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Assessment of Natural Resource Conditions in and Adjacent to Acadia National Park, Maine

U.S. Department of Interior

National Park Service
U.S. Department of the Interior

Natural Resource Program Center

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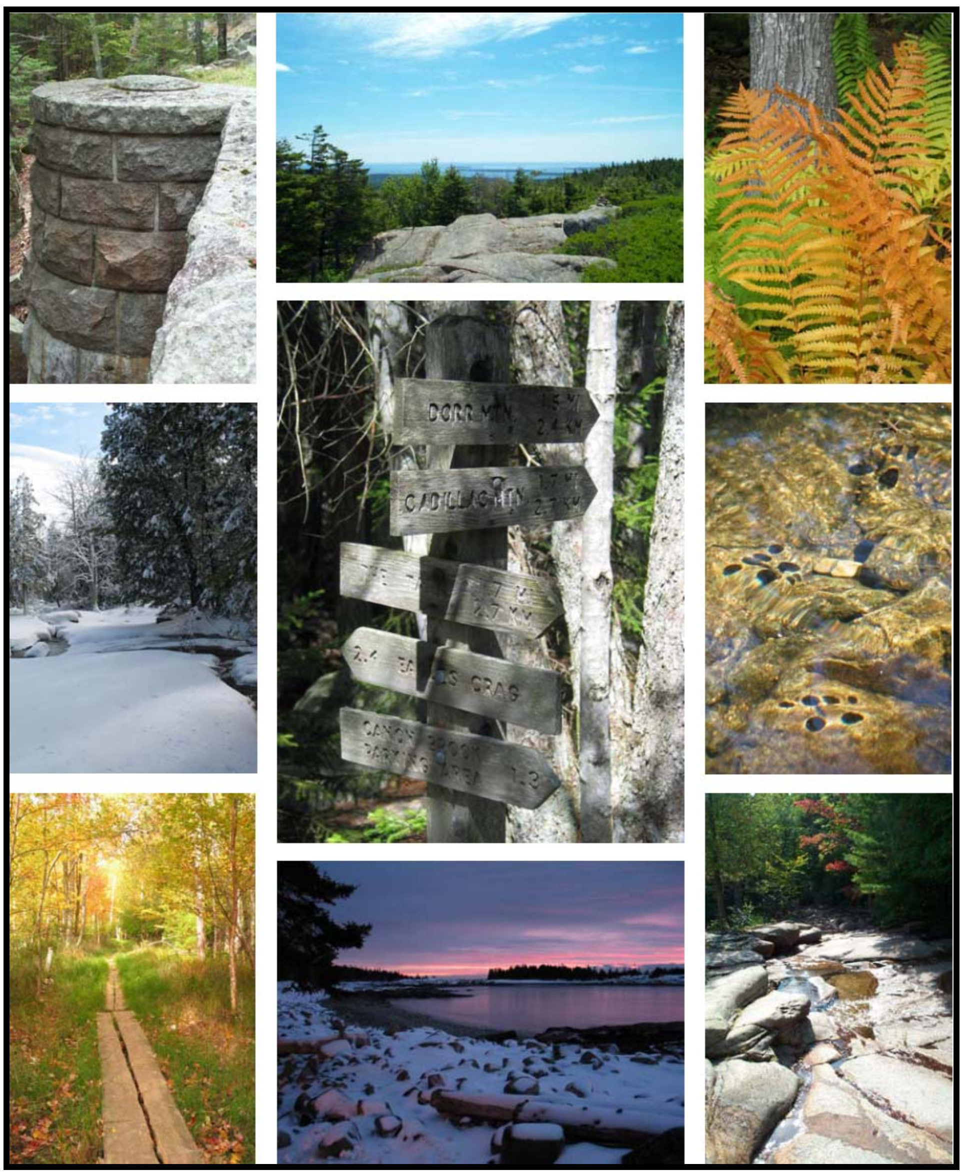
Natural Resource Report NPS/NRPC/WRD/NRR—2008/069



ON THE COVER

Clockwise, from top left: Maple Spring Bridge, view from Sargent Mountain, ferns near Sieur de Monts Spring, water striders on Hadlock Brook, Cañon Brook near Murray Young trail, sunrise from Schoodic Point in winter, Jesup Path in autumn, Cañon Brook in winter. Center: trail signpost near Cadillac Mountain.

All photos: Sarah Nelson or Ken Johnson.

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NPS D-344, November 2008

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Acronyms and Abbreviations

ACAD – Acadia National Park
ANC – acid neutralizing capacity
AOP – aquatic organism passage
C:N – carbon to nitrogen ration
Ca:Al – calcium to aluminum ratio
CACO – Cape Cod National Seashore.
CASTNET – Clean Air Status and Trends Network
CBC – Christmas Bird Counts
CERCLA – Comprehensive Environmental Response, Compensation and Liability Act
CM – Cadillac Mountain
CWD – coarse woody debris
DDE – dichlorodiphenyldichloroethylene, a metabolite of DDT
DMR – Maine Division of Marine Resources
DO – dissolved oxygen
DOC – dissolved organic carbon
EP – Existing problem
EVI – Marine Environmental Vulnerability Index
GIS – Geographic Information System
GMP – General Management Plan
GNOME – General NOAA Ocean Modeling Environment
GRSM–LR – Great Smoky Mountains NP - Loon Rock
H_2SO_4 – sulfuric acid
Hg – mercury
HGM – hydrogeomorphic classification system
HP – Historic problem
IAH – Isle au Haut
IMPROVE – Interagency Monitoring of Protected Visual Environments
ISL – small offshore islands
MANE–VU – Mid-Atlantic/Northeast Visibility Union
MDEP – Maine Department of Environmental Protection
MDI – Mount Desert Island
MDIFW – Maine Department of Inland Fisheries and Wildlife
ME–DOT – Maine Department of Transportation
MeHg – methymercury
MH – McFarland Hill
MNAP – Maine Natural Areas Program
MOSIS – Marine Oil Spill Information System
N – nitrogen
NADP – National Atmospheric Deposition Program
NEC – Northeast Creek
NEEA – National Estuarine Eutrophication Assessment
NETN – Northeastern Temperate Network
NEWS – New England Wadeable Streams Project
NH_4 – ammonium

NLERT – GIS-based decision support system developed by USGS
NO_3 – nitrate
NOAA – National Oceanic and Atmospheric Administration
NPS – National Park Service
NRCS – Natural Resources Conservation Service
NST – National Status and Trends
OK – Problem unlikely
P – phosphorus
PAH – polynuclear aromatic hydrocarbons
PCBs – polychlorinated biphenyls
PEARL – Maine source for environmental information; www.pearl.maine.edu
PP – Potential problem
PRIMENet – Park Research and Intensive Monitoring of Ecosystems
RCRA – Resource Conservation and Recovery Act
ROMO – Rocky Mountain NP
S – sulfur
SCH – Schoodic Peninsula
SHEN – Shenandoah NP
SO_2 – sulfur dioxide
SO_4 – sulfate
S–Rank – State rank
TN – total nitrogen
TP – total phosphorus
TRI – Toxics Release Inventory
Unk – Unknown
URI – University of Rhode Island
USEPA – U.S. Environmental Protection Agency
USGS – U.S. Geological Survey
UV – Ultraviolet radiation
VOCs – volatile organic compounds
WHAM – Wildland Hazard Assessment Methodology
YOSE–TD – Yosemite NP - Turtleback Dome

Executive Summary

This report is an assessment of condition of the natural resources of Acadia National Park (ACAD) and an evaluation of the threats and stressors that act on these resources. A variety of threats to habitat and biological integrity are management concerns at ACAD. Consequently, improved understanding of the state of knowledge regarding the condition of the Park's natural resources and the threats acting on these resources is needed to guide data collection and broader natural resource assessment efforts. As development continues to expand adjacent to the park boundaries and as visitor use increases, park managers are continually challenged to address a spectrum of issues such as water quality degradation, introduction of exotic species, air pollution, habitat fragmentation, recreational use, and others. These may all have dramatic impacts on aquatic and terrestrial ecosystem function and integrity, and habitat quantity and quality.

This Assessment focuses on three broad resource groups: Uplands, Freshwaters (lakes, streams, wetlands, groundwater), and Marine/Coastal areas. It is based entirely on compilations, syntheses and new analyses of pre-existing data, and an in-depth review of the scientific literature associated with ACAD. No new field data were collected for the study. The Assessment is intended to assist Park managers and external researchers by (i) providing a synthesis of information about natural resources at ACAD, (ii) describing the suite of threats known or thought to be affecting these resources, (iii) analyzing information from a series of metrics and other descriptors of resource condition, and (iv) evaluating information richness and identifying key information gaps.

This report is structured into five primary sections: (i) **Park Description**; (ii) **Resource Characterization** (a synthesis of information describing the physical, chemical and biological resources of ACAD); (iii) **Assessment of Threats** (an in-depth review of the suite of environmental threats and stressors present in the Acadia region and their impacts on Park ecosystems); (iv) **Assessment of Resource Condition** (quantitative and qualitative analyses of data from metrics and other descriptors of resource condition); (v) **Conclusions and Information Needs** (a review of the extent of knowledge about natural resources at ACAD and key data gaps).

The Park includes a mix of islands and ocean unequaled along the Atlantic coast of the United States. Most of the Park lands are on Mount Desert Island (MDI); other holdings are on the Schoodic Peninsula, Isle au Haut and several smaller islands. ACAD is located in a broad transition zone between southern deciduous and northern coniferous forests. Local habitats range from coastal to sub-alpine, and include old-growth spruce-fir and jack pine forests, meadows, freshwater wetlands and salt marsh, over 20 lakes (with some of the best water quality in the state), and a stream network occupying 12 major watersheds. Forests and human-affected areas comprise 75% and 10%, respectively, of the total area of ACAD and vicinity. Urban land and areas of herbaceous vegetation increased by 118% and 68%, respectively, between 1976 and 2002, with most of the increase in urban land cover occurring in a buffer area around the Park. ACAD harbors 54% of the plant species listed for Maine. Nearly 20% of ACAD plants are locally-rare or State-listed, while about a quarter are exotic. The Acadia area has over 200 resident bird species, as well as over 40 migrants. Twenty eight freshwater fish species, and 19 amphibians and reptiles are known to be present in the Park. ACAD receives over 2 million visitors per year, with most visits occurring during the summer and fall months.

Some of the major threats to natural resources at ACAD include:

- Ozone - causes leaf damage and reduces growth rate in some plant species.
- Atmospheric deposition of nitrogen, sulfur, acidity, mercury and other contaminants – producing multiple effects on both abiotic and biotic components of terrestrial and aquatic systems, including high mercury levels in fish and other animals, and chronically elevated nitrogen concentrations in streams.
- Nutrient enrichment – of particular concern for the two major estuarine/wetland complexes on MDI as development increases in their watersheds. Although eutrophication remains a threat for the Park's lakes and ponds, current water quality in these waters is good.
- Contaminants – although there are a number of potential contaminant sources in the Acadia region, levels in environmental media are generally low (except for mercury).
- Changes in fire regimes – a major fire on MDI 61 years ago has had a major and lasting influence on terrestrial and aquatic systems, re-setting biogeochemical responses. Other areas have not burned in centuries, possibly longer than the natural fire return interval.
- Altered hydrology – dams, culverts, ditching and other factors have likely resulted in multiple impacts to lakes, stream and wetland habitats.
- Habitat impairment and loss – including fragmentation of terrestrial habitat, and barriers to passage of fish and other aquatic organisms. Over 80% of stream crossings on MDI are thought to completely or partially block passage.
- Visitor use – including trampling of vegetation and disturbance of some birds.
- Exotic species, including invasive species – although ACAD has fewer exotic species than other park units in the Northeast, approximately one quarter of its plant species are non-natives. Park management includes control of invasive species such as purple loosestrife. Currently no aquatic invasive plant species occur in the Park. Approximately one half of the freshwater fish species in the Park are not native to MDI and "bait bucket" introductions may increase this number. Several marine invasive animal species are known to occur in or near ACAD.
- Pests and pathogens – including beech bark disease and hemlock woody adelgid, as well as several pathogens in amphibian populations.
- Climate change – although this will have (and is likely already having) multiple impacts at ACAD, these have so far not been well-studied.

A suite of metrics and other attributes was used to characterize resource condition by assigning to each metric in each resource group a three-class ranking system: "Good", "Caution", or "Significant Concern". This process was based on a very heterogeneous information base – one that made it impossible to conduct a fully quantitative and consistent condition assessment. Because of this, it is potentially misleading to compare condition across the different resource groups by simply summarizing the numbers of metrics assigned to each condition rank value. Nonetheless, a summary of metric rankings is as follows:

Air:	Good (0); Caution (4); Significant Concern (5); Insufficient data (0).
Terrestrial:	Good (9); Caution (10); Significant Concern (1); Insufficient data (5).
Streams:	Good (7); Caution (3); Significant Concern (3); Insufficient data (1).
Lakes:	Good (12); Caution (4); Significant Concern (1); Insufficient data (0).
Wetlands/Estuaries:	Good (3); Caution (2); Significant Concern (2); Insufficient data (7).
Groundwater:	Good (4); other ranks (0).
Marine:	Good (2); Caution (2); Significant Concern (3); Insufficient data (3).

The information on which threat and condition assessments at ACAD are based is best developed for terrestrial systems, lakes/ponds and streams. It is least developed for wetlands and intertidal / coastal areas. While much is known about some stressors (for example atmospheric deposition and other aspects of air quality), the impacts of these stressors on the plants and animals of the Park are generally much less well understood. Synergistic effects from multiple stressors are virtually unstudied at ACAD. There is an urgent need for more information to document temporal trends and variability in population structure and community composition of floral and faunal groups. In addition, inventories are needed for many biological groups.

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Introduction

The U.S. Congress, in its FY 2003 Appropriations Act, instructed and funded the National Park Service (NPS) to assess environmental conditions in watersheds where National Park units are located. A variety of threats to habitat and biological integrity are management concerns for many Parks. Consequently, NPS needs to better understand and evaluate the state of knowledge regarding the condition of its natural resources and the threats that affect these resources, and then use this information to further guide data collection and broader natural resource assessment efforts.

This report is an assessment of condition of the natural resources of Acadia National Park (ACAD) and an evaluation of the threats and stressors that act on these resources. The study (hereinafter referred to as the "Assessment") focuses on three broad resource groups: Uplands, Freshwaters (lakes, streams, wetlands, groundwater), and Marine/Coastal areas. The landscape at ACAD is diverse, including mountains, valleys and flatter terrain, forest and open lands, lakes and ponds, freshwater wetlands and salt marshes, estuaries and extensive rocky shores. As development continues to expand adjacent to the park boundaries and visitor use increases, park managers are continually challenged to address a spectrum of issues such as water quality degradation, introduction of exotic species, air pollution, habitat fragmentation, recreational use, and others. These may all have dramatic effects on aquatic and terrestrial ecosystem function and integrity, and habitat quantity and quality.

Ecologically, many of the natural resources at ACAD are integrally linked to surrounding watershed and coastal areas that lie outside of the Park boundary. Thus, although the primary focus of the Assessment is on Park lands and waters, we also include information from outside of the Park, particularly on Mount Desert Island.

The Assessment is based entirely on compilations and syntheses of pre-existing data, and an in-depth review of the scientific literature associated with ACAD. No new field data were collected for the Assessment. There is an impressive body of scientific research at ACAD, undertaken over many decades. A substantial segment of this material was addressed during our study. The Assessment is intended to assist Park managers and external researchers by (i) providing a synthesis of information about natural resources at ACAD, (ii) describing the suite of threats known or thought to be impacting these resources, (iii) analyzing information from a series of metrics and other descriptors considered useful to assess condition in the Park, and (iv) evaluating information richness and identifying key information gaps.

This report is structured into five primary sections.

***Park description*:** This section includes a brief introduction to ACAD, summarizing the extent and location of Park-associated lands, and providing an overview of the areal extent and composition of the natural resources.

Resource characterization: In this section we present a synthesis of information characterizing the physical, chemical and biological resources of ACAD. Rather than attempting a comprehensive characterization of ACAD ecosystems, we focus on (i) key ecosystem descriptors and (ii) additional selected attributes that are associated with generally accepted measures of resource condition. Further information describing the natural resources of the Acadia region is contained in the sections of this report that address threat and condition assessments.

***Assessment of threats*:** Threat assessments cannot be fully separated from a discussion of resource condition. For example, spatial and temporal patterns of mercury levels or non-native species relate both to assessment of threats and to characterization of condition. To maintain a tighter focus on individual topics in this report, we present most of the assessment information within this section. Information that specifically addresses metrics and other attributes of condition is then summarized within a subsequent section, "Assessment of Resource Condition".

***Assessment of resource condition*:** This Assessment used an information base that is very heterogeneous in terms of both quantity and quality. Consequently, a consistent and fully quantitative assessment of resource conditions was an unrealistic goal. Rather, using our evaluation of threats, approaches adopted by other programs (e.g. Mitchell *et al*. 2006, Kahl *et al*. 2000), as well as ecological theory, we identified a series of metrics or attributes with which to characterize condition. We then assessed condition by describing metric or attribute "values" to the extent possible using available data. For some metrics, it was possible to compare conditions at ACAD with 'external' criteria or regional data sets. For others, it was only possible to make general statements about condition. The approach is further described later in this report.

Conclusions and Information Needs: The Assessment concludes with an overview of information richness and data gaps. Discussion of information needs is largely organized around the series of threat sub-topics and is intended to highlight areas where new research is needed to better understand the action of stressors, document status and trends, and measure ecological condition.

Park Description

Size and Location of Park Lands and Conservation Easements

Acadia National Park (ACAD) preserves approximately 20,000 hectares in Hancock and Knox Counties, located along the Maine coast in the northeastern United States (Figure 1). It consists of land on Mount Desert Island (MDI) plus portions of and entire outlying smaller islands, a portion of Isle au Haut (IAH) to the southwest of MDI, and the tip of the Schoodic Peninsula (SCH) located on Maine's mainland to the east of MDI (Figure 2, Figure 3).

Eighty-five percent of ACAD fee-owned lands are on MDI, 6% on SCH and 9% on IAH (Table 1). Approximately one half of each of MDI and IAH is within the Park. In addition, the Park holds over 200 conservation easements in the Penobscot and Frenchman Bay areas. Park lands are not contiguous but are rather interspersed with private lands.

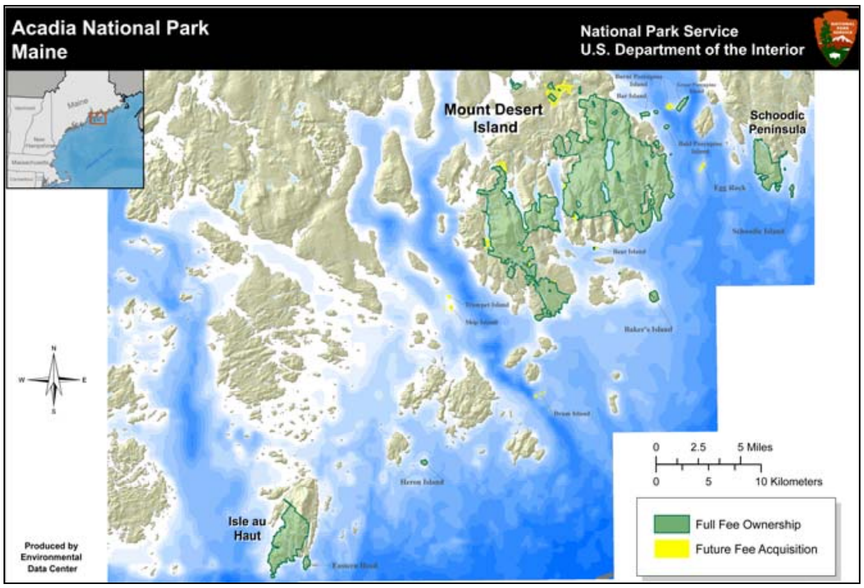


Figure 1. Locator map of Acadia National Park.

The Park was created to protect the natural beauty of the highest rocky headlands along the Atlantic shore of the United States. The enabling legislation specifically mentioned the "historic significance" of the area and the unique natural resources which were of great "scientific interest" (Manski 1998).

The Park's mission statement is: "The National Park Service at Acadia National Park protects and conserves outstanding scenic, natural, and cultural resources for present and future generations. These resources include a glaciated coastal and island landscape, biological diversity, clean air and water, and a rich cultural heritage. Acadia National Park also offers opportunities for high-quality non-consumptive recreation, education, and scientific research" (NPS 1997).

