Energy and Communication Infrastructure

1. DEFINITION

Wind energy and communication tower infrastructure (e.g., television, radio, cell towers) are known to degrade wildlife habitats and cause direct mortality of individuals (Kerlinger 2000, Kerns and Kerlinger 2003, Schwartz 2004). This may lead to reduced population size, alterations of population structure, and perhaps cause local extirpations. Communication towers are common in New Hampshire. Commercial wind energy development is considered the fastest growing sector of the energy market in the United States (deVries 2004, Winegrad in Resolve 2004). Although New England has historically lagged behind the nation in wind resource development, high sustained winds at high elevation sites and production tax credits appear to be creating a competitive siting environment (McLeish 2002).

2. EXPERT OPINION

Wind energy and communication tower infrastructure (e.g., television, radio, cell towers) could degrade critical habitat and cause direct mortality and thereby reduce population size, alter population structure, and perhaps cause local extirpation.

Energy and communication infrastructures are considered a chronic to serious local threat for a variety of species and habitats but could be potentially serious for some species (e.g., American marten, bats, spruce grouse, and migratory birds including osprey) and habitats (e.g., alpine, high elevation spruce fir, talus slope/rocky ridges). Impacts to habitats are somewhat well documented, but weakly documented for most wildlife species.

TABLE 4-18. Number of habitats and species at highest risk due to energy and communication infrastructure. See Table 4-19 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	0
3	0	0
2	3	4
1	6	9

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Habitat loss and degradation

Habitat alteration stemming from the construction of wind and telecommunication structures and access roads can be substantial (Bodin 2004), and can perhaps be exacerbated by the unique and fragile habitats where these structures are often placed (i.e., alpine, cliff and high elevation spruce-fir habitats). American marten, spruce grouse, and Bicknell's thrush are sensitive to the threats posed by towers and turbines. Offshore wind turbines may affect nearby waters and the ocean floor, particularly during the construction phase when the seafloor is disturbed (Kerlinger and Curry 2002).

(B) Collision and mortality

There is extensive evidence that migratory birds and bats, including species of conservation concern in New Hampshire, may experience substantial mortality at some telecommunication towers and wind turbines (Kerlinger 2000, Shire et al. 2000, Kerns and Kerlinger 2003, Resolve 2004, Schwartz 2004). Nocturnally migrating birds may be attracted to lights on towers, become disoriented, and crash into towers or associated guy wires. There is less information available for impacts associated with nearshore or offshore wind facilities, especially in the United States (Kerlinger 2000, Kerlinger and Curry 2002). Impacts would expectedly be greatest when wind facilities are sited near migration pathways or concentrations of wintering or foraging waterfowl and waterbirds

TABLE 4-19. Habitats and species at highest risk from effects of energy and communication infrastructure, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores* 1	2	3	4	5	Rank	Class
SPECIES								
American Marten	High Elevation Spruce-Fir Forest	1	4	3	3	4	2.08	2
Osprey	Marsh and Shrub Wetlands	1	4	4	2	4	2.08	2
Spruce Grouse	Lowland Spruce-Fir Forest	1	4	3	3	4	2.08	2
Peregrine Falcon	Cliffs	2	3	3	3	3	1.88	2
HABITATS								
	High Elevation Spruce-Fir Forest	2	4	3	3	4	2.50	2
	Alpine	3	4	2	2	3	2.04	2
	Talus Slopes and Rocky Ridges	4	3	2	3	2	2.04	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

(Kerlinger 2000). Mortality may be considered insignificant at some locations, but it is not known what cumulative impacts might occur at a regional level (Winegrad in Schwartz 2004).

Towers over 200 feet tall may pose the greatest threat, and as of 1999, there were approximately 60 such towers in New Hampshire (Braile 1999). Although large mortalities from tower collisions have not been recorded in New Hampshire, the issue has received little study, and its overall magnitude remains unknown. Although there are no active wind turbine facilities in New Hampshire, there are several proposals being evaluated by state and local regulators. In an attempt to minimize wildlife impacts, the United States Fish and Wildlife Service (USFWS) produced guidelines for the siting and operation of both communication towers and wind turbines.

4. RESEARCH NEEDS

- More information is needed on the direct threats (habitat loss, mortality, wildlife behavior modifications) of wind farms and communication towers proposed in the Northeast, including New Hampshire. USFWS recommends a minimum of 3 years pre-construction surveys to document impacts to wildlife. Post-construction surveys should assess impacts and lead to modified design and siting criteria.
- Conduct a cost-benefit analysis for each proposed wind energy project and determine its effects on the environment. Benefits should clearly outweigh environmental costs before a project proceeds.

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Introduced Species

1. DEFINITION

Introduced species may compete directly with native species for food or space, may compete indirectly by changing the food web or physical environment, or may prey on or hybridize with native species (Stein and Flack 1996). Rare species with limited ranges and restricted habitat requirements are particularly vulnerable to introduced species. Invasive species (i.e., species that spread rapidly or colonize vigorously) are now regarded as the second-leading threat to at-risk species nationwide, behind only habitat destruction (Stein and Flack 1996). Approximately 42% of federal threatened or endangered species are at risk from invasive species (Stein and Flack 1996). Impacts to many threatened or endangered species is not well known.

2. EXPERT OPINION

Introduced animals (e.g., mammalian predators, zebra mussels) may have extreme impacts on island nesting birds (Roseate tern), dwarf wedgemussels, and eastern pondmussels in the near future. Hemlock-hardwood-pine forests, Karner blue butterflies, and coastal transitional wetlands are seriously threatened as well. Salt marshes and associated at-risk birds and watersheds in the Lakes and Monadnock regions will likely undergo serious impacts from introduced plants in the near future. Invasive species seriously impact several other habitats including pine barrens, floodplain forests, and many watersheds.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Invasive invertebrates

A number of invasive exotic invertebrates have been introduced to the United States via mechanisms ranging from importation of commercial goods to intentional release for control of other invasive species.

TABLE 4-20. Number of habitats and species at highest risk from introduced species. See Table 4-21 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	3
3	2	1
2	8	6
1	12	13

New Hampshire officially recognizes 16 invasive exotic invertebrates that are prohibited for collection, importation, sale, distribution, propagation, or release (Chapter Agr 3800 Invasive Species).

Introductions of invasive invertebrates have significant consequences on critical habitats and associated wildlife species. For instance, hemlock wooly adelgid, first observed in New Hampshire in 2000, is a significant threat to the state's hemlock forests. The insects suck sap from young twigs, retarding or preventing tree growth and causing needles to turn grayish-green and drop prematurely, usually resulting in significant die-offs (McClure et al. 2001). There is some evidence that the adelgid's northward spread is controlled by winter temperatures, but it is unknown if control is sufficient to minimize impacts on New Hampshire's hemlock forests (Sheilds and Cheah 2003).

Ladybird beetles (*Coccinella septempunctata*) introduced to control aphids on agricultural crops are known to prey on Karner blue larvae and immature Monarch butterflies (Schellhorn et al. 2005). Being a generalist predator, ladybird beetles may also harm other species of butterflies.

Wasps and flies marketed and released as biological controls for agricultural pests are often generalist parasites with potentially widespread but undocumented effects on native Lepidoptera.