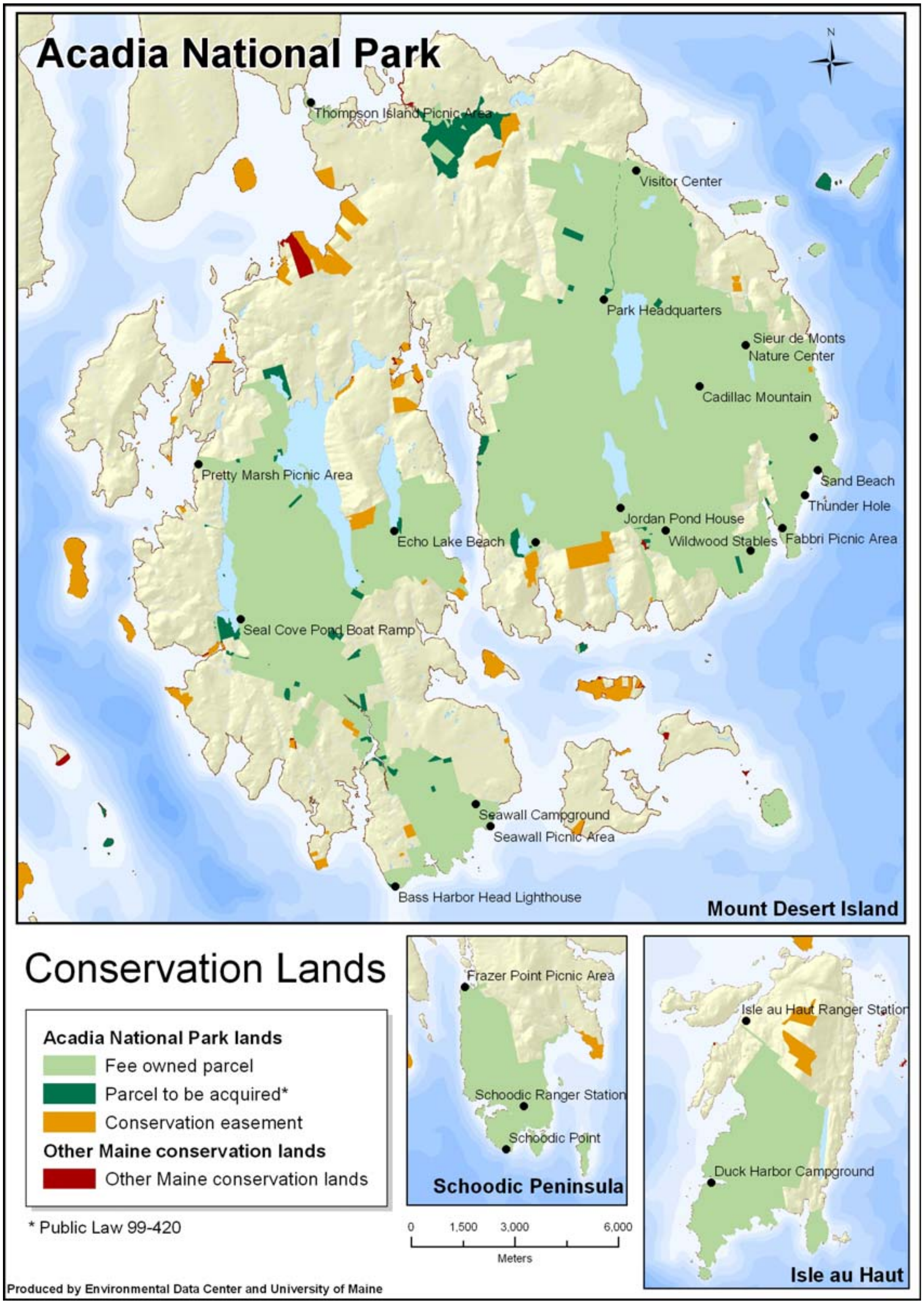


Figure 2. Acadia National Park lands, acquisition parcels, conservation easements, and other conservation lands in the vicinity of the Park. Not shown: several small islands with fee-owned or conservation easement status. Data source: Acadia National Park.

Figure 3. Named features in ACAD and surrounding areas.

The ACAD General Management Plan (GMP) describes the Park's significance as a mix of islands and ocean unequaled along the Atlantic coast of the United States (NPS 1992). Natural resources, as described within the GMP, emphasize the Park's unique location as a transition zone between temperate deciduous and northern coniferous forests overlaying glacially sculptured granite mountains with interspersed glacially scoured lakebeds and bounded by high rocky headlands. Noteworthy natural resources within the Park include old-growth forests, sub-alpine communities, heaths and marshes, an exceptionally diverse flora, over 40 species of mammals, and documented sightings of over 300 bird species. Significant cultural resources include light stations, 19th century frame buildings, an 80 km carriage road system with 17 stone bridges, and the Islesford Historical Museum.

Location and Extent of the Upland, Freshwater, Wetland and Marine/Coastal Systems

For this assessment, we considered not only lands in fee ownership by the NPS, but also other lands that contribute to the major watersheds on MDI (Figure 2). Because of the fragmented nature of ACAD, many of the park-owned lands are ecologically linked to lands in private ownership. The total watershed area considered in this report, therefore, is ~ 32,000 ha, of which lands within the ACAD legal boundary comprise approximately 63% (20,179 ha; Table 1). We use the term ‘ACAD region’ to refer to the total watershed area treated in this document.

Elevation at ACAD ranges from 0 m to 466 m above sea level; the Otter Creek and Cañon Brook sub-watershed on MDI includes both extremes. The total length of roads in the ACAD **region** is 241 km, and the total length of mapped trails is 785 km; within the Park itself, there are 193 km (120 miles) of hiking trails and 71 km (44 miles) of carriage roads (Table 1 and Manski, pers. comm. September 2008). There are 32 ponds and lakes in the ACAD region (Table 1), with a total pond/lake area of 83 ha. Nineteen of these waterbodies are considered “Great Ponds” (surface area >10 acres) by the State of Maine. Of these 19 Great Ponds, 14 are entirely or partially within ACAD (although not legally considered Park-owned resources). Mapped streams total 301 km length in the ACAD region. Including lakes, streams, coastal wetlands and estuaries in the broad category of ‘wetlands’, there are 2,478 ha of wetlands in the ACAD region (this estimate does not include many vernal pools). Approximately 65 km of coastline are within / adjacent to the Park boundary; coastline within the broader ACAD region is substantially longer.

The ACAD region has been delineated into 300 sub-watersheds, 256 of which are on MDI (Perrin 1996). Sixty percent (154) of the MDI watersheds have areas greater than 5 ha. These sub-watersheds can be aggregated into larger units at several spatial scales (Figure 4). Core attributes of watershed clusters (level C in Figure 4) are provided in Appendix 1. At the sub-watershed level, drainages range from 0%-98% within the Park. On average, 51.5% of sub-watershed areas on MDI are within the Park (overall, ACAD lands represent just under 45% of the total area of MDI).

Using USGS-NPS Vegetation Mapping Project (Lubinski *et al*. 2003) data for the ACAD region, we determined land-use/cover for lands within Park boundaries and for the whole-watershed areas, including small offshore islands (total area of offshore islands in fee ownership = 264 ha).

Table 1. Geography of Acadia National Park – key statistics

Total area within park boundary	20,179 ha
Lands under NPS fee ownership	14,501 ha
Conservation easements to NPS	5,067 ha
Acquisition parcels	611 ha
Percent total fee-owned lands on :	
Mt. Desert Island (MDI)	85.2 %
Schoodic (SCH)	5.6 %
Isle au Haut (IAH)	9.2 %
MDI – Total area (park and non-park lands)	28,105 ha
IAH – Total area (park and non-park lands)	2,711 ha
Resource Management Classes	
Natural environment zone [1]	12,343 ha
Outstanding Natural Zone [2]	1,893 ha
Historic and Cultural Zones	197 ha
Development Zone [3]	369 ha
Length of coastline within park boundary	approx. 65 km
Number of major watershed systems (MDI) [4]	12
Number of "Great Ponds" (> 4 ha/10acres):	
Completely surrounded by park lands [5]	12
Partially surrounded by park lands	5
On MDI, not surrounded by park lands	5
Number of ponds < 4 ha completely surrounded by park lands	10
Number of named streams:	
Inside park boundary	13
Partly outside park boundary	21
Maximum elevations:	MDI: 466 m IAH: 163 m SCH: 134 m
Total length of park-maintained paved and unpaved roads:	241 km
Total length of trails	785 km

(1) Predominantly forested lands; development and use limited to trails network.
(2) Areas of 'scenic splendor, natural wonder or scientific importance'.
(3) Visitor center, park housing, campgrounds and other park infrastructure.
(4) See Fig. 4 for finer-scale watershed 'clusters'
(5) Lands within ACAD legal boundary

Data sources: Park areas, 2005 data supplied by ACAD. Resource management classes – NPS 2004. Hydrology and roads: Kahl *et al*. 2000. Other data derived from GIS coverages supplied by ACAD staff.

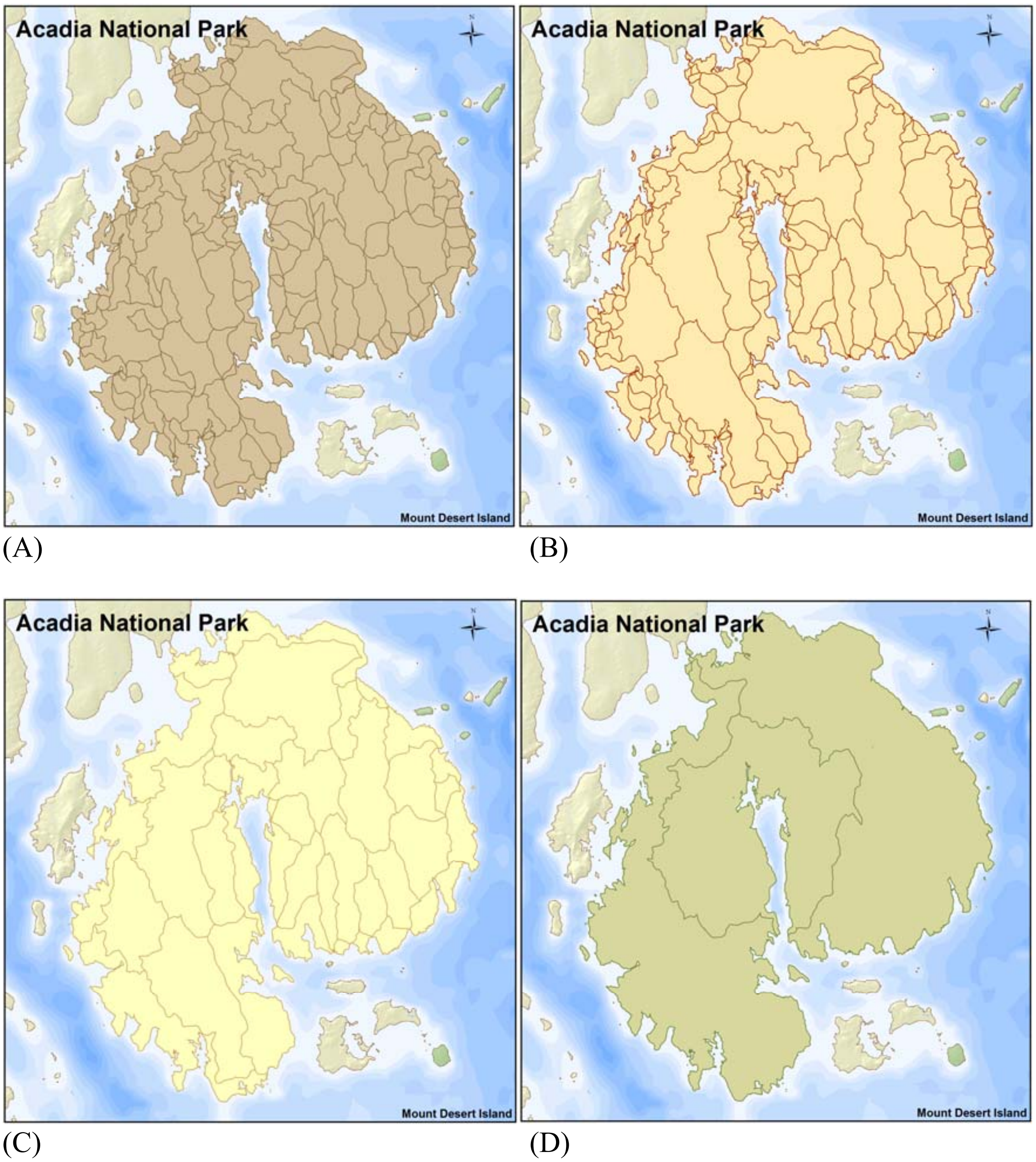


Figure 4. Aggregations of watersheds on MDI. (A) Small watersheds as delineated by Perrin (1996). (B) and (C) are increasing aggregations of small watersheds. (D) Perrin's three drainage districts. For level C drainages, small coastal watersheds were grouped subjectively; interior watersheds were largely grouped based on a hydrology-based code in the Perrin database. The level C aggregation is used for summarizing land cover/use statistics in Appendix 1.

We report statistics based on the attribute LUC-II (Land-use/cover), as reported in the ACAD vegetation map data. Table 2 presents summary data for the ACAD region, while Figures 5 and Appendix 1 provide land-use/cover data summarized by watershed cluster (Level C in Figure 4). The extent of anthropogenic land-use in sub-watersheds greater than 5 ha is shown in Figure 6.

Within the Park (fee-owned lands), forests are the largest landcover type (12,688 ha, or 86.5% of the Park's area), followed by wetlands (1201 ha [8.2%], which includes lakes and riparian areas), herbaceous/shrub/brush rangeland (464 ha [3.2%]), human-affected areas (214 ha [1.5%]; includes utilities, residential, service areas, roads, quarries, etc.), and finally bare rock (92 ha [0.6%]). For the entire area mapped by Lubinski *et al*. (2003) – i.e. ACAD plus surrounding areas – forests and human-affected areas comprise 75% and 10%, respectively, of the total area.

Wang *et al*. (2006) reported on change in land-use/cover over the period 1976-2002 (Table 3). There were large percentage increases in areas of urban land and herbaceous vegetation – 118% and 68%, respectively, between 1976 and 2002. The data in Table 3 cover ACAD itself together with a 5-km buffer zone around the Park. Most of the increase in urban land cover occurred in this buffer area.

Legislative Background and Management Objectives

Acadia National Park was established in 1916 as the Sieur de Monts National Monument. It was was given its current name in 1929, at which time legislation authorized expansion of the Park. In 1986 the permanent boundary was established. Four resource management classes have been defined for ACAD (NPS 1992). Descriptions and areas of these are provided in Table 1. For more information on legislative background and management objectives for ACAD, see Appendix 2.

Human Utilization of Park Resources

ACAD receives over 2 million visitors per year, with most visits occurring during the summer and fall months (Figure 7). Visitation appears to have peaked in the mid 1990s (note that this assumes that the disparity in the two curves in Figure 7A reflects the change in the visitor estimation method). Table 4 provides a synthesis of several visitor use data sets. Hiking trail use is shown in Figure 8. The eastern half of MDI is more visited than the western half. Most popular destinations include Cadillac Mountain, Sand Beach / Thunder Hole and Jordan Pond. Eleven percent of individuals surveyed in the late 1990s visited the Schoodic Peninsula, while 2% visited IAH. Counts of hikers in August indicate that >5,000 visitors enter trails daily. Typically, over 1,400 visitors per day use carriage roads during the peak months of July and August.

Day use visitation to IAH is between 5,500 and 6,900 persons per year, while overnight camper days range from 1,100 to 1,500 per year (Marion 2006). As with MDI, the majority of visitation to IAH occurs from late June through early September. Hiker numbers on IAH trails are much lower than on MDI – a high-use trail on IAH has about 10 visitors per day.

Table 2. Summary land-cover / land-use statistics for fee-owned parcels in ACAD (within-park area) and in the Park plus surrounding areas (total area)*. Data are based on USGS-NPS Vegetation Mapping Project (Lubinski *et al*. 2003).

USGS Land Use Code (LUC-II)	**Within-Park Area (ha)**	**Total Area (ha)**
11 – Residential	16.3	1533.4
12 - Commercial and Services	107.6	363.2
14 - Transportation, Communications, and Utilities	65.1	121.9
16 - Mixed Urban or Built-up Land	9.3	963.7
17 - Other Urban or Built-up Land	4.2	98.1
24 - Other Agricultural Land	3.3	124.4
31 - Herbaceous Rangeland	37.4	503.8
32 - Shrub and Brush Rangeland	426.6	733.6
41 – Deciduous Forest Land	1929.7	2382.6
42 - Evergreen Forest Land	5780.1	11699.6
43 - Mixed Forest Land	4977.8	10717.6
52 – Lakes and ponds **	n/a	933.8
54 - Bays and Estuaries	74.3	311.9
61 - Forested Wetland	876.0	1623.7
62 - Nonforested Wetland	250.6	541.2
74 - Bare Exposed Rock	92.2	163
75 - Strip Mines, Quarries, and Gravel Pits	7.7	203.9
Totals:	*14668.8*	*34020.7*

* See Lubinski *et al*. (2003) for description of area covered by the Vegetation Mapping Project.
** Lubinski *et al*. (2003) classify many smaller lakes and ponds as wetlands, not as lakes/ponds (LUC=52). Many Great Ponds (> 4 ha) are classified as LUC 52. However, Great Ponds are not included within the legal ACAD boundary. Hence within-park statistics are not calculated for LUC 52.
(Statistics produced by the URI Environmental Data Center and University of Maine)

Table 3. Land cover change in the ACAD region, 1976-2002. The study area includes ACAD plus a 5-km buffer zone around the Park. Areas are from Wang *et al*. 2006 [(1)].

Land cover class	1976 acres	1986 acres (% change from 1976)	2002 acres (% change from 1976)
Urban	11,601	16,293 (+40.4)	25,160 (+116.9)
Deciduous forest	74,970	88,651 (+18.2)	89,851 (+19.8)
Coniferous forest	264,402	205,444 (-22.3)	229,997 (-13.0)
Mixed forest	152,861	187,421 (+22.6)	143,627 (-6.0)
Water	653,248	769,047 (+17.7)	801,590 (+22.7)
Wetland	25,341	33,167 (+30.9)	30,368 (+19.8)
Herbaceous vegetation	17,645	20,215 (+14.6)	29,599 (+67.7)
Bare rockface	27,577	17,168 (-37.7)	25,366 (-8.0)

[(1)] Across class areas do not sum to the same total area in each year. The reason for this is unclear.

In addition to Park visitors, local residents both use and have an impact on Park resources. The resident population on MDI is distributed among four towns with a total population in 2000 of 10,424 (Town of Bar Harbor 2005). The population increased by 11% between 1980 and 2000. Between 1992 and 2004, the town of Bar Harbor granted 613 residential building permits and 1,411 commercial building permits. As will be discussed in the *Assessment of Threats* section, residential development in parts of MDI is threatening some Park-associated resources.

Aside from hiking and vista experience, human uses of Park resources include recreational fishing, boating, swimming / beach use and water supply. Fishing is permitted on all lakes in the ACAD region. The Maine Department of Inland Fisheries and Wildlife (MDIFW) has a lead role in fisheries management on Great Ponds (lakes > 4 ha surface area). Management goals of this agency do not always concur with NPS management goals, for example as they relate to the stocking of non-native fish (Kahl *et al*. 2000). There are boat restrictions on most of the lakes and ponds on MDI (MDIFW regulations may be viewed at www.pearl.maine.edu). Internal combustion engines are currently prohibited from: Round Pond, Aunt Betty Pond, Witch Hole Pond, Bubble Pond and Lake Wood. Engines larger than 10 h.p. are prohibited from Seal Cove Pond, Echo Lake, Upper and Lower Hadlock Ponds and Jordan Pond. Personal water craft (jet skis, etc.) are prohibited from Hamilton Pond, Long Pond and Somes Pond, as well as the other lakes with engine-size restrictions.

The following lakes are municipal water supply sources: Eagle Lake (Bar Harbor), Jordan Pond (Seal Harbor), Lower Hadlock Pond (Northeast Harbor), Long Pond (Southwest Harbor) (Figure 9). Swimming is prohibited from these lakes and their feeder lakes (e.g. Bubble Pond which flows into Eagle Lake). There is a swimming beach at Echo Lake.