Zebra mussels have a high potential to signifi-

TABLE 4-21. Habitats and species at highest risk from introduced species, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores*					Rank	Class
		1	2	3	4	5		
SPECIES								
Dwarf Wedgemussel	Aquatic	4	4	3	3	4	3.33	4
Eastern Pondmussel	Aquatic	4	4	3	3	4	3.33	4
Roseate Tern	Coastal Islands	4	4	4	2	4	3.33	4
Karner Blue Butterfly	Pine Barrens	3	4	4	2	4	2.92	3
Nelson's Sharp-tailed Sparrow	Salt Marshes	3	2	4	4	4	2.50	2
Saltmarsh Sharp-tailed Sparrow	Salt Marshes	3	2	4	4	4	2.50	2
Seaside Sparrow	Salt Marshes	3	2	4	4	4	2.50	2
Willet	Salt Marshes	3	2	4	4	4	2.50	2
New England Cottontail	Shrublands	4	2	3	3	3	2.25	2
Brook Floater	Aquatic	2	3	3	2	4	1.88	2
HABITATS								
	Hemlock-Hardwood-Pine Forest	4	4	2	3	4	3.00	3
	Coastal Transitional Watersheds	3	3	3	4	4	2.75	3
	Salt Marshes	3	2	4	4	4	2.50	2
	Floodplain Forests	3	3	2	3	4	2.25	2
	Marsh and Shrub Wetlands	3	3	2	3	4	2.25	2
	Connecticut River Mainstem Watersheds	2	3	2	3	4	1.88	2
	Non-Tidal Coastal Watersheds	2	3	2	4	3	1.88	2
	Pine Barrens	2	3	2	3	4	1.88	2
	Southern Upland Watersheds	2	3	2	4	3	1.88	2
	Tidal Coastal Watersheds	2	3	2	4	3	1.88	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

cantly affect the state's freshwater mussels, especially the state endangered dwarf wedgemussel. After their discovery in Lake Saint Clare 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).

(B) Range expansions and local introductions

A number of species have expanded their range or increased in abundance in the last 100 years either naturally or with the assistance of humans. For instance, coyotes have been expanding eastward since the mid-1900s. The first verified account of a coyote in New Hampshire was in Grafton County in 1944. Between 1972 and 1980 coyotes spread across the state and are now common in every county (O'Brien, undated).

People have likely contributed to the range expansion and increased abundance of mammalian predators (e.g., coyotes, foxes, raccoons, etc.). Readily available food sources (e.g., agricultural crops, trash, pet food, etc.) are thought to facilitate population increases in landscapes fragmented by agriculture and development (Oehler and Litvaitis 1996). Boat visitation has been the vehicle for rat introductions on both Star and Appledore Islands, and raccoons were introduced to the island through an unknown source in 2004. Predation by medium-sized mammals is the most common proximate mortality factor of New England cottontail and has caused high mortalities of common and roseate terns on the Isles of Shoals (Barbour and Litvaitis 1993, Brown and Litvaitis 1995, DeLuca 2005).

(C) Horticultural introductions

Horticulture (arboretums, botanic gardens, nurseries, etc.) 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). Some of these are officially listed as invasive in New Hampshire, including autumn olive, Japanese barberry, glossy buckthorn, and others (Eckardt 1997, Reinartz 1997, Silander and Klepeis 2001, New Hampshire Department of Agriculture 2005). 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.

(D) Aquatic pathways

Invasive exotic aquatic plants and animals enter lakes, streams, and rivers of New Hampshire watersheds via commercial transport, ballast water discharges, aquaculture, boating, landscaping, water transport, private aquarium releases, and bait handling (Courtenay and Robins 1973, Glassner-Shwayder 1996). Negative effects include alterations in nutrient cycling pathways, decreased habitat value of infested waters, decreased water quality, altered community structure, and threats to endangered species (e.g., dwarf wedgemussel) (Estuarine and Freshwater Working Group 2005). Eight of the 14 invasive plants prohibited in New Hampshire already occur in the state, with variable milfoil (*Myriophyllum heterophyllum*) and fanwort (*Cabomba caroliniana*), both aquatic plants, being the most common (Varney and Christie 2003). Twenty-three non-indigenous fish species have been introduced into New Hampshire waters. Of these, 17 are species native to the United States and 6 are species introduced from other countries (exotic). Fifty percent of the exotic species introductions resulted in establishing self-sustaining populations (Estuarine and Freshwater Working Group 2005).

(E) Disturbances that lead to invasions

Disturbance of a salt marsh, such as the construction of a road that restricts tidal flow, can exacerbate the proliferation of invasive plants (e.g., common reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*) (Niering and Warren 1980, Benoit and Askins 1999). The invasion of salt marsh habitats by exotic plants reduces habitat quality for a number of wildlife species. For instance, salt marsh sparrows, a species normally found in *Spartina* grasses, are unlikely to use a marsh dominated by tall, thick stands of common reed. Further, the density of these stands of reed may make prey inaccessible or may reduce foraging success (Benoit and Askins 1999).

Timber harvest in upland habitats can also exacerbate invasions. If invasive exotic plants are already present in or near a forest stand, opening the forest floor to additional sunlight and scarifying the soil with harvesting equipment can create conditions conducive to the spread of invasive exotic plants.

4. RESEARCH NEEDS

- 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

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Mercury

1. DEFINITION

Though naturally occurring, mercury is an air and water quality issue that affects human and ecological health. The redistribution of inorganic mercury (Hg) that is available for methylation is a serious ecological issue in New Hampshire. Fossil fuel burning (particularly coal) and incineration of municipal and hospital waste has significantly enhanced availability of mercury. Some areas of New Hampshire are affected by within-state emission or point sources, while regional and global emissions have statewide impacts (Evers 2005). Mercury distribution is well characterized for northeastern North America (Evers and Clair 2005a). Many habitats are vulnerable to methylmercury (MeHg) production and availability, and species at risk are typically predators or are long-lived (Evers et al. 2005).

2. EXPERT OPINION

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.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Piscivorous food webs

Fish are a primary food web pathway for methylmercury, making aquatic habitats and a broad suite of aquatic species at risk (Evers and Clairs 2005a).

TABLE 4-22. Number of habitats and species at highest risk from the effects of mercury. See Table 4-23 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	0
3	0	3
2	6	7
1	6	9

The loon is a long-lived fish eating bird and has been well studied across North America and in New Hampshire (Evers et al. 1998, 2003). Southeastern New Hampshire was identified as a biological hotspot for methylmercury availability (Evers 2005), and loon blood and egg mercury levels indicate approximately 14% of New Hampshire's breeding population is at risk to behavioral, physiological, and reproductive impacts. DeSorbo and Evers (2005) recently documented that lower bald eagle productivity for the past 10 years in Maine is significantly correlated to chick blood mercury levels. In rivers and streams, ospreys, common mergansers, and belted kingfishers are high trophic level species and have been shown to have elevated mercury levels (Evers et al. 2005). Mercury levels in kingfishers living on lakes are 4 times higher than those on the ocean. Marine foraging terns are less affected by methylmercury than are those foraging in estuaries and freshwater systems (BRI unpublished data). Aquatic mammals dependent on crayfish (Pennuto et al. 2005) and fish are also at high risk, particularly the mink and river otter (Yates et al. 2005).

(B) Insectivorous food webs

Recent work strongly indicates that insectivores can have elevated body burdens of mercury. A Massachusetts study in riverine scrub-shrub wetlands showed that methylmercury can biomagnify through

TABLE 4-23. Habitats and species at highest risk from the effects of mercury, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

		Ranking Scores*						
Species	Habitat	1	2	3	4	5	Rank	Class
SPECIES								
Bald Eagle	Aquatic	3	4	4	2	4	2.92	3
Osprey	Marsh and Shrub Wetlands	4	3	2	3	4	2.63	3
Peregrine Falcon	Cliffs	4	3	2	3	4	2.63	3
Common Loon	Aquatic	3	2	4	4	4	2.50	2
Common Tern	Coastal Islands	4	2	3	3	4	2.50	2
Roseate Tern	Coastal Islands	4	2	3	3	4	2.50	2
Nelson's Sharp-tailed Sparrow	Salt Marshes	3	3	2	3	3	2.00	2
Saltmarsh Sharp-tailed Sparrow	Salt Marshes	3	3	2	3	3	2.00	2
Seaside Sparrow	Salt Marshes	3	3	2	3	3	2.00	2
Willet	Salt Marshes	3	3	2	3	3	2.00	2
HABITATS								
	Coastal Islands	4	2	3	3	4	2.50	2
	Appalachian Oak Pine Forest	4	2	2	3	4	2.25	2
	Hemlock-Hardwood-Pine Forest	4	2	2	3	4	2.25	2
	Northern Hardwood-Conifer Forest	4	2	2	3	4	2.25	2
	Salt Marshes	4	2	2	3	3	2.00	2
	High Elevation Spruce-Fir Forest	4	1.5	3	2	3	1.83	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

the avian insect food web. Some individual northern waterthrushes and red-winged blackbirds had blood mercury levels that exceeded levels in all bald eagles sampled across New England (Evers et al. 2005). Other species at risk in marsh and shrub wetlands include the American bittern and Virginia rail. Estuaries, particularly those surrounded by developed landscapes, and floodplain forest, are prone to methylmercury pollution. Studies of the salt marsh and Nelson's sharp-tailed sparrow and seaside sparrow in four New England National Wildlife Refuges and other estuaries show that blood mercury levels exceed safe standards set for insectivorous songbirds (0.82 ppm, wet weight). These levels were consistently higher than those in associated insectivores, indicating upper trophic level foraging (Lane and Evers 2005). In floodplains, high blood mercury levels in the northern waterthrush indicate New Hampshire breeding species such as the red-shouldered hawk and Louisiana waterthrush could be at risk.

(B) Acidic habitats

Ecosystems sensitive to acidic conditions are of high interest for investigating potential impacts of methylmercury. The synergy of acidity and mercury deposition may harm breeding songbird populations. Long-term acid deposition has lowered calcium availability in the Northeast (Hames et al. 2002) and likely elsewhere in eastern North America (Driscoll et al. 2001), has changed invertebrate faunal assemblages (Schindler et al. 1985), and has increased methylmercury availability (Spry and Wiener 1991). Although not well studied, methylmercury in insectivorous birds and small terrestrial mammals such as shrews and bats may be more of a risk than previously considered. Two consistently acidic habitats are peatlands and high elevation areas. Recent evidence from a riverine scrub-shrub wetland study of a 15-species insectivorous guild found red-winged blackbirds to carry the highest Hg body burdens (Evers et al. 2005). The rusty blackbird, which commonly inhabits peat lands, is a species of high conservation concern that may be harmed by elevated mercury levels. Since 1970, this species has declined precipitously, though the reasons for its troubles remain largely unexplained (Greenough 2005). However, blackbirds depending on insect food webs with an origin in acidified habitats may be harmed by the synergistic relationship of elevated methylmercury and low calcium levels during times of increased energy needs for proper eggs and chick production. Pied-billed grebes in peatland habitats could also be at high risk.

Higher mercury levels and lowered calcium levels in acidified environments at high elevation is of great concern. Rimmer et al. (2005) quantified the distribution of mercury across the Northeast and showed elevated blood mercury levels in the Bicknell's thrush. This species only breeds on mountaintops, generally in areas removed from standing water, indicating that mercury is much more pervasive than once thought and that it could be problematic for some terrestrial systems.

4. RESEARCH NEEDS

- Initiate a steering committee of state agencies (NHFG and NHDES) to work with federal agencies (US EPA, 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.
- Compile a document that identifies the best indicator species and represents all relevant taxa for sensitive habitats and geographic areas in New Hampshire
- Conduct a spatial and temporal analysis of common loon exposure and risk statewide (in process with NHDES)
- Establish a long-term monitoring effort using common loon tissue levels and link with existing and new demographic data collected by the Loon Preservation Committee
- Conduct a risk assessment for species at greatest risk, including the common loon and bald eagle
- Conduct a risk assessment for habitats and their species assemblages
- Collect new tissue samples from species and habitats with little empirical information on mercury exposure, particularly those with compelling evidence of mercury injury. The priority species are the red-shouldered hawk, Bicknell's thrush, and rusty blackbird. Priority habitats are peatlands, high elevation areas, and floodplain forest. Secondary priority should be on the pied-billed grebe, American bittern, and Virginia rail in selected wetland habitats (depending on geography and types).

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Non-point Source Pollution

1. DEFINITION

Non-point source pollution results from land use that allows harmful substances, such as sediments, road salt, fertilizers, pesticides, and petrochemicals, to be flushed into water bodies by rain or snowmelt (New Hampshire Department of Environmental Services (NHDES) 1999). Non-point source pollution is more pervasive and difficult to address than point sources, which are regulated by the Clean Water Act (amended in 1977). Improving water quality will require a broad effort to identify and address the many pathways by which pollutants enter aquatic habitats.

2. EXPERT OPINION

Non-point source pollutants affect many species and habitats of concern in New Hampshire. Impacts will likely be serious for lowland spruce-fir forests and some watershed groups and associated fish, as well as all three freshwater mussel species on the SGNC list in New Hampshire. The impacts from non-point source pollution—primarily from pesticides/fertilizers, stormwater runoff, and sedimentation—to these habitats and associated species are well documented. Severe impacts to other natural communities also likely occur but are not well documented.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Stormwater runoff

In 1998, non-point source pollution was the suspected cause for 92% of sampled water bodies that did not achieve state water quality standards in New Hampshire (NHDES 1999). Runoff from agricultural lands, forestry operations, 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).

Combined Sewer Overflows (CSOs), which allow waste water 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 47 identified CSOs in 6 communities (NHDES 2003).

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

TABLE 4-24. Number of habitats and species at highest risk from the effects of non-point source pollution. See Table 4-25 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	0
3	3	3
2	7	4
1	14	20

TABLE 4-25. Habitats and species at highest risk from the effects of non-point source pollution, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores* 1	2	3	4	5	Rank	Class
SPECIES								
Dwarf Wedgemussel	Aquatic	4	3	4	4	3	3.21	3
Brook Floater	Aquatic	3	3	4	4	3	2.75	3
Eastern Pondmussel	Aquatic	3	3	4	4	3	2.75	3
Northern Leopard Frog	Grasslands	4	3	2	3	3	2.33	2
Bald Eagle	Aquatic	3	2	2	3	4	1.88	2
Osprey	Marsh and Shrub Wetlands	3	2	2	3	4	1.88	2
Peregrine Falcon	Cliffs	3	2	2	3	4	1.88	2
HABITATS								
	Lowland Spruce Fir Forest	3	4	3	3	4	2.92	3
	Connecticut River Mainstem Watersheds	3	3	4	3	4	2.75	3
	Non-Tidal Coastal Watersheds	3	3	4	4	3	2.75	3
	Coastal Transitional Watersheds	3	3	3	3	3	2.25	2
	Tidal Coastal Watersheds	3	3	3	3	3	2.25	2
	Montane Watersheds	2	3	4	3	3	2.08	2
	Hemlock-Hardwood-Pine Forest	3	3	2	2	4	2.00	2
	Northern Upland Watersheds	3	3	3	3	2	2.00	2
	Peatlands	2	3	3	3	3	1.88	2
	Southern Upland Watersheds	2	3	3	3	3	1.88	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

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).