No authorization of hunting and trapping is included in any federal legislation related to ACAD, although these activities are permitted on Great Ponds by Colonial Ordinances. Kahl *et al*. (2000, p. 3-14) provide an extended discussion of hunting and trapping issues at ACAD.

Marine worm (*Nereis virens*) and shellfish (including soft-shelled clam, *Mya arenaria*) harvesting, lobstering and fishing occur in the coastal waters surrounding ACAD. Further information on worm and shellfish areas is presented in the *Assessment of Threats* section.

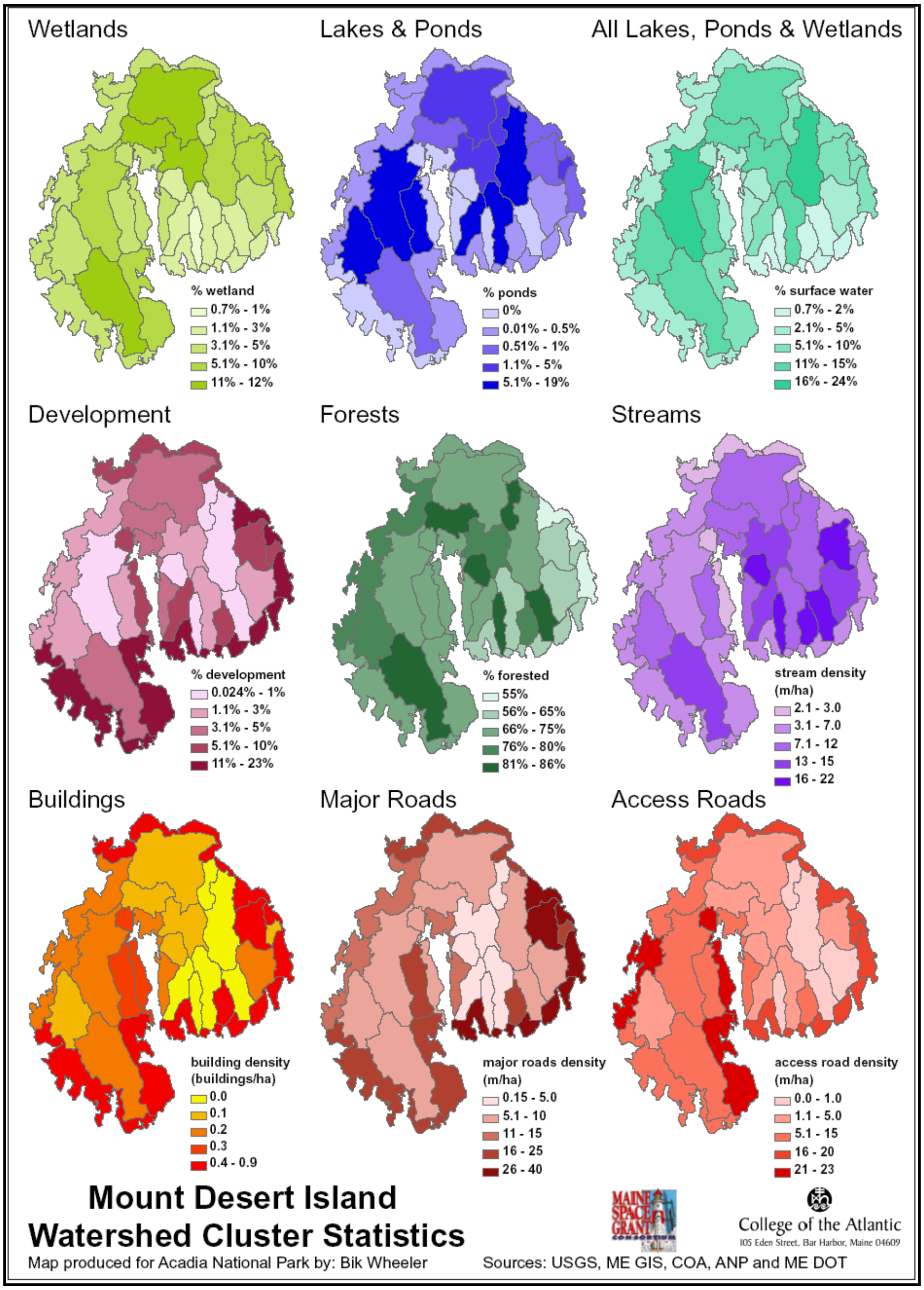


Figure 5. Landcover/use statistics by watershed cluster.

Wetlands, lakes, ponds and development data are from Vegetation Mapping Project database (Lubinski et al. 2003). Note that this database considers some smaller ponds to be wetlands; thus the combined wetland/lake-ponds summary is the most accurate depiction of surface water extent. Buildings data are from building footprint database (courtesy of G. Longsworth, College of the Atlantic, Bar Harbor, ME). Roads data are from ME-DOT GIS coverage. Note also that class breaks are not uniform within any individual map panel. Maps were developed by B. Wheeler (College of the Atlantic).

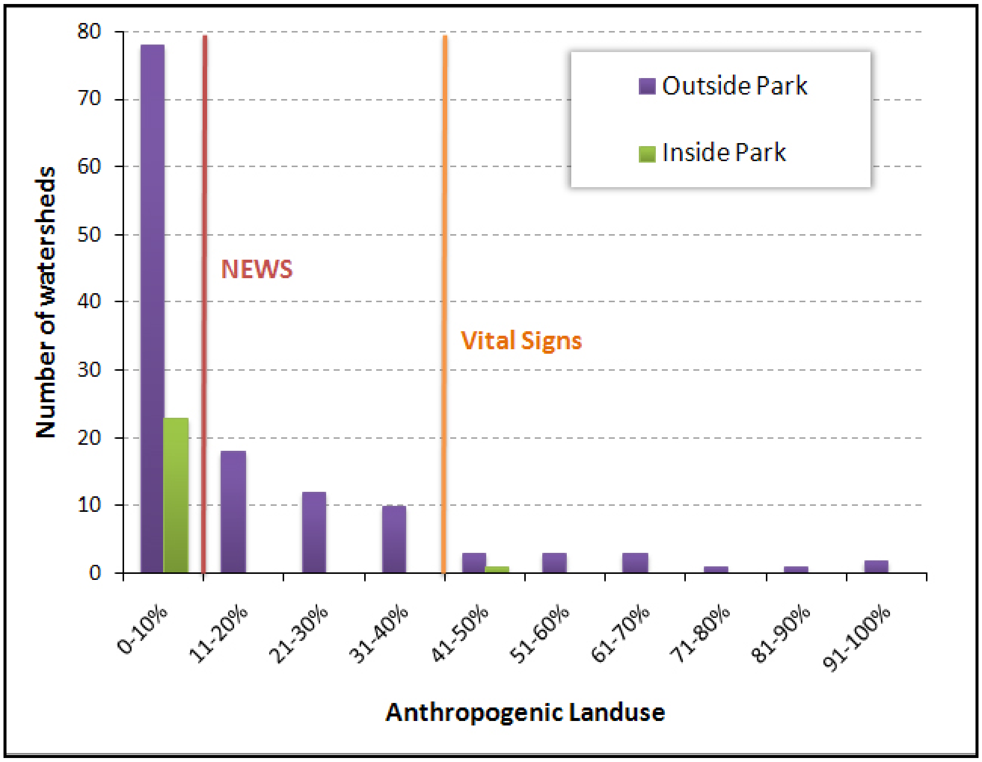
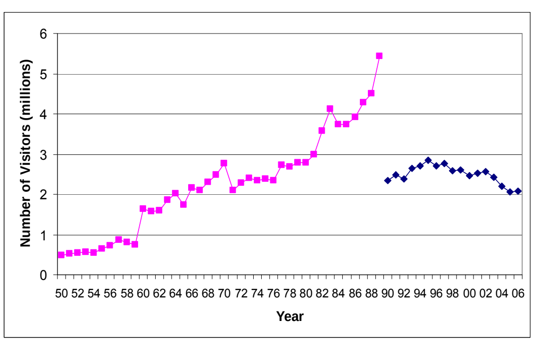
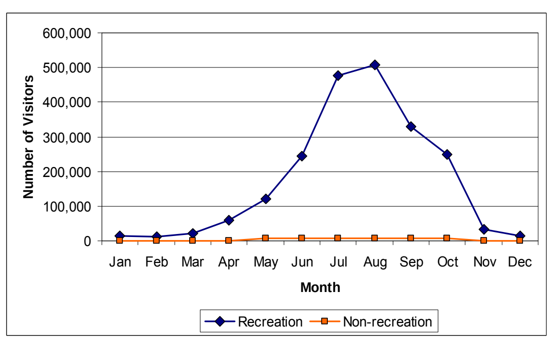


Figure 6. Anthropogenic land-use in watersheds of MDI. Data are derived from Lubinski et al. (2003) and show the number of watersheds with various levels of the "Urban" land-use class. Watersheds inside the Park lie completely within the ACAD legal boundary. Watersheds outside the Park lie partly or fully outside the boundary. Watersheds are those delineated by Perrin (1996) that are > 5 ha (the Sargent Mountain Pond watershed is included, although smaller). The two vertical lines refer to two "reference" values: one adopted by the New England Wadeable Streams Project (<10% of land use in watershed is anthropogenic) (NEWS; Snook *et al.* 2007) and one by the Northeast Temperate Network Vital Signs Monitoring Program (<40% of land use in watershed is anthropogenic) (Mitchell *et al.* 2006). See further information under Assessment of Condition.

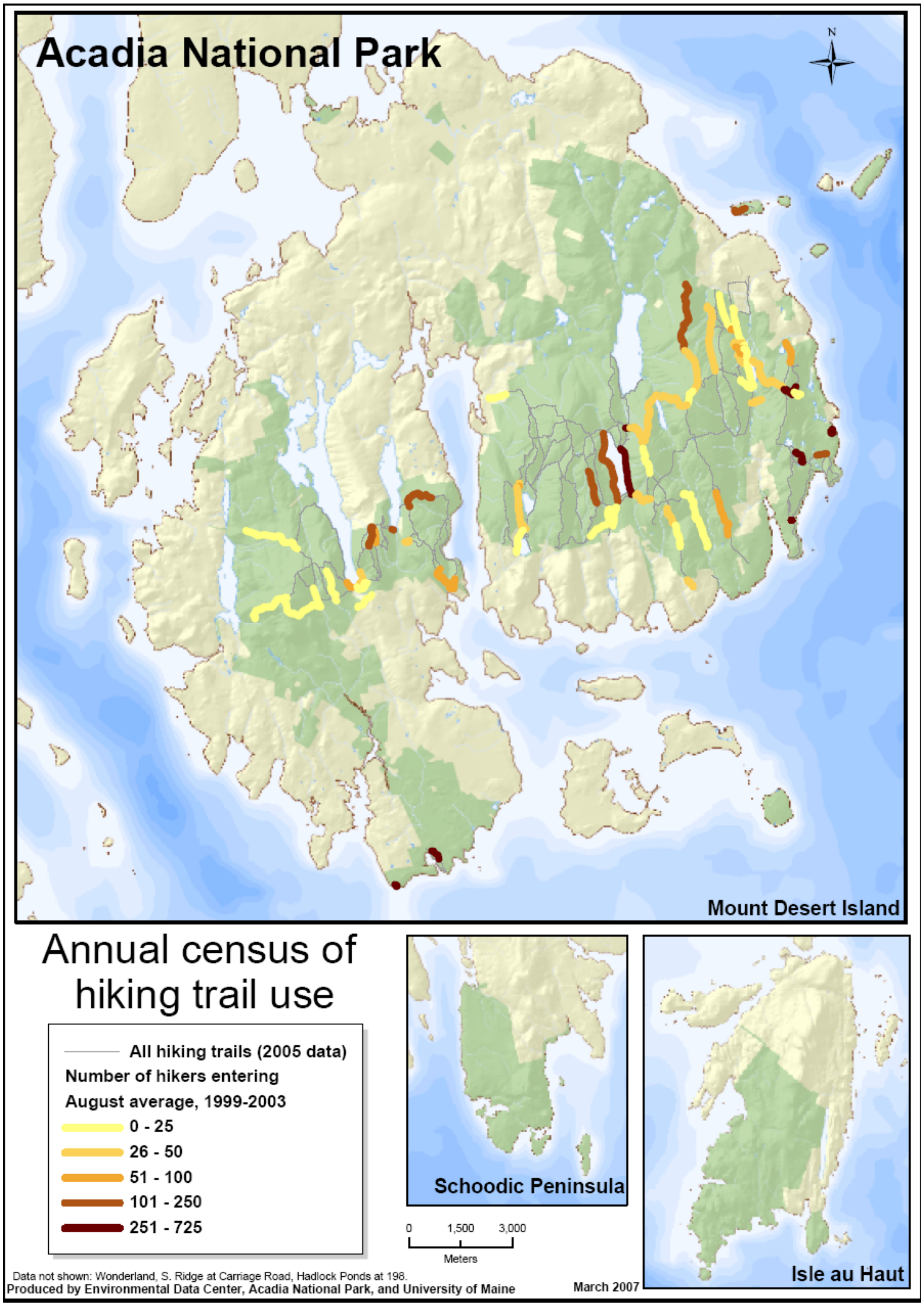


(A)



(B)

Figure 7. Visitation at ACAD. (A) Annual number of visitors, 1950-2006. (B) Monthly number of visitors, 2006. Note that a new method for estimating visitation was implemented in 1990. (Data source: http://www2.nature.nps.gov/stats/)



(Census data from Jacobi 2003d)

Figure 8. Hiking trail use, number of hikers per day.

Table 4. Compilation of visitor use statistics.

A. Visitors to ACAD (see Figure 7)		
B. Visitors, Cadillac summit (1)		
# persons (2001)	5969	
# persons (2002)	4930	
# cars (2001)	1971	
# cars (2002)	1802	
C. Average # hikers / hour on summits: 1999-2001 (# observation days) (2)		
Beehive	59 (3)	
Penobscot	47 (1)	
Champlain	43 (4)	
Gorham	34 (20)	
Beech	30 (12)	
Acadia	27 (10)	
Pemetic	19 (7)	
Dorr	15 (8)	
Sargent	10 (3)	
Bernard	2 (1)	
D. # Hikers entering trails (# observation days): (3) (See also Figure 8)		
	Eastern MDI	**Western MDI**
1999	2759 (42)	2090 (16)
2000	3370 (48)	1726 (20)
2001	3513 (48)	2896 (21)
2002	5219 (50)	2717 (21)
2003	3586 (43)	1904 (18)
E. IAH trail use: average # visitors / trail / day (4): 0.6 (low-use trails - 10.4 (high-use trails)		
F. Estimated daily carriage road use (± 80% confidence interval) for: (5)		
	July	**August**
1997	1663 (208)	1984 (216)
1998	1431 (208)	1796 (211)
1999	1567 (207)	1851 (212)
2000	1379 (208)	1755 (210)
2001	1362 (208)	1552 (207)
2002	1632 (257)	1867 (258)
G. Places visited by visitors (N = 1062 visitor groups) (6)		
Cadillac summit – 76%	Eagle Lake parking area – 32%	Schoodic Peninsula – 11%
Sand Beach/Thunder Hole – 75%	Sieur de Monts area – 32%	Baker Island – 5%
Jordan Pond House - 61%	Acadia Mt. parking area – 28%	Isle au Haut – 2%
Visitor Center – 59%	Pretty Marsh picnic area – 16%	Other park islands – 7%
Seawall area – 55%		
H. Visitor use at Anenome Cave (7) Average # persons entering case per 3-hour period around low tide, May-August, 1998-99 = 47 (± 9)		

Data sources: (1) Jacobi 2001a, 2003a. (2) Jacobi 2001b, 2003c. (3) Jacobi 2003d. (4) Marion 2006. (5) Jacobi 2003b. (6) Littlejohn 1999. (7) Jacobi 2000.

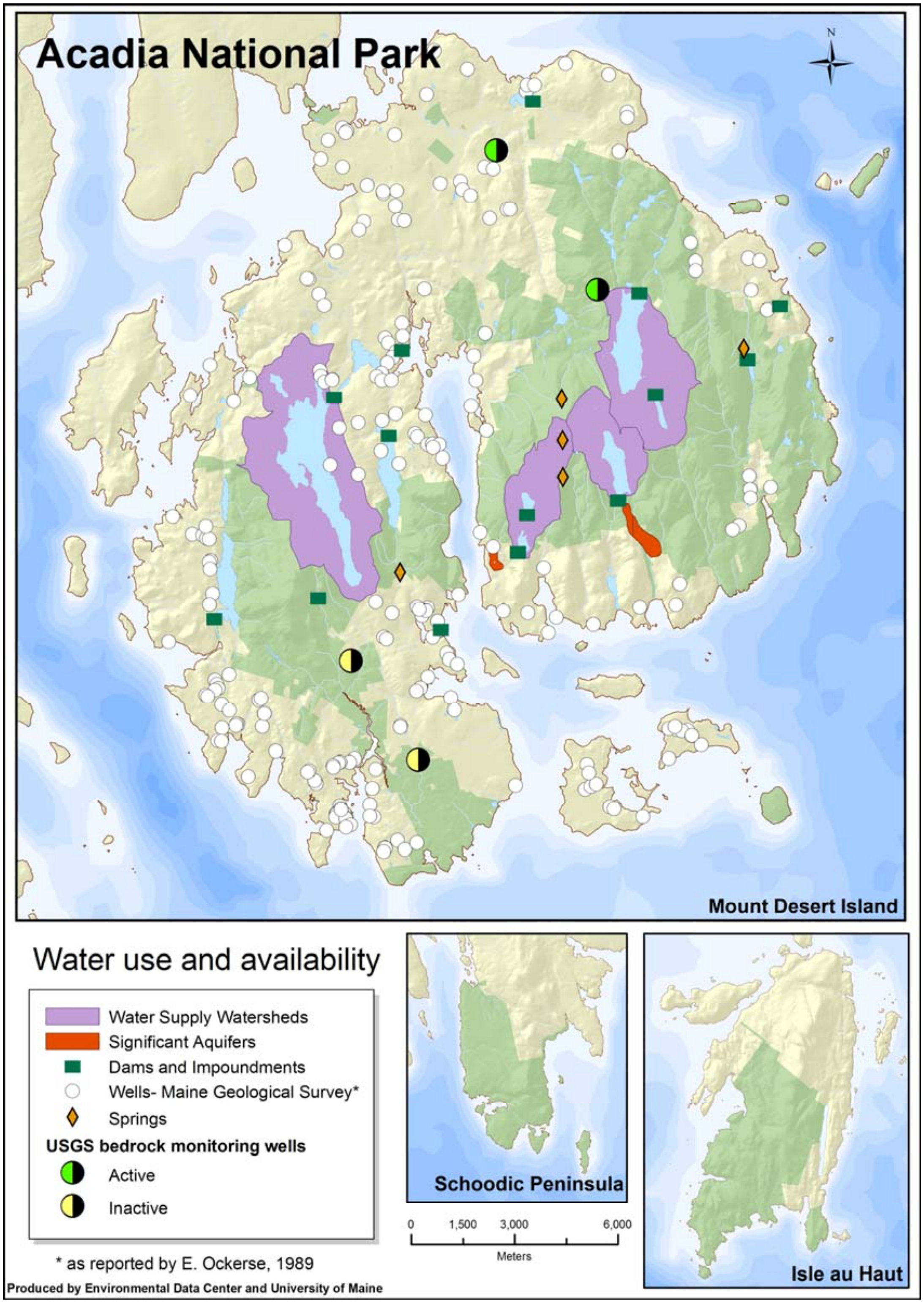


Figure 9. Water supply watersheds, dams, and wells on MDI.
(Data from multiple GIS sources)

Terrestrial, Freshwater and Coastal/Marine Resources

This section provides an overview of the physical, chemical and biological features of the natural resources in the ACAD region. Further information on the ecosystems of ACAD is presented in subsequent sections of this report that address threats and condition.

Terrestrial Systems

Physico-Chemical Environment of Terrestrial Systems

Climate: Kahl *et al*. (2000) provide an overview of weather in the mid-coast region of Maine. ACAD's climate is cool and moist with abundant fog. Daily weather records for MDI exist for over a century. Since 1981, there has been a NOAA weather station on McFarland Hill. Temperatures typically range from -10 C to 35 C. Annual precipitation has ranged from a low of about 60 cm in the drought year of 2001 to almost 220 cm in 2005 (Figure 10). Snowfall depths average about 24 cm (Johnson *et al*. 2007). There appears to be considerable local variation in temperature, precipitation and evaporation.