(B) Sedimentation

Bank erosion and sediment deposition are natural processes that can be accelerated by human activity. Increased 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). 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). A survey of 1,300 landowners along the Connecticut River indicated bank erosion as their primary concern (NHDES 1999).

(C) Chemical applications

Broad-spectrum chemical herbicides and insecticides applied to forests to control hardwood regeneration and outbreaks of eastern spruce budworm caterpillars (*Choristoneura feranafumi*) 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 spruce budworms makes chemical applications less effective (Natural Resources Canada 1997).

Toxic effects of pesticides involve 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). Deposited heavy metals and organic compounds accumulate and persist in the sediment and bioaccumulate in the tissue of fish and benthic communities (NHDES 1999).

The use of chlorinated hydrocarbons (e.g., DDT) causes eggshell thinning in raptors. Although DDT has been banned in the U.S., it is still used on the wintering grounds of many raptor prey species (NatureServe 2005). Continued exposure by raptors to DDT is hypothesized to result from foraging on contaminated migratory birds returning from the tropics.

4. RESEARCH NEEDS

- 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
- Monitor the long-term effects of pesticides on the reproductive fitness of avian predators

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Oil Spills

1. DEFINITION

Oil can be introduced into marine and coastal environments by spills, leaks, or discharges from onshore tanks, vehicles, offshore facilities, and boats. Offshore oil spills from tanker accidents or leakage can significantly harm coastal species and habitats. Oil runoff from impervious surfaces may have smaller and more localized impacts. Due to the high concentration of some species during the breeding or wintering seasons, oil spills can decimate local wildlife. Oil spills are likely to cause immediate adverse effects on wildlife and long-term effects because oil is persistent in some areas (Johnston 1984).

2. EXPERT OPINION

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 and coastal islands and associated species (i.e., roseate and common terns, piping plovers) either immediately or in the long term. The effects of oil spills on dunes and coastal islands are well documented.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

Oil can enter fresh and marine waters from platform construction, drilling, shipping, and spillage, and low-level seepage from surface runoff or subsurface sources (Boesch et al. 2001). Animals coated in oil may experience direct mortality or reduced reproductive success, food can become contaminated, toxins can build up in upper trophic levels, and oil can coat the shores and degrade habitat (Kushlan et al. 2002). The harmful effect of oil on birds is well documented (Chardine 1990). Externally, even a small amount of oil can destroy the weatherproofing and insulating properties of avian plumage resulting in hypothermia and inability to fly, stay afloat, and forage. Ingestion of oil can have equally life threatening toxic effects on the gastrointestinal tract, pancreas, and liver (Pierce 1991).

In 1996, 1,000 gallons of fuel oil were spilled into the Piscataqua River, rapidly entering Great and Little Bays. Nests in the Hen Island tern colony in Little Bay were oiled during incubation. The island was used to anchor containment booms and serve as point for cleanup activity. Data from the New Hampshire Gulfwatch monitoring program documented high levels of polycyclic aromatic hydrocarbons (PAH) in mussels following the spill, followed by a gradual recovery to baseline levels within 2 years (Gulf of Maine Council on the Marine Environment 2003).

An oil spill off the Rhode Island coast resulted in the loss many loons (Evers et al. 2002), and the potential for oil spill impacts to New Hampshire's wintering loon population exists as well. The concentration of common terns and roseate terns on Seavey Island and piping plovers on Seabrook/ Hampton beaches makes an oil spill in the nearby waters potentially catastrophic. Other species potentially harmed include nesting and wintering birds, marine mammals, fish, turtles, and marine and estuarine invertebrates (Research Planning, Inc. 2004). Locations and critical time periods for species and habitats were identified and mapped in case an oil spill occurs again (Research Planning, Inc. 2004).

TABLE 4-26. Number of habitats and species at highest risk from the effects of oil spills. See Table 4-27 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	2
3	1	1
2	1	2
1	2	5

TABLE 4-27. Habitats and species at highest risk from the effects of oil spills, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

		Ranking Scores*						
Species	Habitat	1	2	3	4	5	Rank	Class
SPECIES								
Common Tern	Coastal Islands	4	4	4	2	4	3.33	4
Roseate Tern	Coastal Islands	4	4	4	2	4	3.33	4
Piping Plover	Dunes	4	4	4	1	3	2.67	3
Common Loon	Aquatic	3	4	2	1	4	2.04	2
Bald Eagle	Aquatic	1	4	3	2	4	1.88	2
HABITATS								
	Dunes	4	4	2	2	4	2.67	3
	Coastal Islands	3	4	1	2	4	2.04	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

4. RESEARCH NEEDS

- 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

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Predation and Herbivory

1. DEFINITION

Wildlife abundance and distribution can increase dramatically in response to human modifications to habitats and from the provision of supplemental food sources. For example, landfills and coastal developments provide gulls with nearly limitless food, and gulls subsequently eliminate other seabirds through competition and predation. Species with broad diets, such as raccoons, skunks, and crows, can thrive on food provided by trash, gardens, and bird feeders. Cats and dogs are capable predators with no natural population constraints. In the absence of predators or hunting, white-tailed deer can reach densities high enough to reduce or eliminate insect host food plants. Beaver can affect certain wetland natural community types (e.g., black gum swamps) that beavers historically rarely used. Rare species are often vulnerable to predation and competition from species that are better adapted to human activity.

2. EXPERT OPINION

Coastal birds of conservation concern are highly susceptible to mortality from subsidized predators, especially gulls. The threat is well documented and somewhat localized, yet severe, in dunes and coastal islands. More widespread but less severe harm likely occurs to species in cities and towns where predator densities are high and where domestic animals prey on wildlife.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Gulls

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 allowed for exponential increases in the numbers of gulls along the entire northeastern coast. 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 1995). 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 5 study islands was 56% in 1999 (n=251) and 41% in 2000 (n=605) (Goodale 2000).

TABLE 4-28. Number of habitats and species at highest risk from the effects of predation and herbivory. See Table 4-29 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	1	3
3	1	3
2	1	2
1	2	12

(B) Other Predators

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).

TABLE 4-29. Habitats and species at highest risk from the effects of predation and herbivory, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores* 1	2	3	4	5	Rank	Class
SPECIES								
Piping Plover	Dunes	4	4	4	3	4	3.67	4
Common Tern	Coastal Islands	4	3	4	4	4	3.50	4
Roseate Tern	Coastal Islands	4	3	4	4	4	3.50	4
New England Cottontail	Shrublands	4	3	3	4	4	3.21	3
Karner Blue Butterfly	Pine Barrens	3	3	3	4	4	2.75	3
Purple Martin	Grasslands	4	3	2	3	4	2.63	3
Rusty Blackbird	Lowland Spruce-Fir Forest	2	4	4	3	3	2.50	2
Non-breeding Birds		3	2	3	3	3	1.88	2
HABITATS								
	Coastal Islands	4	3	4	4	4	3.50	4
	Dunes	4	3	4	3	4	3.21	3
	Shrublands	2	3	3	3	4	2.08	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

(C) Herbivory

Heavy browsing of blue lupine plants by white-tailed deer and woodchuck can severely reduce blue lupine populations and result in Karner blue butterfly mortality by accidental ingestion of eggs and larvae.