Geology and Soils: Calhoun *et al.* (1994) provide a concise description of the geologic history of the ACAD region. Most of area is underlain by granite, which gives the Park much of its rugged character. The dominant soil class is a shallow, stony Schoodic-rock outcrop-Lyman complex derived from granite and schist tills (Kahl *et al*. 2000). Soils in valleys are mainly sandy loams and range from excessively to moderately well-drained. Organic soils, including a range of poorly- to well-decomposed peats, are associated with wetlands. An extensive discussion of hydric soils in the ACAD region is provided by Calhoun *et al*. (1994). The distributions of hydric and erodible soils are shown in Figure 11, while Figure 12 shows soil pH. The shallow depth and reduced buffering capacity of many soils in the Park, coupled with steep slopes, influence the chemistry of surface waters (Kahl *et al.* 2000). Soil composition in the eastern portions of MDI has been affected by the 1947 fire (see *Threats: Fire*).

Soil chemistry is influenced by atmospheric deposition of acidity, nitrogen, sulfur and other elements. The recently established Northeastern Temperate Network (NETN) long-term forest monitoring sites are beginning to produce baseline data to evaluate long-term trends in soil and vegetation characteristics. Data from this program, as well as from other studies, are discussed under *Threats: Atmospheric Deposition (Acidity and Related Chemistry).*

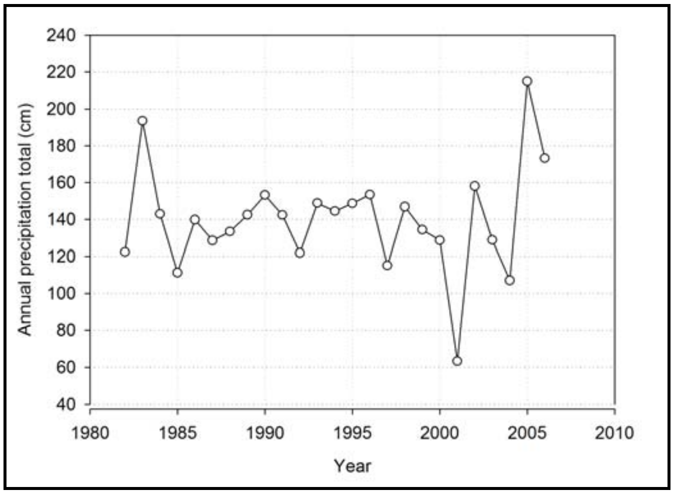
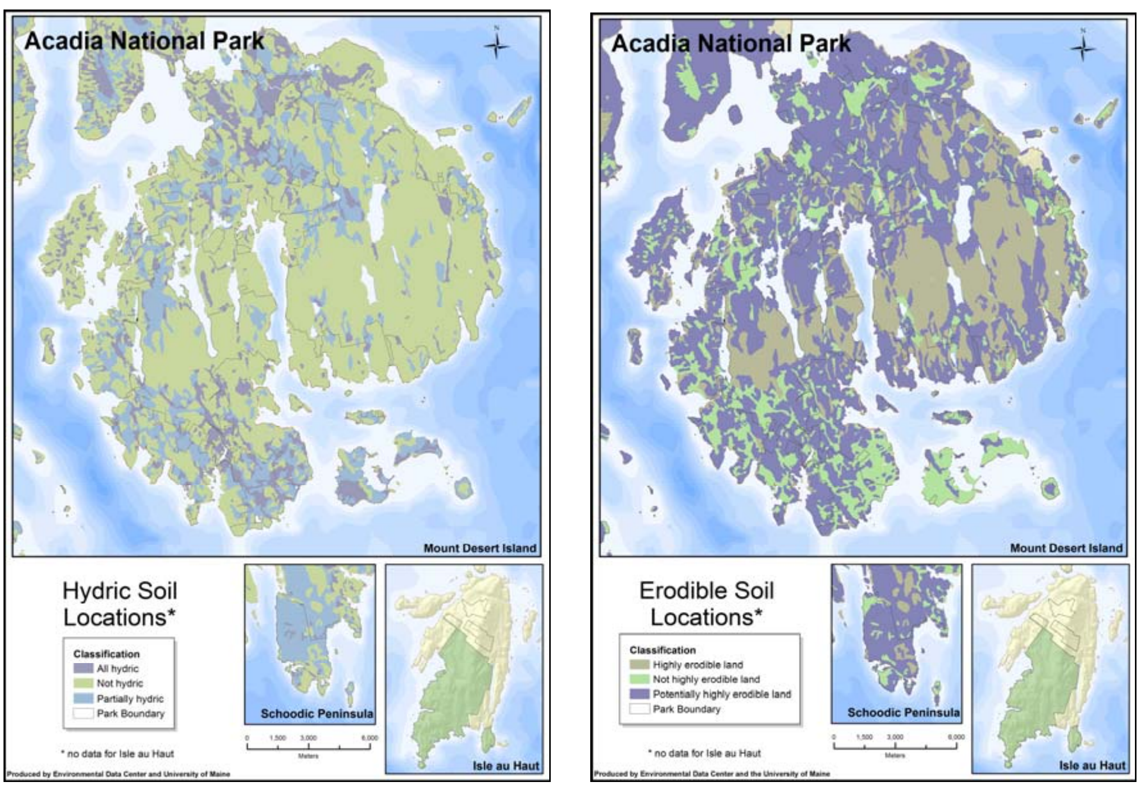


Figure 10. Annual precipitation measured at the McFarland Hill NADP site, 1982-2006. State of Maine 30-year normal precipitation mean (1971-2000) is 105 cm. McFarland Hill site mean precipitation (1981-2005) is 138 cm.
(Data sources: NADP; means from Seger *et al*. 2006)



(A) (B)

Figure 11. Distribution of hydric and erodible soils in the ACAD region.
(Data from NRCS soils GIS coverage, courtesy of ACAD Office of GIS)

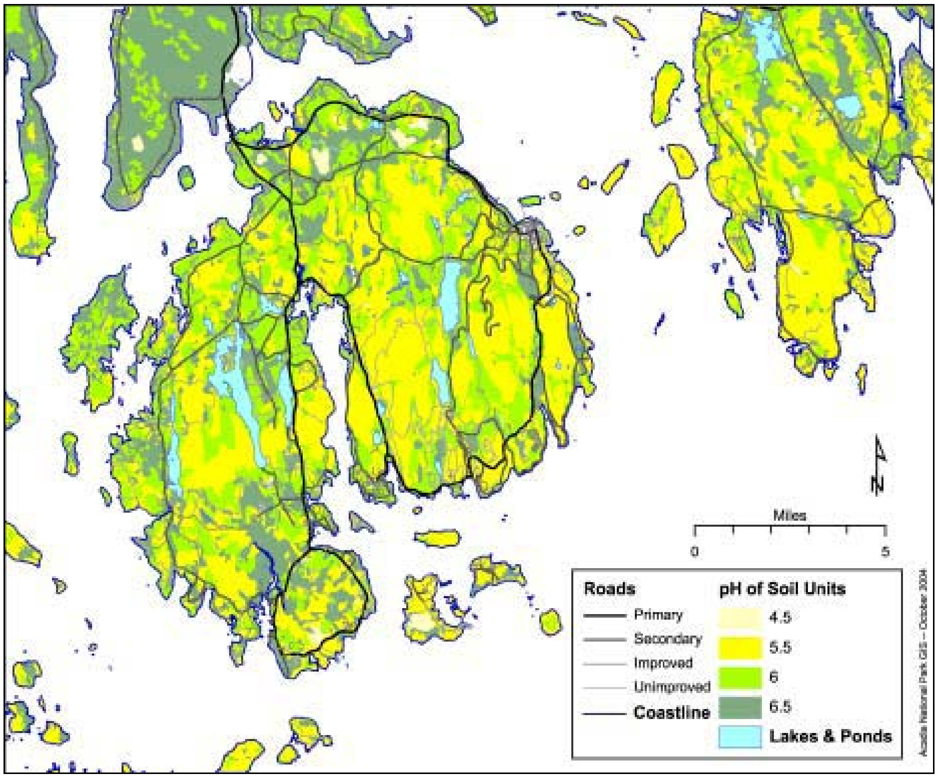


Figure 12. Soil pH at ACAD and vicinity.
(Figure from Maniero and Breen 2004, with permission)

Biological Resources of Terrestrial Systems

Terrestrial Plant Communities: ACAD is located in a broad transition zone between southern deciduous and northern coniferous forests. Local habitats within ACAD range from coastal to sub-alpine including old-growth spruce-fir forests, wetlands (heaths, marshes), meadows, and jack pine forests. ACAD harbors 1,135 of the 2,103 taxa (54%) listed for Maine (Campbell *et al.* 1995). Nearly 20% (~183 taxa) of vascular plants at ACAD have been designated locally-rare or State-listed (calculated from data in Greene *et al.* 2005). A third of the plants (~283 taxa) are exotic (Greene *et al*. 2005) (see *Threats: Exotic Species*).

MDI is the most floristically diverse unit of the Park, supporting more than one half of Maine's known plant species (Table 5). Isle au Haut supports 1/3 of plant taxa listed for Maine. Current knowledge of the Schoodic Peninsula flora is limited. Most field surveys at SCH have been restricted to the southern 1/3 of the peninsula (Mittelhauser *et al*. 1996). Greene *et al*. (2005) believe that the current flora for MDI is more-or-less complete but that further surveys are needed for IAH and SCH units of ACAD. Many taxa currently listed for MDI are not documented for SCH or IAH. For example, of 12 members of Lycopodiaceae (clubmoss family) listed for ACAD, only one has been documented for SCH. Similarly, four common tree species, *Fagus grandifolia* (American beech), *Picea mariana* (black spruce), *Populus grandidentata* (big-

Table 5. Documented taxonomic richness for selected plant and animal groups in ACAD and vicinity. Note that, for some groups, documented diversity is likely less than actual diversity. Data are for MDI, SCH and IAH park units, except where noted.

Group	Number of ACAD Taxa				
	Present in Park *	Unconfirmed in Park *	Historic Records *	Total Taxa	State-Listed Taxa **
Vascular plants (1)	894		241	1135	18
Freshwater plants (1)				91	6
Fresh and Salt Wetland plants (9)				220	
Marine macroalgae (8)				146	0
Lichens (10)				379 taxa (103 genera)	
Birds (2)	230	117	17	364	21
Birds – residents (3)				205	
Mammals (2)	43	7	1	51	0
Snakes (2)	5	-	1	6	1 (historic ACAD record)
Turtles (2)	2	3	1	6	2 (both unconfirmed ACAD records)
Amphibians (2)	12	1	2	15	0
Fish – freshwater (2)	27	-	5	32	0
Fish – estuarine/marine (2)	11	3	-	14	0
Fish – Bass Harbor marsh system (4)				23	0
Freshwater mussels (5)				3	0
Dragonflies/damselflies (6)				107	
Mayflies (6)				58	
Butterflies/Moths (11)				1479	
Butterflies/Moths (7)				155	
Beetles (11)				1175	
Beetles (7)				315	
Ants (11)				42	
Ants (7)				44	

* 'Present in park' = taxon records from within park boundaries. 'Unconfirmed' = reported in the area but not within park boundaries. 'Historic' = written record of taxon that has not been observed since ca. 1970. For full metadata, see http://www.pearl.maine.edu/DADataUpload/MetaData/ACAD05_09.HTM.

** State endangered and threatened species include faunal taxa proposed for listing (IFW 2007). Endangered and threatened taxa do not include all rare taxa.

Data sources
(1) Vascular plants: Greene *et al*. 2005. See Table 7 for listing of rare taxa. Freshwater plants: Greene *et al*. 1997.
(2) W. Gawley (ACAD), derived from NPSpecies database and accessed from www.pearl.maine.edu in March 2007.
(3) G. Mittelhauser (this report). Resident species include breeders, summer residents and winter residents. Excluded are migrant and vagrant species.
(4) Doering *et al*. 1995.
(5) Nedeau et al. 2000, Vaux (2005). Data from MDI only.

(Table 5, continued)

(6) Multiple sources, as compiled by Vaux (2005). Data from MDI, only. Key original data sources are: Odonates – MDDS (2005) and White (1989) following MDDS (2005). Mayflies – Burian and Gibbs (1991), Burian *et al*. (1995) and Mack (1988). Note that historical data of Procter (1946) for odonates and mayflies are not included here since those data are included in the more recent inventories.
(7) ACAD "bioblitz" data provided by W. Gawley (ACAD) and accessed at www.pearl.maine.edu. Ant data are from MDI, only; beetle and butterfly/moth data are from SCH, only.
(8) Mathieson *et al*. 1998.
(9) Calhoun *et al*. 1994. Note that this total includes taxa from lakes and ponds, and freshwater and salt marshes. The total of 220 taxa is likely an under-estimate.
(10) Sullivan 1996.
(11) Procter 1946.

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toothed aspen), and *Quercus rubra* (red oak) – all common to New England – have not been documented for SCH. A similar case can be made for IAH.

The USGS-NPS Vegetation Mapping Program (Lubinski *et al*. 2003) recently used remote sensing and field data to describe spatial vegetation and land-use patterns in the ACAD region. Using the National Vegetation Classification System to classify field-collected data, a total of 53 vegetation community types (associations) were recognized at ACAD. They include 10 upland forest types, 13 upland woodland types, 2 wetland forest types, 3 wetland woodland types, 6 non-forested upland types, 6 shrub or dwarf shrub wetland types, and 13 herbaceous wetland types. Vegetation associations derived from field-based data were cross-walked to map classes based on remote-sensing data. These map classes are shown in Figure 13.

Spruce - Fir Forests are the most extensive vegetation type, covering over 60% of natural vegetated classes and over half of all vegetated classes. ACAD is within the southern coastal range limit of this association. Among the natural vegetated classes, the rarest are the *Dune Grassland*, *Pitch Pine - Heath Barren* and *Pitch Pine - Corema Woodland*, and the *Crowberry - Bayberry Headlands*.

Several species and communities within these vegetation types are at the edge of their geographic ranges making the study and preservation of local populations critical from a species conservation standpoint. Certain physical features of the Park, including habitats with thin soils and steep slopes, abundant surface waters, and high mountains contribute to ACAD's sensitivity to perturbations (Kahl *et al.* 2007b). Further, stressors such as fire, grazing, pests/pathogens, ozone, airborne pollutants, heavy metals, visitor use, and land-use patterns can influence some or all of ACAD's plant species. For example, fire has played a critical role in shaping ACAD's vegetation. The 1947 fire burned most of the eastern side of MDI (Figure 14), and evidence of past burns is also present in trees and soils throughout the park (Patterson *et al.* 1983). The present vegetation on the MDI unit of ACAD includes large areas of 60-year-old forest and woodland, as well as areas that have had a longer time since disturbance to develop. Additional information on the stressors acting on ACAD terrestrial vegetation is provided under the *Threats Assessment*.

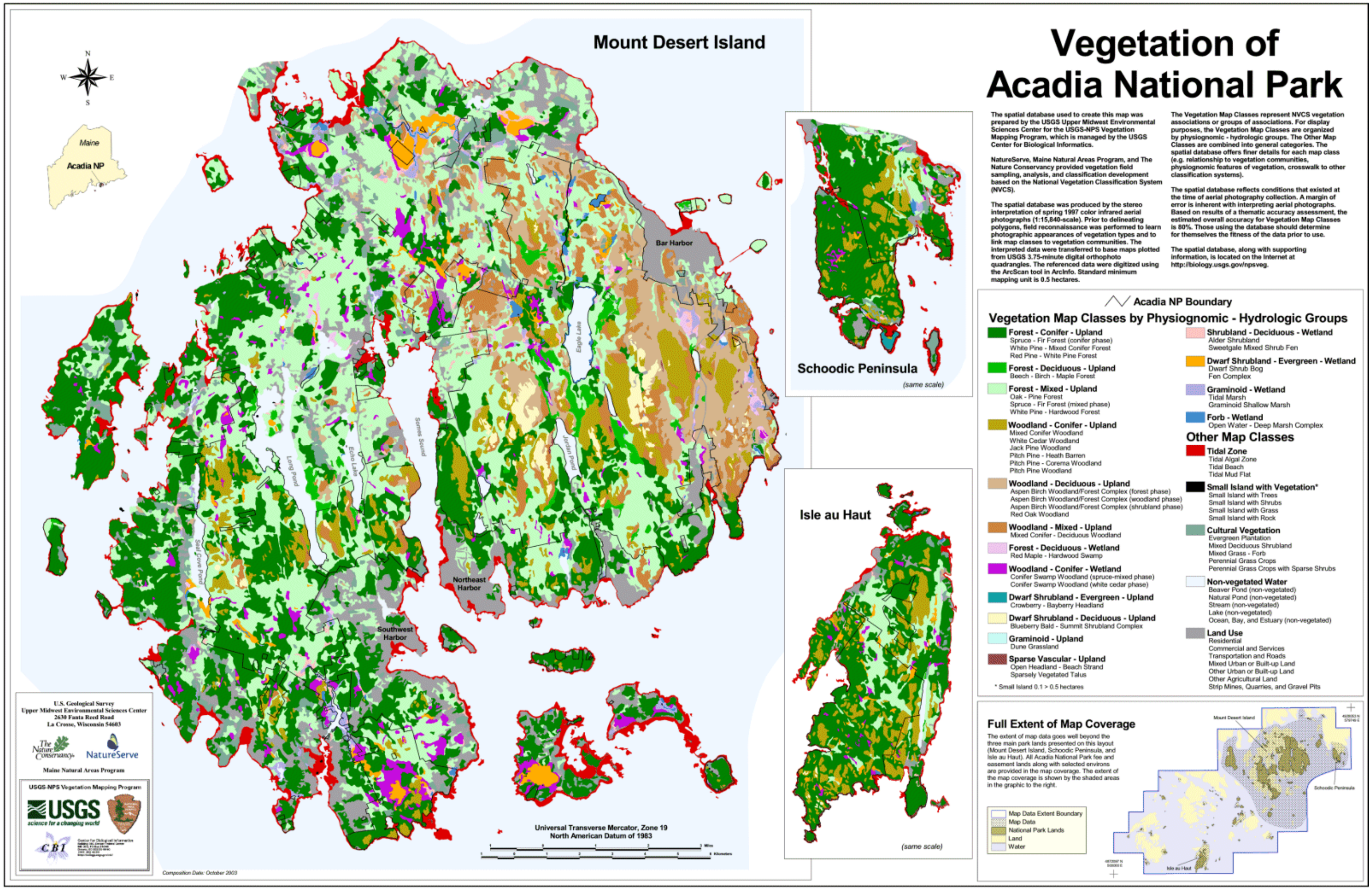


Figure 13. Vegetation and land-use in the ACAD region (from Lubinski *et al*. 2003).