4. 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

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Recreation

1. DEFINITION

Most Americans participate in some kind of outdoor recreation. Recreation demand and trends in New Hampshire show a marked increase in the past 10 years (New Hampshire Office of State Planning 2003). For example, the White Mountain National Forest saw a 23 percent increase in trail use between 1974 and 1995 (New Hampshire Office of State Planning, 1997). Between 1996 and 2003, wheeled off-highway recreational vehicle (a.k.a., ATV) registrations in New Hampshire more than doubled for resident and more than tripled for non-resident owners. Similarly, boating registrations doubled between 1980 and 1990 and continued to increase by 19 percent from 1990 to 2000.

Recreational activities often degrade land, water, and wildlife resources by simplifying plant communities, increasing animal mortality, displacing and disturbing wildlife, and distributing refuse (Boyle and Samson 1985). Some activities may have little or no effect. A number of factors influence the nature and severity of recreational impacts on wildlife, including the characteristics of the activity (type, location, time, predictability, frequency, magnitude) and the characteristic of the habitat or wildlife (species, group size, age, and sex) (Knight and Cole 1995).

2. EXPERT OPINION

Recreational activity is currently affecting species and habitats of conservation concern in New Hampshire. These effects are projected to continue into the foreseeable future. Impacts are likely serious to critical and well-documented for species inhabiting the rarest habitats, such as dunes, caves, coastal islands, cliffs, rocky ridges, and some aquatic habitats (such as sand-cobble shores and banks). Recreation is a serious localized threat to a subset of alpine natural communities. Grasslands, forests, and aquatic habitats may be seriously impacted, depending on specific local recreational activities.

TABLE 4-30. Number of habitats and species at highest risk from the effects of recreation. See Table 4-31 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	1	2
3	3	7
2	9	6
1	19	27

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Human disturbance

Activities such as wildlife viewing, fishing, climbing, caving (or spelunking), boating, snowmobiling, ATV-ing, and hiking can cause unintentional disturbance. Disturbance from these activities may alter behavior and in some cases cause nest abandonment. For example, disturbance by anglers and boaters can disturb nesting and foraging activity of common loons (Titus 1978, Titus and VanDruff 1981, Christenson 1981, Kelly 1992). Depending on the time of year, water-based recreation can disturb roosting, feeding, or breeding by a variety of wildlife (Knight and Cole 1995). Offshore boating activities (whale watching, fishing, tour boats) can flush species from coastal islands, causing them to expend energy reserves (United States Fish and Wildlife Service (USFWS) 1994). Piping plovers lose valuable foraging time when beach goers and their pets are present (Burger 1991, Staine and Burger 1994). Snowmobiles can disturb deer that are concentrated in deer yards.

A study by Thomas (1995) of non-tactile disturbance from visits to hibernacula indicated a dramatic arousal of bats (little brown bats and northern myotis) and an increase in flight activity, and repeated

TABLE 4-31. Habitats and species at highest risk from the effects of recreation, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores*					Rank	Class
		1	2	3	4	5		
SPECIES								
Piping Plover	Dunes	4	4	4	4	4	4.00	4
Common Loon	Aquatic	4	3	4	4	4	3.50	4
Peregrine Falcon	Cliffs	4	3	4	3	4	3.21	3
Cobblestone Tiger Beetle	Aquatic	4	3	3	3	4	2.92	3
Eastern Pipistrelle	Caves and Mines	4	3	3	3	4	2.92	3
Bald Eagle	Aquatic	4	2	3	4	4	2.75	3
Indiana Bat	Caves and Mines	4	3	3	3	3	2.63	3
Northern Myotis	Caves and Mines	4	3	3	3	3	2.63	3
Small Footed Bat	Caves and Mines	4	3	3	3	3	2.63	3
Osprey	Marsh and Shrub Wetlands	4	2	3	4	3	2.50	2
Brook Floater	Aquatic	1	4	4	4	3	2.29	2
Common Tern	Coastal Islands	3	3	3	2	4	2.25	2
Roseate Tern	Coastal Islands	3	3	3	2	4	2.25	2
Karner Blue Butterfly	Pine Barrens	2	3	4	3	3	2.08	2
Spruce Grouse	Lowland Spruce-Fir Forest	3	1	4	4	3	1.83	2
HABITATS								
	Dunes	4	4	4	4	4	4.00	4
	Caves and Mines	3	3	4	4	4	3.00	3
	Cliffs	3	3	4	3	4	2.75	3
	Talus Slopes and Rocky Ridges	3	3	4	3	4	2.75	3
	Hemlock-Hardwood-Pine Forest	4	2	4	3	3	2.50	2
	High Elevation Spruce-Fir Forest	2	3	4	4	4	2.50	2
	Northern Hardwood-Conifer Forest	4	2	4	3	3	2.50	2
	Appalachian Oak Pine Forest	4	2	3	3	3	2.25	2
	Coastal Islands	3	3	3	2	4	2.25	2
	Coastal Transitional Watersheds	3	3	3	3	3	2.25	2
	Pine Barrens	2	3	4	3	3	2.08	2
	Shrublands	3	3	3	3	2	2.00	2
	Lowland Spruce-Fir Forest	1	3	4	4	4	2.00	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

disturbance may lead to energy depletion to the point of mortality. The presence of low flying aircraft can frighten cliff nesting avian species from their nests, causing them to inadvertently kick out eggs or chicks from the nest (White et al. 2002). Noise disturbance from off-highway recreational vehicles and boats may cause detectable behavioral changes (Bowles 1995). Off-road all terrain vehicles (ATVs) and snowmobiles can be a significant disturbance to wildlife.

(B) Habitat degradation

All forms of recreation can modify vegetation, soil, water, and microclimate, affecting those species that depend on specific habitat conditions (Cole and Landres 1995). ATVs and snowmobiles can significantly degrade terrestrial and wetland habitats, causing erosion, sedimentation, altered hydrology, and acting as a vector for invasive species.

Though robust in their ability to withstand severe environmental conditions, alpine communities and their soils have low tolerances for trampling, particularly dwarf heath shrubs and erect forbs (Sperduto and Cogbill 1999, Cole and Monz 2002). Hikers can trample vegetation, causing soil erosion and reductions in vegetative cover and height. 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 when propagules travel 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 involves tree cutting and ground surface leveling and facility construction. Snowmobiles damage shrubs and saplings (Neumann and Merriam 1972), reduce vegetation abundance, and change species composition (Keddy et al. 1979). Water is affected both by water–based recreation, such as fishing and boating, and by land-based activities such as hiking and off-road vehicles. Trampling affects shorelines by eroding soils, eliminating protective cover, and causing sedimentation and turbidity (Cole and Landres 1995).