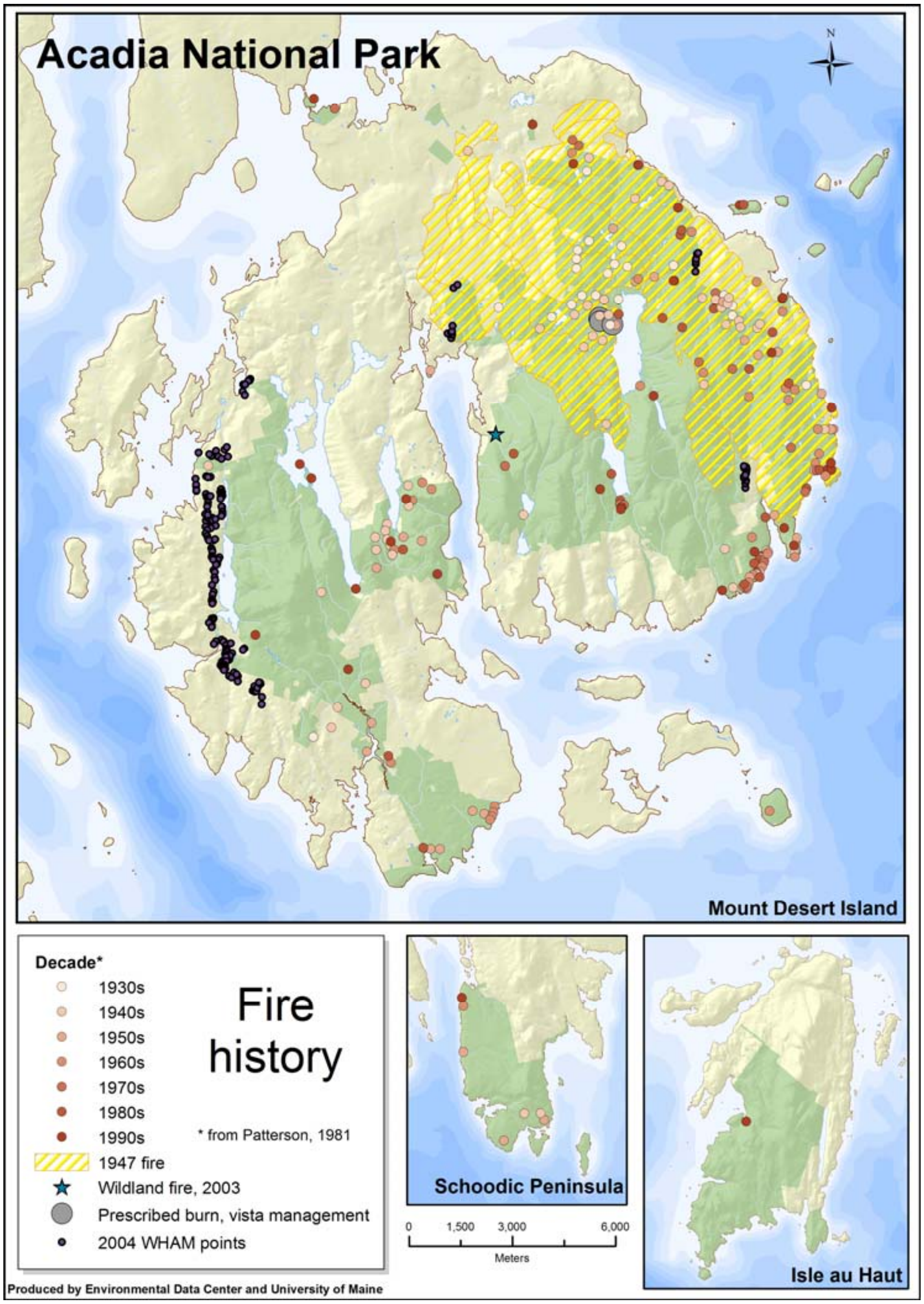


Figure 14. Fire history, prescribed burns and fire risk at ACAD. The 1947 fire is shown by the shaded area. Other fires are shown as point data, by decade. The WHAM points indicate structures with medium – very high fire risk as assessed in the wildland/urban interface structure assessment program.
(Data from Patterson 1981 and other sources supplied by ACAD Office of GIS)

Exemplary Natural Plant Communities: The Maine Natural Areas Program (www.mainenaturalareas.org) recognizes a number of exemplary natural plant communities in the ACAD region. These are listed in Table 6, along with their S-Rank (State rank) values that characterize community rarity. One of the outstanding natural communities at SCH is the jack pine woodland. Jack pine (*Pinus banksiana*) occurs on dry, acidic sites with shallow soil. Jack pine woodlands are rare in Maine, with only a few sites known statewide. Little Moose Island at SCH contains an extensive and diverse example of a Downeast Maritime Shrubland community. Although not part of ACAD, Great Cranberry Island (Figure 3) is notable for the outstanding example of a Coastal Plateau Bog Ecosystem, one of the best examples of this type in Maine.

Rare Plants: ACAD harbors a wide range of plant communities, including species of international, national, regional, and state significance (Greene *et al.* 2002). Six plant species at ACAD are listed as globally rare (Brumback *et al.* 1996). No federally listed plant species occur in ACAD. According to Greene *et al*. (2005), 14 taxa listed as being endangered or threatened in Maine have been documented at ACAD (Table 7A). However, more recent data published by the Maine Natural Areas Program indicate that the number of threatened and endangered species at ACAD is larger (Table 7B).

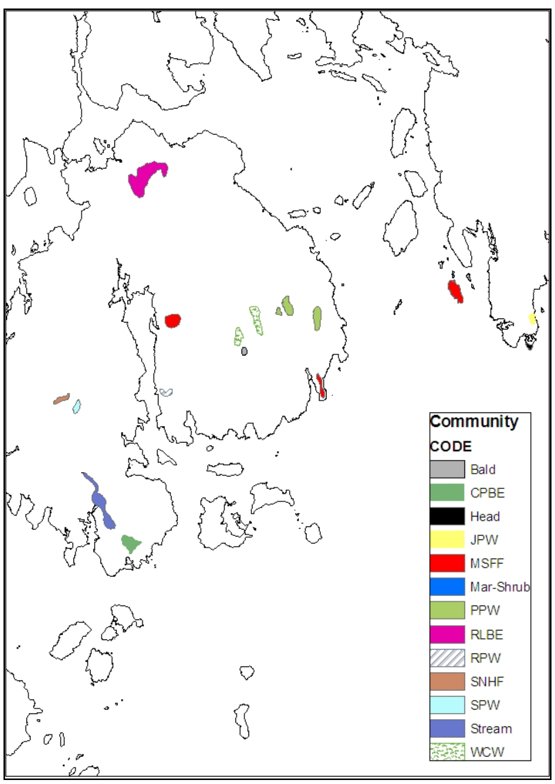
State-endangered species are New England northern reed grass (*Calamagrostis stricta* subsp. *inexpansa*), swarthy sedge (*Carex adjusta*), and a historic record for beach plum (*Prunus maritima*), last documented in 1920 at IAH. State-threatened species include Nantucket shadbush (*Amelanchier nantucketensis*), screw stem (*Bartonia paniculata*), pickering's bluejoint (*Calamagrostis pickeringii*), inkberry (*Ilex glabra*), Acadian and prototype quillworts (*Isoetes acadiensis* and *I. prototypes*), one-sided rush (*Juncus secundus*), Marsh felwort (*Lomatogonium rotatum*), northeastern sea-blight (*Suaeda calceoliformis*), boreal blueberry (*Vaccinium boreale*) and an historic record for alpine clubmoss (*Huperzia selago*), last documented in 1920, also at IAH.

Though ranked only as threatened in Maine, on a global scale *Isoetes prototypus* is the rarest plant at ACAD. It is known from 11 locations globally, one on MDI and 10 in New Brunswick and Nova Scotia and is considered globally rare (G1). Also considered globally rare (G2) is *Isoetes acadiensis*, which occurs in 1 pond at ACAD and is distributed from Newfoundland to New York. *Suaeda calceoliformis*, although globally secure, is locally extremely rare and has been documented from only one site at ACAD (Greene *et al.* 2005).

Locational information for *Kalmia latifolia,* a species uncommon on MDI, suggests that it was destroyed by the 1947 fire and has not re-established colonies since. *Prunus maritima*, now thought to be extinct, was observed at IAH in 1920. IAH also harbors Maine's only population of *Ilex glabra*. Maine and Nova Scotia populations are disjunct, making this population worthy of preservation and careful study. Given our limited current floristic understanding of IAH and SCH (Greene *et al.* 2005), it is critical that these areas are surveyed rigorously to document additional populations of these rare or thought-to-be-extinct taxa as well as to document any new taxa that may have gone unnoticed in previous studies.

Table 6. Exemplary natural communities in the ACAD region. Locations of communities are shown in figure inset.

Natural Community Name	*Locations*	*Code*	*S-Rank **
Coastal Plateau Bog Ecosytem	MDI, Great Cranberry Island Heath **	CPBE	S3
Raised Level Bog Ecosystem	MDI	RLBE	S4
Cinquefoil-Blueberry Low Summit Bald	MDI	Bald	S3
Maritime Spruce-Fir Forest	MDI	MSFF	S4
Pitch Pine Woodland	MDI	PPW	S3
Red Pine Woodland	MDI	RPW	S3
Spruce-Pine Woodland	MDI	SPW	S4
Spruce – Northern Hardwood Forest	MDI	SNHF	S4
Streamshore Ecosystem	MDI	Stream	S4
White Cedar Woodland	MDI	WCW	S2
Jack Pine Woodland	MDI, SCH	JPW	S3
Downeast Maritime Shrubland	SCH	DEMS	S3
Open Headland	SCH	Head	S4



Footnotes:
* State rank ranges from 1 (rare) to 5 (common). S3 = rare in Maine (on the order of 20-100 occurrences); S4 = apparently secure in Maine.
** Not within ACAD boundary.
(Information source: Maine Natural Areas Program [www.mainenaturalareas.org, accessed 7/2007])

Table 7A. Rare plant species at ACAD, with state and global conservation status and potential stressors (Greene *et al*. 2002).

Taxon	State (Global) Rank [(1)]	State Status [(1)]	# Populations ACAD [(2)]	Potential Stressors [(2)]
Amerlanchier nantucketensis (Nantucket shadbush)	S2 (G3Q)	T	6	Loss of habitat
Bartonia paniculata (Screwstem)	S1 (G5)	T	~ 6	Possibly changes in hydrology
Calamagrostis pickeringii (Pickering's reed bent-grass)	S1 (G4)	T	~ 1	Possibly changes in hydrology
Calamagrostis stricta ssp. inexpansa (Northern reed-grass)	S1 (G5T5)	E	(ACAD has largest population in ME)	ACAD population threatened by carriage road activity; spread of invasive *Celastrus orbiculata* (Oriental bittersweet)
Carex adusta (Swarthy sedge)	S2 (G5)	E	Possibly extirpated from ACAD	Lack of disturbance
Carex recta (Salt-marsh sedge)	S1 (G4)	T	1	Trampling by hikers and visitor overuse; non-native species
Carex vacillans (Brackish sedge)	S1 (G?)	SC	1	Possibly non-native species
Carex wiegandii (Wiegand sedge)	S3 (G3)	SC	9	Changes in hydrology
Isoetes acadiensis (Acadian quillwort)	S2? (G2G3)	T	1	Changes in hydrology; non-native plant and animal species
Isoetes prototypus (Prototype quillwort)	S1 (G1?)	T	1	Changes in hydrology; non-native plant and animal species
Lomatogonium rotatum (Marsh felwort)	S1 (G5)	T	2	Trampling by hikers; non-native species
Mertensia maritima * (Oysterleaf)			2	Trampling by hikers; winter storms; non-native species
Minuartia glabra (Smooth sandwort)	S3 (G4)	SC	Regionally rare; common in ACAD	Trampling by hikers
Minuartia groenlandica (Mountain sandwort)	S3 (G5)	SC	Regionally rare; common in ACAD	Trampling by hikers
Montia fontana (Blinks)	S2 (G5)	SC	3	Unknown
Oryzopsis canadensis (Canada mountain-ricegrass)	S2 (G5)	SC	2	Loss of habitat; trampling and erosion from excessive trail use

Table 7A (continued)

Taxon	State (Global) Rank (1)	State Status (1)	# Populations ACAD (2)	Potential Stressors (2)
Potamogeton confervoides (Alga-like pondweed)	S3 (G4)	SC	8	Changes in hydrology; non-native plant and animal species
Sagina nodosa ssp. borealis * (Knotted pearlwort)			2	Non-native species
Selaginella rupestris * (Ledge spike-moss)			1	Trampling by hikers; invasive *Rumex acetosella* (Sheep sorrel)
Suaeda calceoliformis (American sea-blite)	S1 (G5)	T	1 (only 1 other population in ME)	Excessive trail use; trampling by visitors
Vaccinium boreale (Alpine blueberry)	S2 (G4)	T	2	Excessive trail use; trampling by visitors; erosion of minimal soil layer via heavy use or damage to adjacent vegetation

Table 7B. Other ACAD plant taxa listed by Maine Natural Areas Program as threatened or endangered in Maine, but not included in list of Greene *et al*. 2002.

Taxon	State (Global) Rank (1)	State Status (1)
Adlumia fungosa (Allegheny vine)	S1 (G4)	T
Botrychium lunaria (Moonwort)	S1 (G5)	E
Callitriche heterophylla (Water-starwort)	S2 (G5)	SC
Carex bushii (Bush's sedge)	SX (G4)	PE
Carex silicea (Sea-beach sedge)	S3 (G5)	SC
Clethra alnifolia (Sweet pepper-bush)	S2 (G5)	SC
Cypripedium reginae (Showy lady's-slipper)	S3 (G4)	T
Dryopteris fragrans (Fragrant cliff wood-fern)	S3 (G5)	SC
Eleocharis aestuum (Bay spikerush)	S2? (G3)	SC
Huperzia selago (Alpine clubmoss)	S1? (G4G5)	T
Ilex glabra (Ink-berry)	S1 (G5)	T

Table 7B (continued)

Taxon	**State (Global) Rank** (1)	**State Status** (1)
Juncus secundus (Secund rush)	S1 (G5?)	SC
Kalmia latifolia (Mountain-laurel)	S2 (G5)	SC
Listeria auriculata (Auricled twayblade)	S2 (G3)	T
Parietaria pensylvanica (Pennsylvania pellitory)	SX (G5)	PE
Potamogeton bicupulata (Snail-seed pondweed)	S3 (G4?)	SC
Proserpinaca pectinata (Comb-leaved mermaid-weed)	S1 (G5)	SC
Prunus maritima (Beach plum)	S1 (G4)	E
Salicornia maritima (Jointed glasswort)	SH (G5)	PE
Salix humilus var. tristis (Dwarf praire willow)	SU (G5)	
Spiranthes lacera var. gracilis (So. Slender ladies' tresses)	SH (G5)	PE
Suaeda maritima ssp. richii (Rich's sea-blite)	S1 (G5T3)	SC
Subularia aquatica (Water awlwort)	S3 (G5)	SC
Zannichellia palustris (Horned pondweed)	S2 (G5)	SC

(1) Designations from Maine Natural Areas Program list of rare, threatened and endangered plant species in Maine (www.mainenaturalareas.org; accessed May 5, 2007).
State ranks: **S1** Critically imperiled in Maine because of extreme rarity (five or fewer occurrences or very few remaining individuals or acres) or because some aspect of its biology makes it especially vulnerable to extirpation from the State of Maine. **S2** Imperiled in Maine because of rarity (6-20 occurrences or few remaining individuals or acres) or because of other factors making it vulnerable to further decline. **S3** Rare in Maine (on the order of 20-100 occurrences).
Global ranks: **G1** Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals or acres) or because some aspect of its biology makes it especially vulnerable to extirpation from the State of Maine. **G2** Globally imperiled because of rarity (6-20 occurrences or few remaining individuals or acres) or because of other factors making it vulnerable to further decline. **G3** Globally rare (on the order of 20-100 occurrences). **G4** Apparently secure globally. **G5** Demonstrably secure globally.
State legal status: **E** Endangered; Rare and in danger of being lost from the state in the foreseeable future, or federally listed as Endangered. **T** Threatened; Rare and, with further decline, could become endangered; or federally listed as Threatened. **SC** Special Concern; Rare in Maine, based on available information, but not sufficiently rare to be considered Threatened or Endangered. **PE** Potentially endangered.

(2) Based on information in Greene *et al.* 2002

* Taxon not included in MNAP list

Rare plant conservation is a high priority for ACAD. The report by Greene *et al*. (2002) identified a number of critical questions that have to be addressed in order to develop a long-term plan for the conservation of rare species at ACAD. Their effort helped prioritize species for monitoring, develop appropriate protocols for monitoring, and provide management responses for some selected rare taxa.

Table 7A identifies potential stressors for 20 rare plants found at ACAD (based on Greene *et al*. 2002). Potential stressors are species-specific and include factors such as habitat loss, change in hydrology, invasive species, visitor over-use, trampling by hikers and walkers, and erosion. These are further discussed in the individual *Threats* sections. Careful study of these rare plants will no doubt reveal additional stressors as well as best approaches for their conservation.

Birds: For this study, we focused on resident ACAD taxa, excluding species that occur in the region only as migrants or vagrants. Nevertheless, it is important to note that ACAD is a significant stopover location for many migrants. Appendix 3 provides a list of migrant species. We include all resident bird species in this terrestrial section, even though some taxa are associated with freshwater, wetland or marine environments.

A recent study of bird assemblages of Northeast Creek and Bass Harbor Marsh documented a total of 152 species, of which 41% were determined to be breeding species and 59% non-breeding species (Wilson *et al*. undated[1]). While some of the non-breeding taxa were known to be local breeders on MDI, others were using the wetlands for migration stop-over sites.

To assess the status of birds in the ACAD region, we conducted new analyses of existing data and literature resources. We compiled up-to-date population information on all species using multiple data sources, including systematic surveys, scientific publications, agency reports, and general observations for each species. To develop a list of resident species (i.e., breeders, summer residents, or winter residents) within the Park, we consulted ACAD's 'NPSpecies' database, which is designed to track species status in the park through links to references, museum vouchers, and observations. We also consulted Sibley (2000) to determine migrants and vagrants in the ACAD region and excluded them from our analysis. We divided resident species into three categories: land birds, marsh birds, and marine birds. Although some birds can be placed in more than one category, each species was assigned to only one category.

Condition, population trend and stressors were determined on a species-level basis. Population trends used Christmas Bird Counts and Breeding Bird Surveys. Data for the CBC have been collected every December/January (with few exceptions) on MDI since 1934 and on Schoodic Peninsula since 1957; we used these data to assess long-term changes in bird populations in the ACAD region. Breeding bird survey data are available for three consecutive years (1995-1997). Appendix 4 contains more information on the approaches used to develop the bird analyses.

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[1] The final version of the Wilson *et al*. report was not available when this Assessment was prepared. Hence we do not include here a more detailed summary of data from the Wilson *et al*. study.

The ACAD region provides habitat for 205 species of resident (i.e., breeding, summer resident, and winter resident) birds (Table 8)[2]. Although scattered species lists for specific areas within ACAD have been generated over the years (Greene *et al*. 2002), details on distribution of species and population size within ACAD are lacking for most species and are not of sufficient resolution to document fine-scale patterns of distribution. We separate out specific details for MDI, IAH, SCH, and small offshore islands (ISL) where possible.

Of the 205 total resident bird species, 136 species are landbirds (Appendix 5), 29 species are marsh birds (Appendix 6), and 40 species are marine birds (Appendix 7). There has been little to no effort to discern population status or distribution throughout ACAD for 93% of land birds, 79% of marsh birds, and 58% of marine birds. Although less research emphasis has been placed on land birds versus water birds, land birds have a significant percentage of species of conservation concern: 46% for land birds, 59% for marsh birds, and 68% for marine birds (Table 8).

Stressors potentially affecting species of conservation concern in ACAD are detailed for land birds (Appendix 8), marsh birds (Appendix 9), and marine birds (Appendix 10). Documentation of these potential stressors within ACAD has been limited. Appendix 11 summarizes park specific 'existing problems' and 'potential problems' based on the best information available. This information is further discussed under *Assessment of Threats*.

Terrestrial Mammals: Forty-three mammal species are known to inhabit ACAD and another seven are suspected (based on their presence outside the Park) (Table 5; species list can be found at http://www.pearl.maine.edu/linkeddatasets/acad_mammals.htm). No mammal species is state-listed for conservation purposes. Fuller and Harrison (2003) provide an excellent overview of the status of mammal populations on MDI. Related spatial data available as GIS layers from the ACAD Office of GIS include the Fuller and Harrison survey transects and mammal observation locations.

Although some population trend information is available, long-term monitoring data for most mammal species do not exist. Fuller and Harrison (2003) recommend that such monitoring be implemented and they provided a thorough evaluation of different survey methodologies. The white-tailed deer (*Odocoileus virginianus*) population on MDI is currently stable or declining and is below forage carrying capacity (Long *et al*. 1997). For more information on the status of deer and other mammal species, see section on *Threats: Herbivory / Predation*.

Amphibians and Reptiles: Twelve amphibian species are known to inhabit ACAD and another one may also be present (Table 5). Two species are known from historical records only. The Park is known to hold seven reptile species, with another three species possibly present but unconfirmed (Table 5). Two reptile species are known from historical records only. A detailed survey of ACAD herpetofauna was conducted in 2001 and documented 18 species (Brotherton *et al*. 2004) including the first IAH record for the northern ring-necked snake (*Diadophis punctuatus edwardsii*).

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[2] The Maine Audubon (www.maineaudubon.org) field checklist of Maine birds includes a total of 299 species for the state.

Table 8. Resident birds of ACAD: Summary of species richness, conservation status, population trends and information quality. For species-level information on population trends and stressors, see Appendices 3-10. Data are from multiple sources – see text for more information.