(C) Mortality

Recreation may directly or indirectly result in wildlife mortality. Off-road vehicles can be a source of mortality for ampibians, reptiles, and other wildlife. Walkers can inadvertently trample eggs and chicks if walking across coastal islands or dunes. Fourteen percent of loon mortality in New England from 1989 to 1996 was due to boat trauma (Miconi et al. 2000), and lead poisoning by ingesting lead fishing sinkers and jigs is the largest cause of known adult loon mortality in New Hampshire (Tufts University Wildlife Clinic, unpublished data). Additionally, incidental take occurs when one species is mistaken for another, as when upland bird hunters mistake spruce grouse for ruffed grouse and when American marten are caught in fisher traps (Jillian Kelly, NHFG, personal communication). Studies on recreational effects on tiger beetle populations have indicated populations were low to nonexistent where heavy recreational activities were observed and that abundance increased in areas where recreational use was limited and vehicles were prohibited (USFWS 1990). A long-term study in Connecticut documented the extirpation of two wood turtle populations following an increase in human recreation (Garber and Burger 1995).

4. RESEARCH NEEDS

- Studies of site-specific potential for mortality and other threats to New Hampshire's priority wildlife
- Measure energetic costs of behavioral responses to disturbance
- Measure habitat responses to recreation and population responses to recreationally induced habitat change

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Scarcity

1. DEFINITION

All wildlife species have a minimum effective (self-sustaining) population size (Allee et al. 1949). In populations that are depressed or isolated, the reproductive contribution of successfully breeding individuals may be disproportionately high, limiting natural buffering of random demographic and genetic variation and decreasing population stability (Allee et al. 1949, Richter-Dyn and Goel 1972, Ferson and Burgman 1990, Dennis et al. 1991). Susceptibility to failure of demographic processes may be compounded by normal (extrinsic) ecological events, such as weather, competition, or predation, or natural disturbance, resulting in extinction (Caughley 1994). Some wildlife have naturally low minimum effective population sizes because of their life history traits or dependency on uniquely occurring ecological conditions (Allee et al. 1949, Adler and Nuernberger 1994). In either case, the balance between reproductive success and ecological process is precarious, and the risk of localized extinction is high.

2. EXPERT OPINION

Small population size is an extensive to somewhat localized threat for a small number of New Hampshire's wildlife, and particularly severe for species with highly specialized habitat or life history traits. Threats are well documented for timber rattlesnakes, piping plovers, roseate terns, cobblestone tiger beetles, and Karner blue butterflies.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Demographic stochasticity

Some severely depressed or declining populations of wildlife are immediately at risk of extirpation (Dennis et al. 1991, Goodman 1987). New Hampshire's timber rattlesnake population is very small and is extremely isolated from other populations, and potential den sites are rare. The host plant of the Karner blue butterfly is rare. After declining sharply between 1980 and 2001, with a corresponding decline in fecundity (United States Fish and Wildlife Service, unpublished data), Karner blues were not observed in the wild until translocated butterflies were released in 2002 (NHFG, unpublished data). Low population densities and skewed age and sex ratios have raised concerns over the effect of road mortality on the viability of some turtle populations in the region (Marchand and Litvaitis 2004, Gibbs and Steen 2005).

TABLE 4-32. Number of habitats and species at highest risk from the effects of scarcity. See Table 4-33 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	5
3	0	9
2	0	3
1	1	6

(B) Ecological conditions

Until population health is restored, some severely depressed or recovering populations of wildlife are immediately at risk of extirpation due to widespread ecological conditions (Caughley 1994), like weather (Pollard 1991) and predation. Failure to exclude predators has resulted in the failure of common and roseate terns colonies in the Gulf of Maine (Donehower 2003). Annually in New Hampshire, a significant proportion of the state's few piping plover nests fail because of predation and storms (NHFG, unpublished data). Overwintering survival of Karner blues may be limited by the number of days with snow cover (Dirig 1994), and in general, mating success, oviposition, and lepidopteran survival are limited by

TABLE 4-33. Habitats and species at highest risk from the effects of scarcity, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores* 1	2	3	4	5	Rank	Class
SPECIES								
Timber Rattlesnake	Appalachian Oak Pine Forest	4	4	4	4	4	4.00	4
Cobblestone Tiger Beetle	Aquatic	4	4	4	3	4	3.67	4
Karner Blue Butterfly	Pine Barrens	4	4	4	3	4	3.67	4
Roseate Tern	Coastal Islands	4	4	4	3	4	3.67	4
Piping Plover	Dunes	4	3	4	4	4	3.50	4
Blandings Turtle	Marsh and Shrub Wetlands	4	4	1	4	4	3.00	3
Lynx	Upland Forests	4	4	2	3	4	3.00	3
Spotted Turtle	Marsh and Shrub Wetlands	4	4	1	4	4	3.00	3
American Marten	High Elevation Spruce-Fir Forest	3	4	4	4	2	2.92	3
White Mountain Arctic	Alpine	4	4	3	3	2	2.67	3
White Mountain Fritillary	Alpine	4	4	3	3	2	2.67	3
Spruce Grouse	Lowland Spruce-Fir Forest	4	3	4	3	2	2.63	3
Marbled Salamander	Marsh and Shrub Wetlands	4	4	3	3	1	2.33	2
Hognose Snake	Pine Barrens	4	3	3	2	3	2.33	2
Ringed Boghaunter	Peatlands	2	4	3	2	3	2.00	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

weather (Pollard 1991, USFWS 2002). Cobblestone tiger beetle larvae inhabit burrows for 2 years at one location in the Connecticut River, and population estimates seldom exceed 100 individuals. Flooding or hydrologic alteration could decimate the population (Nothnagle 1993). During winters with unusually shallow snow depth, New Hampshire's small marten population may be limited by competition with overlapping fisher populations. Kelly (2005) found that areas with low catch per unit effort for fisher were more likely to have higher values for marten. Krohn et al. (1995) observed differing age and recruitment ratios for marten across areas of overlap with fisher.

(C) Population isolation

Isolated or sparsely distributed populations may be subject to adverse demographic and genetic effects because of limited immigration (Nei 1972, Brown and Kodric-Brown 1977, Fahrig and Merriam 1985, Pulliam 1988, Taylor et al. 1993). Viability of the low density New Hampshire lynx population may depend on lynx dispersing from larger populations (Litvaitis et al. 1991). Increasing southern Canadian and northern Maine human populations may hamper lynx dispersal (Carroll 2005). Spruce grouse are isolated in the WMNF (Todd 2003), and their habitats are fragmented by conversion of low elevation spruce and fir habitat to deciduous land cover (NHFG GIS). Historic Karner blue butterfly and extant frosted elfin populations are separated by distances greater than documented dispersal capabilities (King 1998). Ringed boghaunter populations are sparsely distributed, little is known about their dispersal, and habitat utilization may be hampered by development.

(C) Natural rarity and sensitive life history

Because of their life history traits or unique ecological niches, some species have naturally small breeding populations (Allee et al. 1949). Small changes in survival rates, landscape connectivity, or habitat availability may result in extirpation. Blanding's, box, wood, and spotted turtles may require 5 to 15 years to reach sexual maturity in New Hampshire (Carroll 1991, Degraaf and Yamasaki 2001) and therefore require high adult survival. Bog lemming observations are rare in New Hampshire. Although little is known about the life history traits driving their rarity in New Hampshire, elsewhere the species appears to occur in isolated metapopulations with few individuals in each location and limited dispersal (Clough and Albright 1987, Reichel and Corn 1997). Disruption of individual colonies in a metapopulation may jeopardize the entire metapopulation (Hanski and Simberloff 1997). Marbled salamanders are extremely rare in New Hampshire but little is known about their population dynamics. White Mountain fritillary and arctic butterflies are endemic to New Hampshire, occur only on Mt. Washington, and may be susceptible to climate change (Pollard 1991, McFarland 2003).

4. RESEARCH NEEDS

- Evaluate population genetic structure for the New Hampshire timber rattlesnake population
- Evaluate opportunities to develop captive breeding in zoos for high priority species, especially invertebrates
- Investigate link between species population dynamics and habitat / natural community distribution and conditions

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Transportation Infrastructure

1. DEFINITION

As human populations grow and expand, the demand for improved and more extensive transportation networks rises. Major transportation infrastructures in New Hampshire include roads, railroads, and airports. Direct threats from construction, improvements, maintenance, and regular use of transportation networks include habitat loss and fragmentation, inhibition of wildlife dispersal, and direct mortality. Several indirect threats are known and summarized under Altered Hydrology, Development, Introduced Species, Mercury, Non-point Source Pollution, and Predation and Herbivory (see Forman et al. 2003 for a detailed review of known impacts).

2. EXPERT OPINION

Roads have a somewhat to very extensive effect on species and habitats of conservation concern in New Hampshire. Well-documented impacts are likely to be critical for Appalachian oak pine forests, and serious for pine barren species, vernal pools, marsh and shrub wetlands, and floodplain forests in the near term. In the next decade, threats may become critical or serious to rare species, including timber rattlesnake, hognose snake, black racer, Blanding's, spotted, and wood turtles, Jefferson salamander, Fowler's toad, American marten, and Karner blue butterfly. In the longer term, threats will be serious or greater for many forest habitats, watersheds, and wide-ranging species, and area-sensitive species.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Rapid growth

New Hampshire's human population density and associated development are rapidly increasing, especially in the southern counties (Society for Protection of New Hampshire Forests 2005).

TABLE 4-34. Number of habitats and species at highest risk from the effects of transportation infrastructure. See Table 4-35 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	1	0
3	3	8
2	8	4
1	6	12

Increasing human population density leads to increasing road densities, road widening, and traffic volume (see Development threat).

(B) Uncoordinated planning

Local land use planning efforts often are isolated from large-scale conservation planning efforts. Lack of planning and coordination among towns, transportation and natural resources agencies, and the conservation community may result in the most ecologically significant resources being affected.

(C) Habitat loss and fragmentation

The construction of roads, railroads, and airports results in a considerable loss of habitat (Trombulak and Frissell 2000). Wildlife is affected well beyond the scope of the actual physical disturbance (Forman 2000, Forman and Deblinger 2000, Jones et al. 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). Areas bisected by roads result in smaller blocks of contiguous habitat, fragmenting the landscape, reducing habitat quality, and isolating populations (Saunders et al. 1991)

(D) Vegetation management

Areas surrounding airport runways and roadsides

TABLE 4-35. Habitats and species at highest risk from the effects of transportation infrastructure, in descending order by Rank.See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores*					Rank	Class
		1	2	3	4	5		
SPECIES								
Jefferson Salamander	Vernal Pools	4	3	3	4	4	3.21	3
Blandings Turtle	Marsh and Shrub Wetlands	4	4	2	3	4	3.00	3
Spotted Turtle	Marsh and Shrub Wetlands	4	4	2	3	4	3.00	3
Fowlers Toad	Pine Barrens	4	3	2	4	4	2.92	3
Northern Leopard Frog	Grasslands	4	3	2	4	4	2.92	3
Karner Blue Butterfly	Pine Barrens	2	4	4	4	3	2.75	3
Racer	Pine Barrens	4	4	2	3	3	2.67	3
Hognose Snake	Pine Barrens	4	3	3	3	3	2.63	3
Wood Turtle	Floodplain Forests	4	3	1	3	4	2.33	2
American Marten	High Elevation Spruce-Fir Forest	3	2	4	4	3	2.29	2
Bobcat	Upland Forests	4	3	2	3	2	2.04	2
Spruce Grouse	High Elevation Spruce-Fir Forest	2	2	4	4	4	2.00	2
HABITATS								
	Appalachian Oak Pine Forest	4	4	3	3	4	3.33	4
	Vernal Pools	4	3	3	4	4	3.21	3
	Floodplain Forests	4	3	2	3	4	2.63	3
	Marsh and Shrub Wetlands	4	3	2	3	4	2.63	3
	Coastal Transitional Watersheds	3	3	4	3	3	2.50	2
	Lowland Spruce-Fir Forest	2	3	4	4	4	2.50	2
	Salt Marshes	2	3	4	4	3	2.29	2
	Non-Tidal Coastal Watersheds	3	3	3	3	3	2.25	2
	Tidal Coastal Watersheds	3	3	3	3	3	2.25	2
	Hemlock-Hardwood-Pine Forest	3	2	3	3	3	1.88	2
	Northern Hardwood-Conifer Forest	3	2	3	3	3	1.88	2
	Southern Upland Watersheds	2	3	3	3	3	1.88	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

often are cleared of native vegetation and are maintained as homogenous mowed habitat, largely due to safety concerns (Forman et al. 2003). Because roads are extensive in the landscape, roadside habitat loss can be substantial. Mowing during critical times can have serious effects on local populations of plants or wildlife (e.g., Karner blue butterfly, frosted elfin butterfly, Persius duskywing skipper, and grasshopper sparrow). Karner blue butterflies are attracted to abundant non-native nectar plants along road edges (S. Fuller, NHFG, unpublished data).

(E) Dispersal

The effects of roads as barriers to wildlife movement are widespread (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 may be ineffective for passage of aquatic organisms (Jackson 2003).

(D) Mortality and collision

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). 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). Turtles are attracted to the bare soil and open canopy of road shoulders, 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, may cause safety concerns for motorists.

4. RESEARCH NEEDS

Note: A group of biologists from NHFG and other environmental agencies and staff from the Department of Transportation will meet in the future to determine research priorities related to roads as determined by a Roads Working Group forum held on December 1, 2004 hosted by the NHFG, Concord.

- 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

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Unregulated Take

1. DEFINITION

Loss of individuals may result in locally reduced population size, altered population structure, or extirpation, especially for small or isolated populations and species that depend on high adult survivorship. In New Hampshire, many species are currently unregulated (exceptions include threatened or endangered species, game species, and those protected under New Hampshire Fish and Game possession rules). Regulated species may be vulnerable to incidental take from legal activities (e.g. hunting, trapping, and commercial fishing). Enforcement of incidental take may be difficult, and penalties may not be sufficient to deter illegal take.

2. EXPERT OPINION

Unregulated take is considered a chronic to serious threat for wildlife species found in pine barren, cliff, alpine, floodplain, and peatland habitats. Unregulated take was considered very localized but may have more extensive and more severe effects on wildlife populations with limited distributions (e.g., timber rattlesnakes and hognose snakes) or high exposure to human populations (e.g., Blanding's and spotted turtles) or human activities (i.e., trapping of American marten). Some local populations are likely to be affected in the short-term. However, effects on populations of long-lived species may go undetected for years. Effects are weakly to somewhat documented for most species or habitats and well documented for timber rattlesnakes.

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) 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). It is illegal to possess, sell, or import timber rattlesnakes (state endangered), eastern hognose snakes (state threatened), Blanding's turtles, spotted turtles, wood turtles, eastern box turtles, and marbled salamanders (state endangered) (RSA 212-A, New Hampshire Fish and Game (NHFG) Rules Fis 800). 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). No other reptiles and amphibians are regulated at this time. Painted turtles were one of the top reptile species exported from the United States (Franke and Telecky 2001). Harvesting snapping turtles for food is currently unregulated in New Hampshire, and at least one commercial collector has been reported (Taylor in Tyning 1997, M. Marchand, personal observation); strict regulations in surrounding states (e.g., Maine) may increase collection pressure for New Hampshire's populations.