	LAND SPP.	MARSH SPP.	MARINE SPP.
Total # Species (A)			
	136	29	40
Priority Status of Taxa (B)			
Priority		*# Species*	
1	2	1	2
2	39	10	13
3	36	8	13
T	1	0	4
E	2	1	2
SC	6	1	5
Taxa of Regional Concern (C)			
Concern Level		*# Species*	
Moderate	23	5	8
High	15	2	6
Highest	4	2	8
"Management concern"	--	2	--
Population Trends (D)			
Trend		*# Species*	
Increasing	18 (MDI); 12 (SCH)	4 (MDI); 1 (SCH)	8 (MDI); 6 (SCH)
Decreasing	3 (MDI); 2 (SCH)	0 (MDI); 1 (SCH)	2 (MDI); 6 (SCH)
No Change	23 (MDI); 23 (SCH)	0 (MDI); 2 (SCH)	13 (MDI); 14 (SCH)
Insufficient data	93 (MDI); 99 (SCH)	25 (MDI); 25 (SCH)	16 (MDI); 13 (SCH)
Population Status Data Quality (E)			
Quality Category		*# Species*	
1	127	23	23
2	6	6	11
3	0	0	3
4	3	0	2

(A) Species numbers refer to breeding, summer and/or winter residents.
(B) Maine Priority Status: Maine Fish and Wildlife priority codes(Maine Department of Inland Fisheries and Wildlife 2005): **1**: high potential for state extirpation without management intervention and/or protection; **2**: moderate to high potential for state extirpation without management intervention and/or protection; **3** low to moderate potential for state extirpation, yet, there are some remaining concerns regarding restricted distribution, status, and/or extreme habitat specialization. **T**: Threatened in Maine; **E**: Endangered in Maine; **SC**: 'Special Concern' in Maine (Maine Department of Inland Fisheries and Wildlife 1996). Note that a species may have a numeric priority status as well as a listing status (T, E, SC).
(C) Regional Concern: Conservation priority categories for birds in BCR 14 (Dettmers 2007).
(D) Population Trends: Trends are for Christmas Bird Count (CBC) data, only. For more information on analytical methods used in this analysis, as well as other trend analyses, see Appendix 3.
(E) Data Quality: 1) Poorly known: little or no effort to discern population status or distribution throughout ANP; 2) Scattered reports: existing information may or may not correctly estimate status or distribution; 3) Generally well known: scattered anecdotal reports likely reflects status and distribution, but only poor or incomplete data available; 4) Reliable data: park-wide survey with good status and distribution information.

The 23 amphibian and reptile species from the ACAD region may be compared to the total of 36 species known from Maine's mainland (Hunter *et al*. 1999). Maine is one of the most depauperate states in terms of herpetofauna (Brotherton *et al*. 2004). The authors of the 2001 survey state that:

> "The 18 species of amphibians and reptiles documented at Acadia are mostly species that are common to the Northeast …. and are representatives of species that are even more widespread. Many are at or close to the northern limit of their distributions. From a preservation of species at risk perspective, Acadia does not support any species that are exceptionally rare, such that it could be considered a critical site for a rare or declining species. The only species present that is listed by the State of Maine is the four-toed salamander (*Species of Special Concern*). The four-toed salamander is a habitat specialist (*Sphagnum*-dominated wetlands and vernal ponds) difficult to detect and its true abundance is likely underestimated, both at Acadia and throughout much of its range. Thus, Acadia is not currently a significant refuge for locally rare and endangered amphibian and reptile species. However, this may change in time as Maine experiences coastal development and urban-suburban populations expand" (Brotherton *et al*. 2004).

According to these authors, while most of ACAD's amphibian and reptile species appear to be maintaining themselves, some evidence suggests that the herpetofauna of the Park is in decline. The populations of 16 species "appear to be relatively unchanged in overall population size, one (painted turtle) has increased, one (American toad) has declined, and two (dusky salamander, northern leopard frog) appear to be extirpated or nearly so." The authors suggest that declines may be because of the same factors believed to be responsible for amphibian declines worldwide. Of particular interest is the emerging role of multiple and synergistic stressors (e.g., habitat loss, degradation, and chemical stressors) in potentially weakening amphibian fitness. Two such stressors have been identified at Acadia: amphibian disease and mercury. These are further discussed in the *Threats* section.

Bank *et al*. (2006) reported that the dusky salamander (*Desmognathus fuscus*) is currently found in <15% of the number of streams from which this species had been reported during the middle years of the 20th century (Figure 15).

Chalmers and Loftin (2006) studied the habitat of four-toed salamander (*Hemidactylium scutatum*). They recorded this salamander in 36 wetlands at ACAD – previously, the species had been known from just 32 sites in the entire state (Chalmers 2004). A series of biotic and geomorphological factors were associated with nesting presence of this species. Biotic factors included the presence of plant species (e.g. *Sphagnum*, *Calamagrostis canadensis*, *Spiraea alba* and *S. tomentosa*) and absence of other species such as *Kalmia angustifolia* or deciduous forest canopy. Nesting presence was also associated with wood substrate, water flow and shoreline gradient.

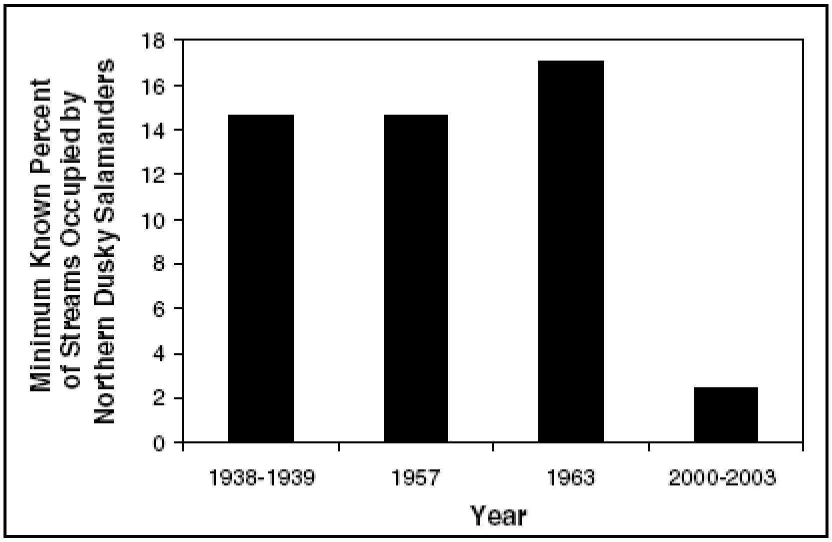


Figure 15. Minimum known percent of streams (n = 37) occupied by northern dusky salamanders in ACAD, 1938–2003.
(Figure from Bank *et al*. 2006, used with permission)

Terrestrial Invertebrates: There is a long history of invertebrate collections on MDI, including the extensive collections of Procter between 1928 and 1945 (Procter 1946). However, with the exception of recent bioblitzes conducted by ACAD and external researchers, there are few comprehensive recent collections. Species richness for selected invertebrate groups is presented in Table 5. In this report we do not address invertebrate assemblages in further detail.

Freshwater Systems (Lakes, Streams, Riparian Systems, Wetlands and Groundwater)

Physico-Chemical Environment of Freshwater Systems

Drainage Systems: Twelve major watershed systems drain the interior of MDI (Perrin 1996); additional watersheds drain directly to the ocean (Figure 4, Figure 16). The alignment of the interior watershed systems roughly parallels the north-south orientation of Acadia ridges and valleys resulting from glacial action. These drainages are characterized by bold topographic relief of up to 450 m across a distance of only 6-8 km (Kahl *et al*. 2000). The largest of these watershed systems extends to 2,700 ha and comprises up to nine sub-watersheds.

Lakes and Ponds: Nine Great Ponds (lakes ≥ 4 ha) and 11 smaller lakes (< 4 ha) are completely surrounded by ACAD (Table 1, Figure 16). Five lakes are partially within the Park and two are completely outside. Surface areas range from 0.5 ha (e.g. Sargent Mountain Pond, located near the top of Penobscot Mountain) to 359 ha (Long Pond). Jordan Pond is the deepest lake at 46 m (Figure 17).

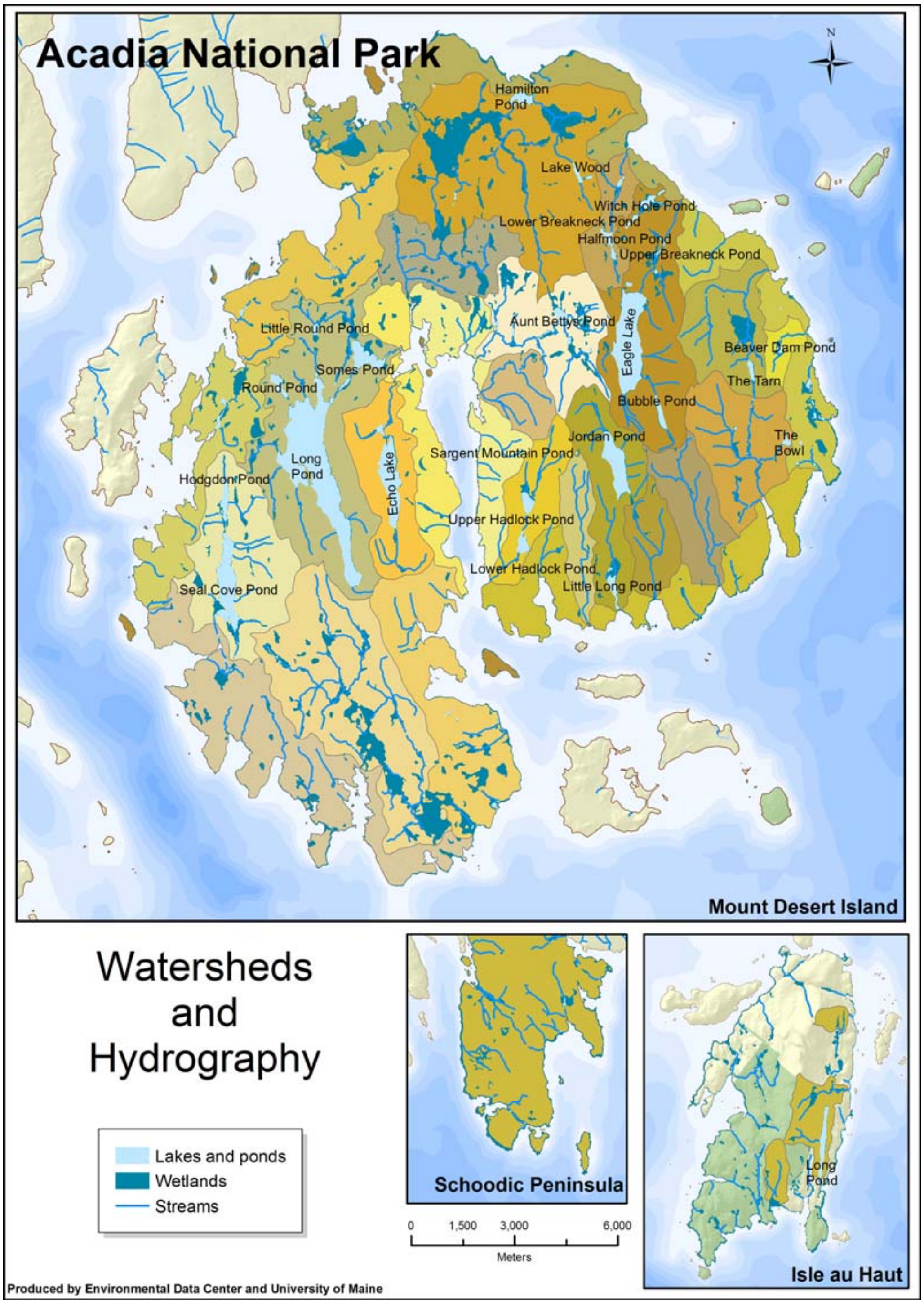


Figure 16. Watersheds and hydrography of ACAD and vicinity. Watersheds shown are clusters of sub-watersheds aggregated into drainage systems.

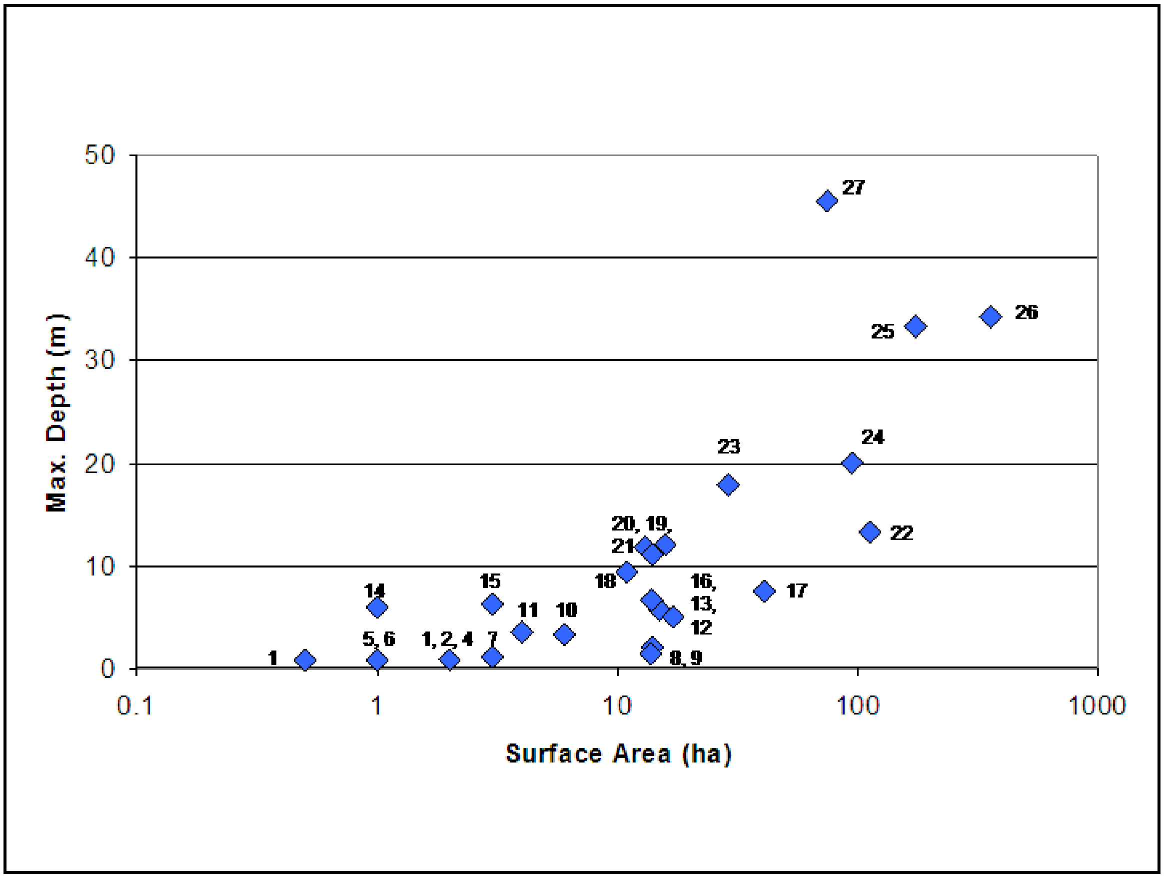


Figure 17. Lakes and ponds in the ACAD region: area-depth relationships.

Lake codes: (1) Bear Brook P. (2) The Bowl. (3) Sargent Mountain P. (4) Seawall P. (5) Fawn P. (6) Duck P. (7) The Tarn. (8) Little Long P. (9) Aunt Betty's P. (10) Lake Wood. (11) Upper Breakneck P. (12) Little Round P. (13) Round P. (14) Half Moon P. (15) Lower Breakneck P. (16) Hodgdon P. (17) Somes P. (18) Witch Hole P. (19) Upper Hadlock P. (20) Bubble P. (21) Lower Hadlock P. (22) Seal Cove P. (23) Long Pond (IAH). (24) Echo L. (25) Eagle L. (26) Long P. (27) Jordan P.

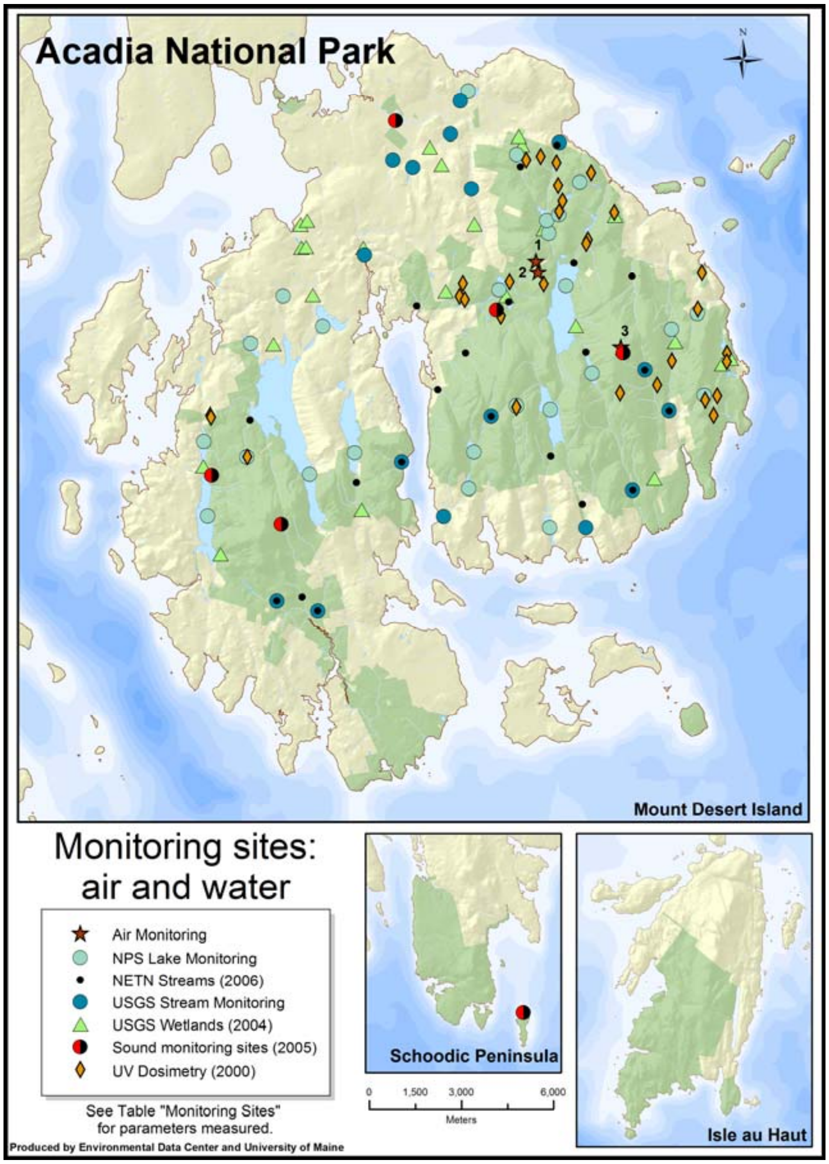


Figure 18. Air and surface water monitoring sites.

Lake water quality data for ACAD lakes extend back to the 1940s (Fuller and Cooper 1946), although the first survey using present-day analytical techniques was done in the 1980s (Kahl *et al*. 2000). Currently, ACAD scientists monitor water quality on 19 lakes (Figure 18); eight are sampled once per year, two are sampled twice per year and nine are visited on a 3-year rotation.

Table 9 provides an overview of productivity-related water quality data for ACAD lakes. Figure 19 compares selected water quality parameters for ACAD and all surveyed Maine lakes.

Table 9. Selected morphological and productivity-related parameters for lakes and ponds in the Acadia region. Lake area-depth relationships are depicted in Figure 18.