TABLE 4-36. Number of habitats and species at highest risk from the effects of unregulated take. See Table 4-37 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	0	0
3	0	1
2	0	2
1	6	13

(B) Human values

Humans have a negative perception (fear) of some species and regard others as pests. Negative

TABLE 4-37. Habitats and species at highest risk from the effects of unregulated take, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores*					Rank	Class
		1	2	3	4	5		
SPECIES								
Timber Rattlesnake	Appalachian Oak Pine Forest	4	3	3	3	4	2.92	3
American Marten	High Elevation Spruce-Fir Forest	3	2	4	4	3	2.29	2
Spruce Grouse	High Elevation Spruce-Fir Forest	1	4	4	4	3	2.29	2
Hognose Snake	Pine Barrens	3	3	2	3	3	2.00	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

perceptions may lead people to destroy wildlife regardless of actual danger. Only 1 of the 11 native New Hampshire snakes are venomous, and this species (timber rattlesnake) is extremely rare and unlikely to strike unless provoked. 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.

(C) 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 and bobcat may be incidentally captured in leghold traps designed for canids or killing (e.g., conibear) traps designed for mustelids. American marten may be taken in fisher traps. Spruce grouse may be confused with ruffed grouse and taken by hunters (J. Kelly, NHFG, personal communication). Turtles may be taken in conibears set under water for beaver and otter but the impact on at-risk turtle populations is unknown (K. Tuttle and E. Orff, NHFG, personal communication). On a larger scale, incidental take of non-target species is a persistent problem in the commercial fishing industry (National Marine Fisheries Service 1998).

(D) 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.

4. 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)
- Create list of pet stores, pet trade expos, and web sites that sell reptiles and amphibians in New Hampshire; survey which species of reptiles and amphibians are for sale (both native and non-native)
- Assess Cliff, Floodplain Forest, and other vulnerable habitats for risk of over collection of vegetation

- Compile information on incidental captures (e.g., survey trappers and hunters) and assess ways to eliminate or reduce mortality of non-target species

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Unsustainable Forest Harvesting

1. DEFINITION

Timber harvests greatly affect (positively or negatively) the current and future condition of New Hampshire's forests and associated wildlife habitats (NHDFL and SPNHF 1997). When done in an ecologically sustainable manner, timber harvesting can enhance New Hampshire's economy while enhancing certain wildlife habitat. However, if neglected or overlooked, non-timber values such as soil quality, wetland and water quality, forest age structure, plant and wildlife habitat, and others may suffer (Hansen et al. 1991, DeGraaf et al. 1992, Cullen 1996). For instance, high-intensity harvesting that exceeds forest growth over large areas increases habitat fragmentation and dramatically decreases age-class diversity (McCarthy 1995, Hunter 1999). This, in turn, results in less available wildlife habitat, especially for species that require mature forest or abundant coarse woody debris (e.g., American marten) (Hargis et al. 1999). Additionally, ecologically unsustainable harvesting can result in forest type conversion (e.g., from spruce-fir to tolerant hardwoods) (Hunter 1990, Hunter 1999), thereby reducing habitat for certain species.

2. EXPERT OPINION

Ecologically unsustainable forest harvesting, including liquidation harvesting and harvesting that leads to forest type conversions, is a serious to critical threat to New Hampshire's lowland spruce fir forests and associated wildlife species, especially American marten, spruce grouse, and three-toed woodpecker. Harvesting without regard to soil productivity and erosion, water quality, plant and wildlife habitat, and other non-timber values is a serious threat in most forest types. Harvesting in general is ecologically unsustainable in high-elevation spruce-fir forests and floodplain forests and is a serious threat in both forest types.

TABLE 4-38. Number of habitats and species at highest risk from the effects of unsustainable forest harvesting. See Table 4-39 and Appendix A and B for details. Risk Category 4 = Greatest risk.

Risk Category	Habitats	Species
4	1	0
3	0	4
2	7	1
1	9	15

3. KNOWN WILDLIFE EXPOSURE PATHWAYS

(A) Liquidation harvesting

The state of Maine defines liquidation harvesting 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 5 years" (Sec. A-1. 12 MRSA c. 805). Liquidation harvesting commonly leads to subdivision and development that causes a decrease in available wildlife habitat and fragmentation of what remains (Maine Forest Service (MFS) 2002). MFS has concluded that 3% to 12% of all harvests in Maine are liquidations (6,300 to 25,200 ha/yr) (MFS 2002). No such assessment has yet been completed for New Hampshire. However, based on observations of wildlife and forestry professionals, similar percentages are expected in this state, mostly in the north. This has serious implications for American marten, three-toed woodpecker, spruce grouse, and other species. The Society for the Protection of New Hampshire Forests and the Timberland Owners Association is in the process of assessing timber harvest patterns in New Hampshire.

(B) Forest type conversion

Forest type conversion is most pronounced in low

TABLE 4-39. Habitats and species at highest risk from the effects of unsustainable forest harvesting, in descending order by Rank. See Appendix A and B for details additional information on specific threats and rankings.

Species	Habitat	Ranking Scores*					Rank	Class
		1	2	3	4	5		
SPECIES								
American Marten	High Elevation Spruce-Fir Forest	3	4	4	4	3	3.21	3
Spruce Grouse	High Elevation Spruce-Fir Forest	3	4	4	4	3	3.21	3
Common Tern	Coastal Islands	4	3	3	3	4	2.92	3
Roseate Tern	Coastal Islands	4	3	3	3	4	2.92	3
Three-toed Woodpecker	Lowland Spruce-Fir Forest	2	3	3	3	4	2.08	2
HABITATS								
	Lowland Spruce Fir Forest	4	3	4	4	4	3.50	4
	Hemlock-Hardwood-Pine Forest	3	3	4	3	3	2.50	2
	High Elevation Spruce-Fir Forest	2	3	4	4	4	2.50	2
	Northern Hardwood-Conifer Forest	3	3	4	3	3	2.50	2
	Appalachian Oak Pine Forest	2	3	4	4	3	2.29	2
	Northern Upland Watersheds	3	3	3	3	2	2.00	2
	Floodplain Forests	2	3	3	3	3	1.88	2
	Peatlands	2	3	3	3	3	1.88	2

* 1=Scope, 2=Severity, 3=Timing, 4=Likelihood, 5=Information

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. According to mapping conducted for the Comprehensive Wildlife Conservation Strategy (see low elevation spruce-fir forest profile), New Hampshire only has 34% of the low elevation spruce-fir forest that is ecologically possible (106,411 ha of 311,629 ha possible).

(C) Lack of on-timber values

Timber harvesting can have a significant impact 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 1997).

Harvesting near vernal pools may reduce canopy cover, increase water temperatures not suitable to breeding amphibians, and cause premature drying of the pool (Calhoun and deMaynadier 2004).

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).

4. RESEARCH NEEDS

- Assess current timber harvest levels and patterns in New Hampshire to better understand the extent of

unsustainable harvesting in the state
- Determine the forest structure and management actions needed to sustain three-toed woodpeckers
- Define long- and short-term impacts of clear-cutting on vernal pool wildlife survival and reproductive success

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