Lake/Pond	**Area (ha)**	**Total Drainage Area (km^2)**	**Flushing Rate (times per year)**	**Secchi Depth (m)**	**Alkal-inity (mg/L)**	**Conduc-tivity (uS)**	**Chl a (ppb)**	**Trophic State (1)**
Long P	380.0	18.2	0.3	7.3	3.4	51.5	2.8	O
Eagle L	188.6	9.7	0.3	10.7	3.0	37.7	2.4	O
Seal Cove P	103.2	11.5	1.9	6.9	4.4	45.0	2.7	M
Echo L	95.5	5.9	0.6	8.0	5.5	65.0	2.2	O
Jordan P	75.3	5.0	0.2	13.3	3.5	37.5	1.0	O
Somes P	41.7	22.4	12.8	4.3	5.3		6.8	
Long P (IAH)	25.5	1.2		8.1	2.0	88.0	2.0	
Hodgdon P	18.2	3.2	4.0	4.8	4.4	50.0	7.9	
Hamilton L	16.6		7.0					
Upper Hadlock P	15.4	3.4	4.1	6.6	2.9	47.0	2.7	M
Lower Hadlock P	15.0	4.7	4.6	7.0	2.6	55.0	1.2	
Round P	14.6	1.0	1.5	4.6	7.3	37.0	4.1	
Little Long P	13.8	8.3	25.9					
Bubble P	13.4	1.9	1.9	9.6	3.8	36.5	1.7	O
Aunt Betty P	13.0	5.3	37.1	1.6	6.7	54.0		
Witch Hole P	9.7	1.1	1.2	4.1	2.9	31.0	4.1	M
Lower Breakneck P	8.5	1.5		4.2	4.5	42.0		
The Tarn	7.7	0.8	10.1	1.0	5.5	88.0		
Lake Wood	6.9	1.5	7.6	3.5	4.3	28.5	2.7	
Little Round P	4.9	0.8	3.4					
The Bowl	4.0	0.2	1.3	6.0	1.7	47.0		M
Upper Breakneck P	3.6	1.2	51.0	3.3	5.8	45.0		
Bear Brook P	3.0					93		
Seawall P	2.0	0.6						
Halfmoon P	0.4			4.7	3.2	25.5		
Sargent Mt. P	0.4	0.0		3.4	-0.1	31.0		M
Duck P	0.1	0.5		1.6	0.6	34.0		

(1) O = oligotrophic (unproductive), M = mesotrophic (moderately productive)
Empty cells indicate no data.
Lakes in boldface are those currently monitored routinely by ACAD staff.

Data sources: morphology and water quality data from Maine Dept. of Environmental Protection, accessed from PEARL Web site (www.pearl.maine.edu) which also provides associated metadata. ME DEP calculates overall lake average values for water quality parameters from date-specific data provided by ACAD staff and others. Where data are available from multiple stations, these data have been averaged. Period of data record varies among lakes. Trophic state designations taken from Seger *et al.* (2006).

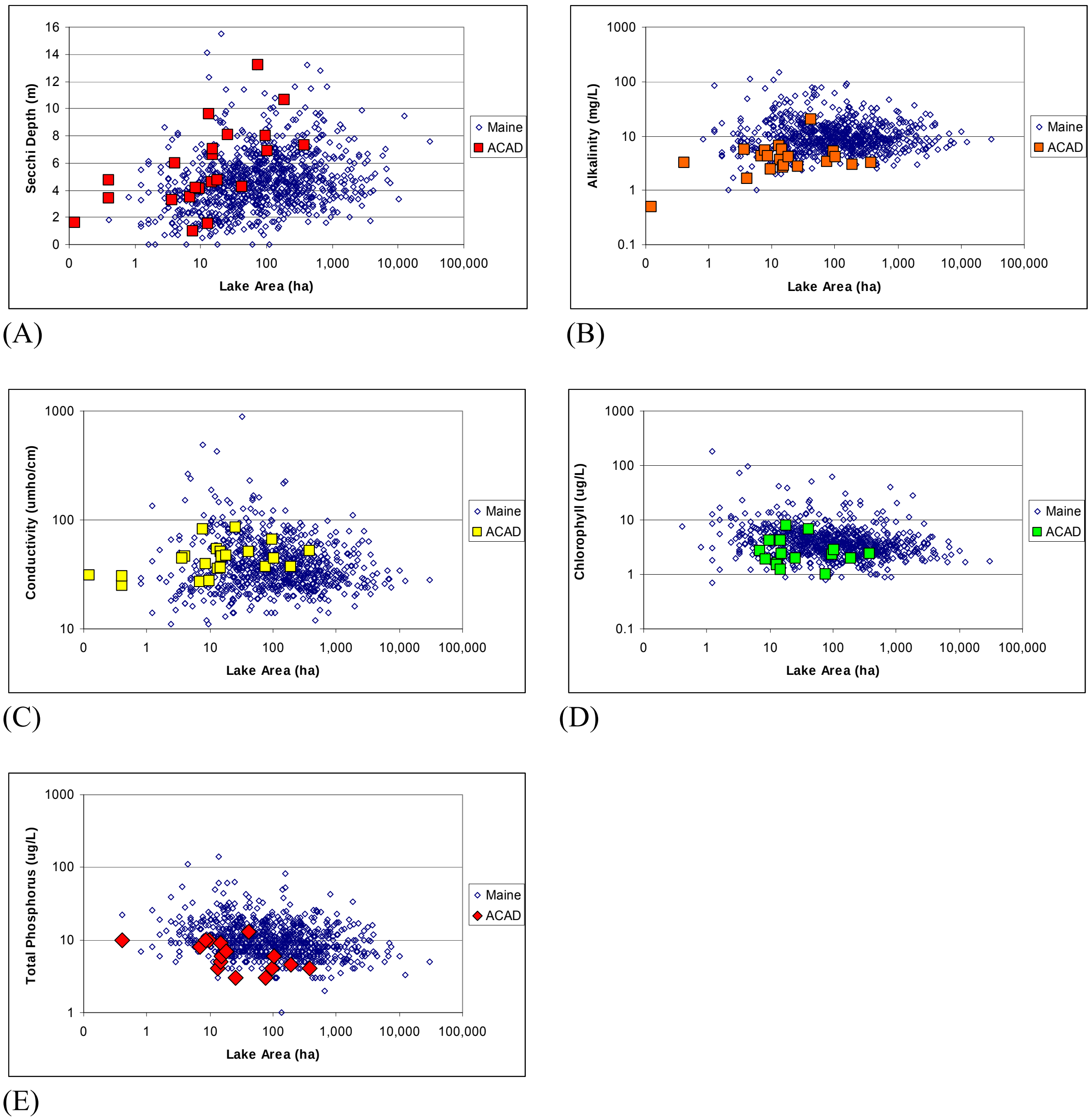


Figure 19. Water quality of ACAD lakes compared to the population of all surveyed lakes in Maine. (A) Secchi depth, (B) Alkalinity, (C) Conductivity, (D) Chlorophyll, (E) Total phosphorus. For some lakes, data are not available for some water quality parameters. Note that all lakes in the state have not been surveyed; consequently, the population of "all surveyed lakes" is smaller than the population of all Maine lakes. Note the logarithmic scales.

All data are lake averages as provided by Maine Dept. of Environmental Protection and accessed at www.pearl.maine.edu. Where there are >1 sampling stations in a lake, data have been averaged across stations. Total phosphorus data are for epilimnetic cores.

Chemically-resistant granites underlying most of the ACAD region result in surface waters with low alkalinity and nutrient concentrations. The alkalinity of nine of 24 ACAD region lakes and ponds is in the lowest 10^{th} percentile for all Maine lakes, with only two small ponds (Little Long Pond and Bear Brook Pond) having greater alkalinity than the state average (Kahl *et al*. 2000). Alkalinity data (Figure 19B) indicate that most ACAD lakes have low buffering capacity, making them susceptible to acidification from atmospheric deposition. Phosphorus concentrations in ACAD lakes tend to be on the low end of range for Maine lakes (Figure 19E). Since phosphorus is typically the nutrient that limits lake productivity, most ACAD lakes are relatively unproductive, with low chlorophyll concentrations and high water transparency (see below). Nevertheless, in terms of total ionic strength (as measured by conductivity), ACAD lakes are similar to the statewide population (Figure 19C).

While some ponds are stained with humic compounds (e.g. Round, Duck and Hamilton Ponds), many are clear because freely-draining soils dominate their watersheds (Kahl *et al*. 2000). Average water column transparency (Secchi depth) ranges from about 1.0 meter (The Tarn, Duck and Aunt Betty Ponds) to >13 m at Jordan Pond. This lake has some of the clearest water in the State. Large lakes at ACAD tend to exhibit higher Secchi depths (greater water transparency) than other large Maine lakes (Figure 19A). Paralleling trends in water transparency, chlorophyll concentrations in larger ACAD lakes tend to be lower that the statewide average (Figure 19D). At least five lakes are oligotrophic (low productivity). Other ACAD lakes are mesotrophic (moderately productive); none can be considered eutrophic (high productivity). Although higher productivity may be a 'natural' condition of lakes in some regions, oligotrophic lakes are frequently considered to be in 'good' condition because of their generally high water clarity.

Most lakes in the ACAD region are circum-neutral, with mean pH values between 6.5 and 7.5 (Figure 20). Only 2 waterbodies are acidic (pH ≤5.0). Duck Pond is part of a naturally acidic wetland system where acidity derives mainly from natural organic matter. Sargent Mountain Pond has a small watershed with minimal soil development; its water is acidic largely as a result of atmospheric deposition (Kahl *et al*. 2000). For more information, see *Threats: Atmospheric Deposition (Acidity and Related Chemistry)*.

Some trend data for ACAD lakes are summarized in Table 10. Other trend analyses regarding lake water quality parameters, including Secchi depth, are currently being carried out by a number of researchers (K. Webster and P. Vaux, University of Maine, unpublished data; J. Runde, NPS, pers. comm. 2007). Although published results from this work are not yet available, there is evidence of increasing transparency in some ACAD lakes, at least during the period 1980-2000 (Figure 21). Other lake water quality trend data are discussed under *Threats: Acidity and Related Chemistry*.

Streams: Most of MDI's 41 named streams flow through the Park at some point and many streams have their headwaters in the Park (Figure 16; Kahl *et al*. 2000). Streams are typically less than 3-5 km long and reported widths for second order streams are 2-6 m (Dubuc *et al.* 1988). Discharge records exist for several streams, including three USGS continuous-record, streamflow gaging-stations: Cadillac Brook (USGS station 01022835) and Hadlock Brook

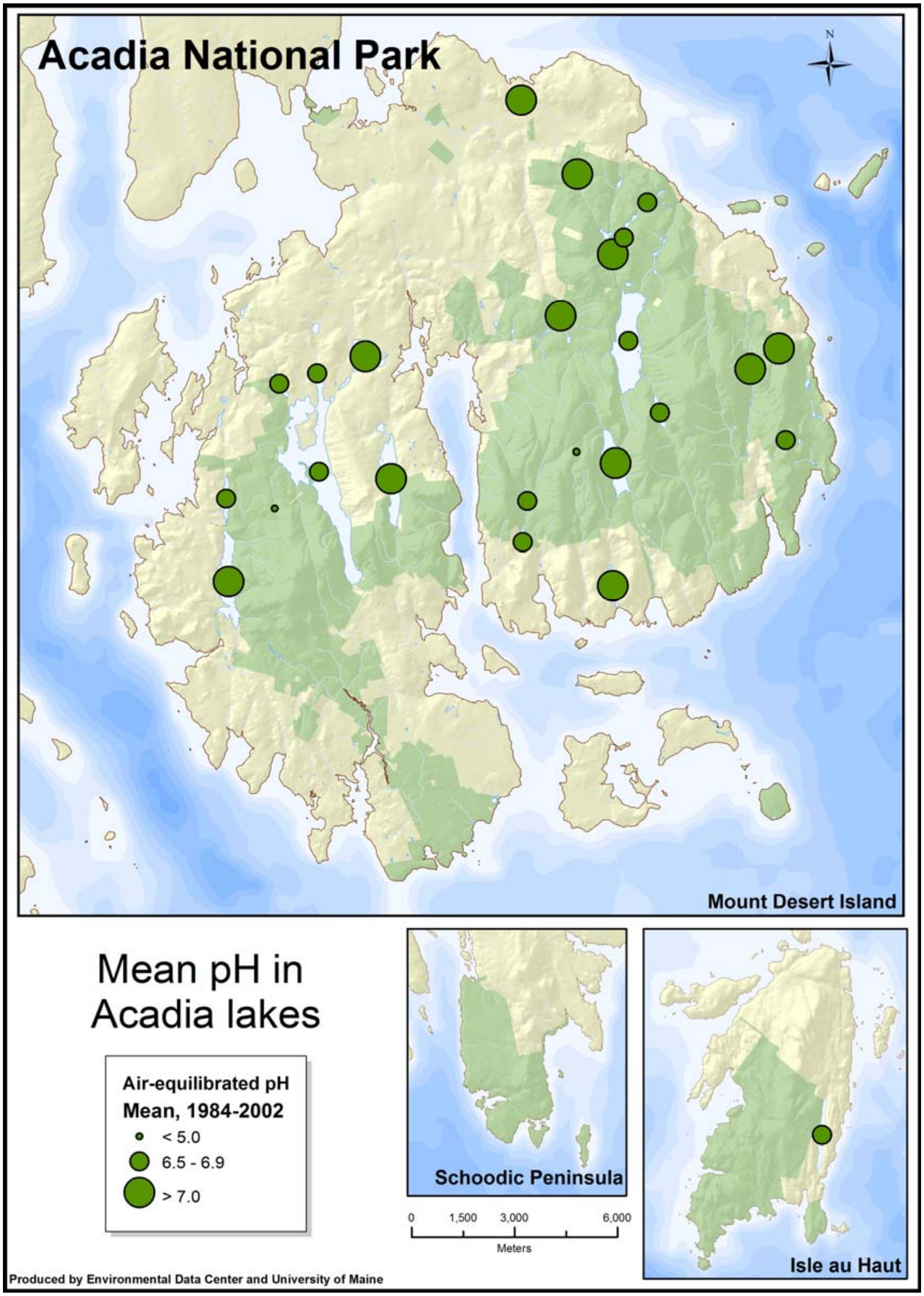


Figure 20. Mean pH in ACAD lakes and ponds.
(Data provided by B. Gawley, NPS)

Table 10. Comparison of trend results for regional and ACAD lakes for the period 1990-2000. Values are median slopes for set of sites in each region. Trend significance levels: * $p < 0.05$; ** $p < 0.01$; ns $p > 0.05$. (Kahl *et al*. 2004)

Parameter [1]	***Acadia Lakes (N=21)***	***New England Lakes***
Aluminum	+ 0.05 ns	+ 0.09 ns
Base cations (Ca + Mg)	- 0.43 *	- 1.48 **
Sulfate	- 0.39 *	- 1.77 **
Nitrate	- 0.06 ns	+ 0.01 ns
Gran ANC	+ 0.33 ns	+ 0.11 ns
Hydrogen	+ 0.02 ns	- 0.01 ns
DOC	insufficient data	+ 0.03 *

[1] Units for sulfate, nitrate, base cations [Ca + Mg], Gran ANC and hydrogen are µeq/L/year. Units for DOC are mg/L/year. Units for aluminum are µg/L/year.

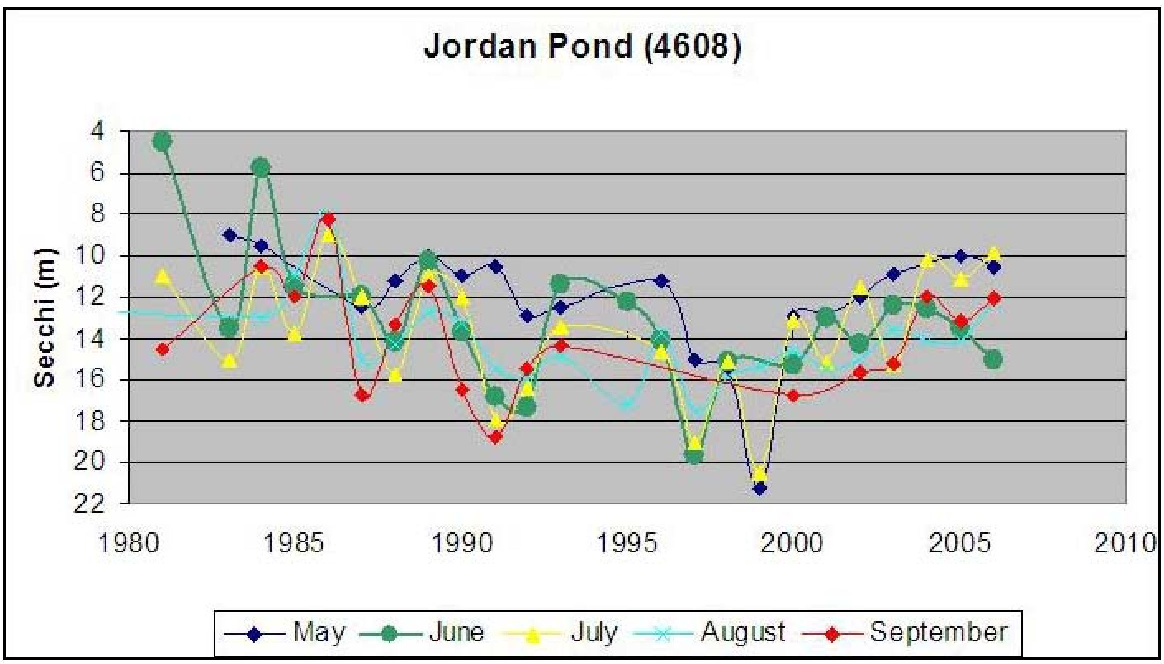


Figure 21. Trends in water transparency (Secchi depth) at Jordan Pond, 1980-2006, by month. Monthly means from Maine Dept. of Environmental Protection, accessed at www.pearl.maine.edu (March 2007).

(USGS station 01022860), both of which have eight years of data but were discontinued in 2006; and Otter Creek (USGS station 01022840) which was initiated in 2006. All other stream discharge measurements were one-time measurements or estimates related to specific projects (see list in Kahl *et al*. 2000).

Recent (late 1990s on) stream water quality data are available for a number of streams across MDI (Figure 18). These include data from the following programs:

- Hadlock – Cadillac paired watersheds studies, 1998-2000. This work was initiated during the PRIMENet (Park Research and Intensive Monitoring of Ecosystems) program and continued with funding from the NPS Natural Resources Challenge to assess the ecological effects of atmospheric deposition of nitrogen and mercury; included a survey of streams across the Park for Hg and full chemistry (Kahl *et al.* 2003, Kahl *et al*. 2007a and 2007b).
- USGS study of 14 small watersheds on MDI from 1999 to 2001 (Nielsen *et al*. 2002c). Data include nutrients, major ions, some metals, and basic water-quality parameters including dissolved oxygen, temperature. Figure 22 presents a selection of these data.
- NPS Northeast Temperate Network; stream monitoring on MDI began in 2006. 3 sites are monitored every year (Cadillac Brook, Hadlock Brook, Otter Creek); 17 sites are monitored every other year (Hunters Brook, Kebo Brook, Sargent Brook, Jordan Stream, Breakneck Brook, Aunt Betty's Pond Inlet, Marshall Brook, Lurvey Spring, Browns Brook, Man o'War Brook, Stanley Brook, Eagle Lake Inlet, Duck Pond Brook, Lake Wood Outlet, Duck Brook, Lurvey Brook).
- Monitoring by ACAD scientists at sites representing a range of stream sizes and levels of anthropogenic impacts (Breen *et al*. 2001). This monitoring also includes macroinvertebrate sampling (see below).
- A study of mercury in streams across MDI (Peckenham *et al*. 2007).
- A study of the impacts of vehicular traffic on stream water quality (Peckenham *et al*. 2006).
- Nutrient loading studies focusing on Bass Harbor Marsh, Northeast Creek and Somes Sound.

Streamwater survey data exist for the early 1980s (Kahl *et al*. 1985), and intensive monitoring data exist for the late 1980s for upland watersheds around Hadlock Pond (Heath *et al*. 1992). Several other projects have sampled streams for brief periods or in surveys, including Reeb (1992), Bank (2005), and many single-site studies; these data are not yet integrated into the Park's streamwater database.

Most streams are dilute, with acid-neutralizing capacities generally below 100 µeq/L (Figure 23). Stream water quality is further discussed under *Assessment of Threats* (see especially the sections on *Atmospheric Deposition* and *Nutrient Enrichment*) and *Assessment of Condition*.

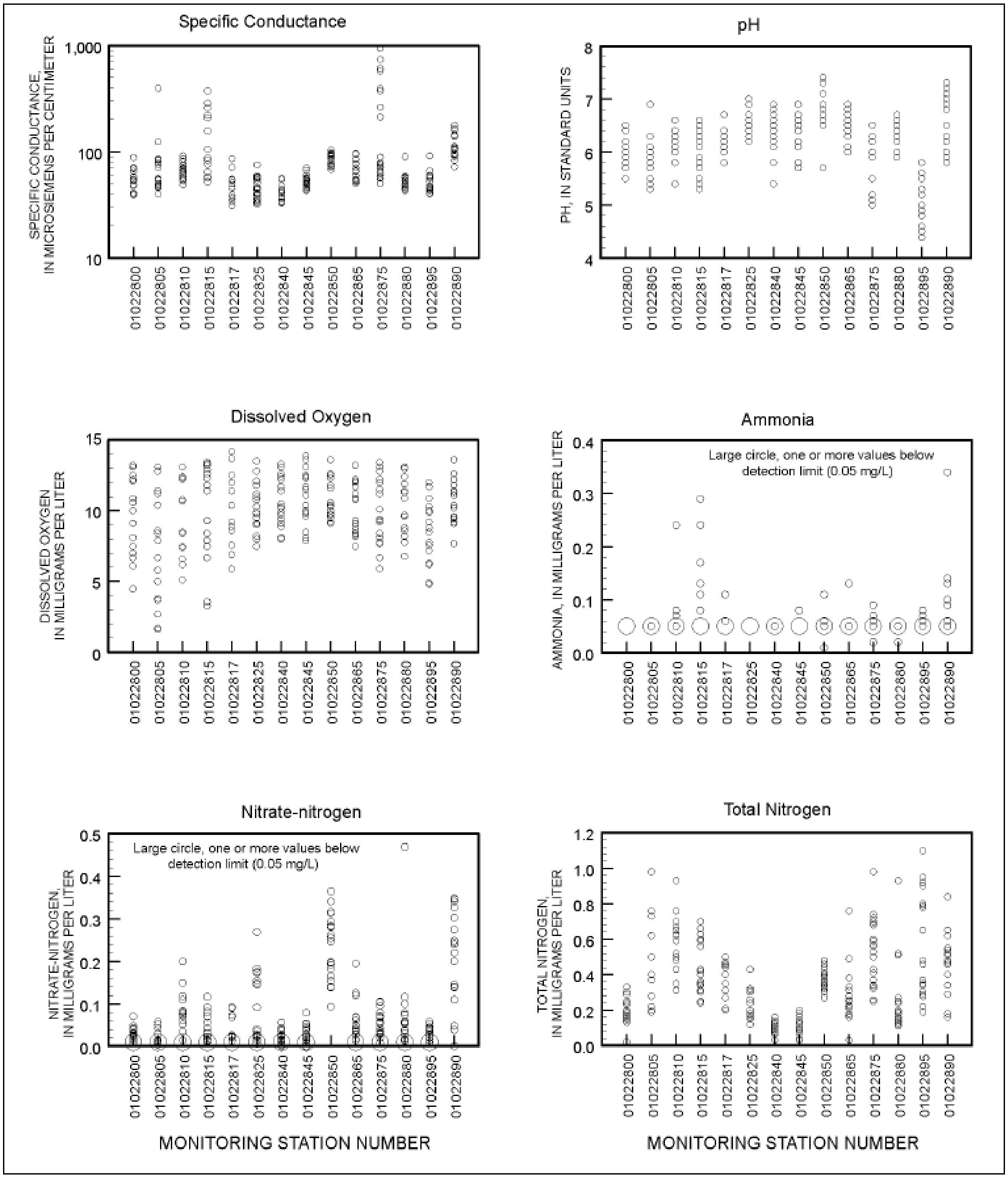


Figure 22. Distribution of specific conductance, pH, dissolved oxygen, and nitrogen species in streams on MDI.
(Figure from Nielsen *et al*. 2002c, used with permission)

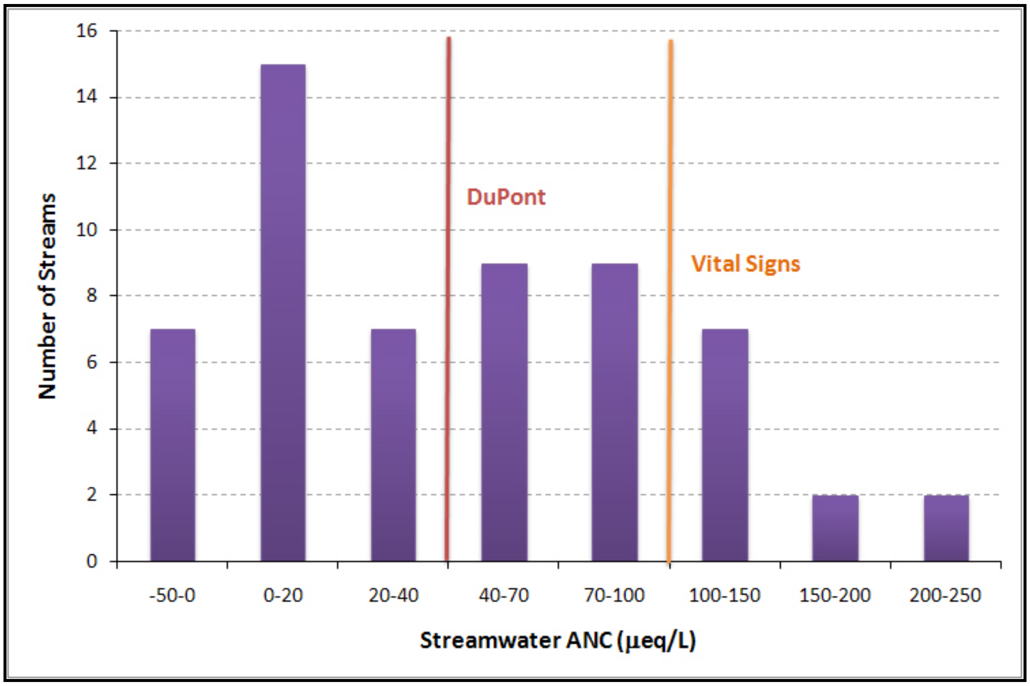


Figure 23. Acid-neutralizing capacity (ANC) in MDI streams. Vertical lines are tolerance criteria for aquatic organisms: 40 µeq/L suggested by Dupont et al. (2005) and 100 µeq/L adopted by Mitchell et al. 2006. See further information under Assessment of Condition.

Wetlands: Wetlands comprise approximately 11% of fee-ownership lands in ACAD and 5% of conservation easements (Calhoun *et al*. 1994). There are two major freshwater / estuarine wetland complexes. Northeast Creek, in the northern part of MDI, drains an extensive low-lying wetland and Bass Harbor Marsh on the southwest side of the island drains another.

Calhoun *et al*. (1994) provide detailed descriptions of the geologic history, morphology, hydrology and biology of ACAD wetlands. As these authors note, "[t]he Acadia region has a wealth of wetland settings owing to coastal influences and geologic and glacial history." The mountainous eastern region of MDI supports wetlands along valleys and in areas of groundwater discharge, while the gentler landscape of the western half of the island supports the majority of the area's estuarine wetlands, peatlands and riverine wetlands. Neighboring islands, including IAH, support ombrotrophic peatlands, hillside seep forested wetlands, estuarine and marine wetlands.

ACAD wetlands have been classified using the Cowardin system (Cowardin *et al*. 1979). Aggregating the classes into systems reveals the following representation, expressed as % of total wetland area (Calhoun *et al*. 1994):

Marine (37.5%)	Estuarine (20.0%)	Riverine (<1%)
Lacustrine (10.7%)	Palustrine (31.6%)	

According to recent analyses of the Vegetation Mapping Project (Lubinski *et al*. 2003), forested wetlands comprise 1,463 ha on MDI, non-forested wetlands 514 ha, and bays and estuaries 199 ha. Appendix 1 provides watershed-level wetland and other landcover statistics for MDI, SCH and IAH regions and outlying islands. Figure 5 depicts some of these data.

Neckles *et al*. (2008) compared total wetland areas and number of wetland polygons in nine parks of the Northeast Temperate Network. As expected from its size relative to other parks, ACAD has the largest extent of wetlands. Of the 280 ArcHydro catchments[3] on MDI that intersect the Park, 172 contain wetland complexes. Approximately 78% of these complexes contain emergent or scrub-shrub vegetation. Basin size, water chemistry and hydrology are all factors that influence wetland type (Neckles *et al*. 2008).

Nielsen *et al*. (2006) recently developed a preliminary hydrogeomorphic (HGM) classification of wetlands on MDI. This classification is based on three key factors that determine how wetlands function: position in the landscape, dominant source of water, and hydrodynamics. Unlike the HGM approach, the widely-used Cowardin system for delineating wetlands does not include much hydrologic information. For example, the Cowardin system groups most of the nontidal freshwater wetlands on MDI into the palustrine hydrologic system, without further definition of sources of water (Nielsen *et al*. 2006). The HGM classification defines 12 wetland classes (Table 11). Ground-truthing indicated that the classification had an 88% accuracy rate for undisturbed wetlands and 82% rate for disturbed wetlands. The authors do not provide statistics on the relative abundance of the various classes of wetlands on MDI.

Wetlands of the ACAD region are further discussed later sections in this report.

Groundwater: Nielsen (2002a) and Kahl *et al*. (2000) provide overviews of the geohydrologic setting of MDI. Groundwater exists in bedrock and surficial units. With the exception of a small glaciofluvial deposit south of Jordan Pond (Figure 9), there are no significant surficial aquifers on MDI (Nielsen 2002a). However, some residents obtain water from dug (shallow) wells. In many parts of the ACAD region, coarser glacial till is capped by deposits of the Presumpscot Formation, a glacio-marine ‘clay’ or silt. These deposits inhibit percolation into the groundwater and thus increase surface runoff (Kahl *et al*. 2000). Wells in the ACAD region are generally >150 feet in depth, with many being >400 feet (Figure 24). Most of these wells have a yield of <15 gallons per minute.

The chemistry of groundwaters is less studied than that of surface waters. Hansen (1980, cited by Kahl *et al*. 2000) characterized MDI groundwater as ‘soft’ and of a sufficient quality for domestic use. Groundwater chemistry data exist for USGS monitoring wells. Other data are reported to the Maine Drinking Water Program, in particular from wells that serve commercial operations. According to Kahl *et al*. (2000), “high concentrations of radon in groundwater from MDI pose a potential concern to human health”.

[3] Catchments delineated in GIS using ESRI ArcHydro tool.

Table 11. Hydrogeomorphic classes of wetlands on MDI (based on Nielsen *et al*. 2006).

Class	**Landscape setting**	**Source of water**
Riverine – Upper Perennial	Within 50 m of perennial stream, at roughly same altitude	Primarily lateral exchange with perennial 1st/2nd order stream; may also have groundwater inflow
Riverine - Nonperennial	Within 50 m of intermitten stream, at roughly same altitude	Primarily lateral exchange with intermittent stream; may also have groundwater inflow
Riverine - Tidal	Within 50 m of a tidal stream, at roughly same altitude	Primarily lateral exchange and flooding with tidal freshwater stream; may also have groundwater inflow
Depressional - Closed	In topographic depression; no surface inflow or outflow	Inflow from groundwater, precipitation or overland flow
Depressional - Semiclosed	In topographic depression, some surface-water outflow	Inflow from groundwater, precipitation or overland flow
Depressional - Open	In topographic depression; surface inflow and outflow	Inflow from groundwater, precipitation, overland flow or stream flow
Depressional – No Groundwater Input	In topographic depression, but underlain by Presumpscot Formation; may have surface-water inflows or outflows	Precipitation, overland flow or stream inflow
Mineral Soil Flat	Wide, flat area, low topographic relief in surrounding area, mineral soils	Precipitation
Organic Soil Flat	Wide, flat area, low topographic relief in surrounding area, organic soils	Precipitation
Tidal Fringe	Adjacent to tidal saltwater body, within 50 m of limit of saltwater influence	Overbank flow (lateral exchange) from estuary or other saltwater body
Lacustrine Fringe	Adjacent to large open-water lake or pond (within 100 m and same altitude; lake or pond must be large enough to control water level in wetland	Overbank flow (lateral exchange) from lake; may also have groundwater inflow
Slope	On a sloping surface or hillside	Return flow (discharge) from groundwater

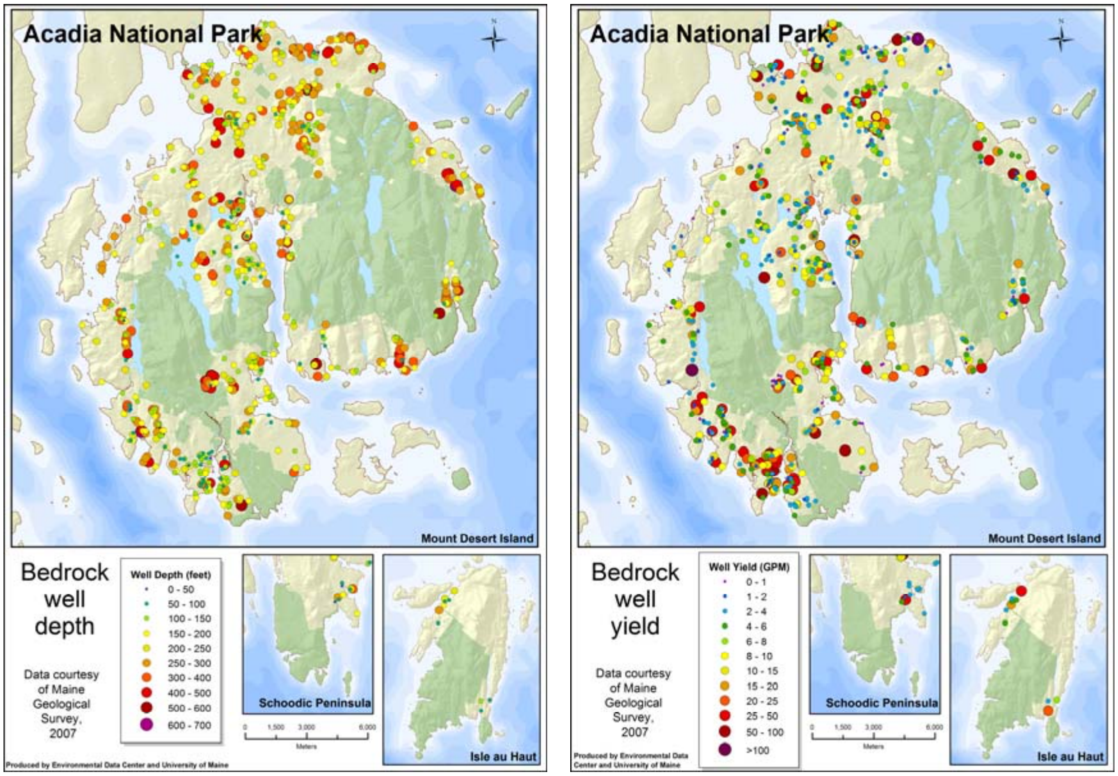


Figure 24. Bedrock well depths and yields.

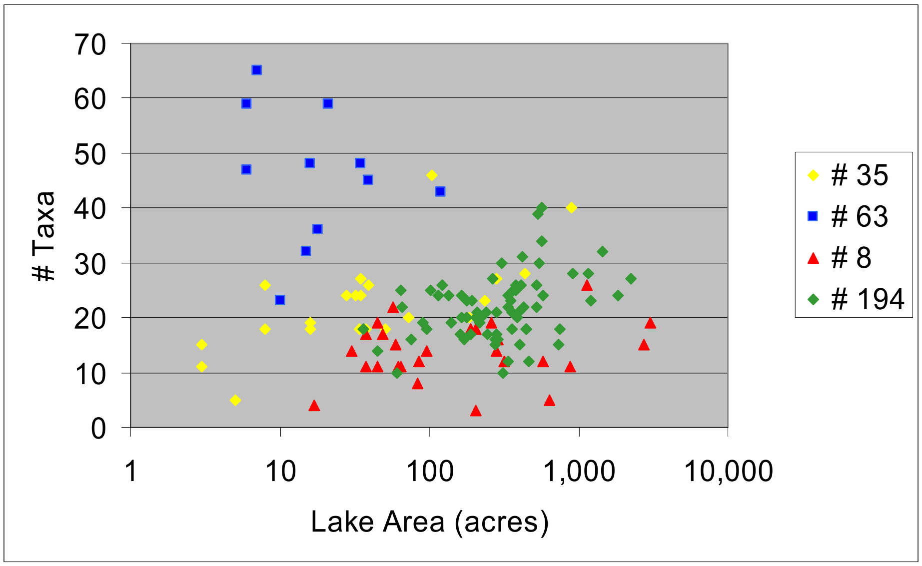
Biological Resources of Freshwater Systems

Freshwater Plants: The most comprehensive survey of freshwater plants in the ACAD region is that of Greene *et al*. (1997). Thirty-nine lakes and ponds were surveyed across all three park units. A total of 92 taxa were collected from the ACAD region (80 fully aquatic species and 12 semi-aquatic shoreline species), including eleven taxa that had not been previously reported from the island[4]. The highest species richness was recorded from Somes Pond (46 taxa) while the lowest number of species was observed in a pond at SCH (2 taxa). Figure 25 compares plant diversity in ACAD ponds and other Maine waters as a function of lake area and alkalinity (an indicator of potential productivity). Although different sampling designs make it difficult to compare data across different studies, plant diversity in ACAD lakes and ponds appears to mirror that of other Maine waterbodies of similar size and alkalinity (Vaux 2005).

The rarest plant at ACAD is a freshwater species, the Prototype quillwort (*Isoetes prototypus*). It is known from 11 locations globally, one on MDI and 10 in New Brunswick and Nova Scotia. Also considered globally rare is the Acadian quillwort (*Isoetes acadiensis*) which occurs in one pond at ACAD and is distributed from Newfoundland to New York. The list of aquatic species

[4] In comparison, 130 obligate aquatic plant species and 438 wetland species are known to occur in Maine (Vaux 2005).

(A)



(B)

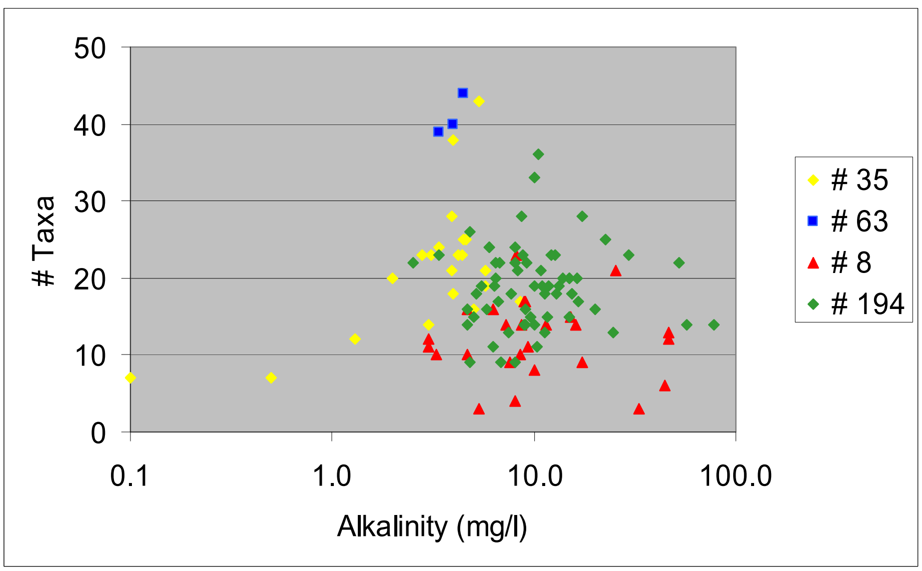


Figure 25. Relationship between number of aquatic macrophyte species (per lake) and (A) lake area, (B) alkalinity in ACAD and other Maine lakes. ACAD lakes are shown in as yellow diamonds. (Figure from Vaux 2005)

Data are from four different studies and are shown separately because sampling type and effort was not consistent among studies. Studies are: #35 = Greene et al. (1997); #63 = Dieffenbacher-Krall (1998); #8 = Cameron (2000); #194 = MNAP rapid bioassessment surveys (unpublished data, courtesy of D. Cameron).

reported by Greene *et al*. (1997) included seven species that were state-listed or proposed for state listing. About 30 other species appeared to be locally rare in the Park. Of these, 21 occurred at a single sampling site. Eight aquatic or semi-aquatic species at ACAD are known only from historic records; they were not re-located during the Greene *et al*. survey or in the previous 20 years of sampling on MDI.

Calhoun *et al*. (1994) provide an excellent review of freshwater wetland and salt marsh plant communities in the ACAD region. They list a total of 220 taxa in five major community types (aquatic bed/freshwater marsh, salt marsh, emergent peatland, shrub peatland, and forested wetlands). This taxon total is an under-estimate of total species richness since several species included in the list of Greene *et al*. (1997) are not included in the Calhoun *et al*. list.

Little (2005) and Neckles *et al.* (2008) contain information on ACAD wetland plant communites. Human-impacted wetlands tend to be sedge meadow or cattail marsh, whereas non-degraded wetlands tended to have fen communities.

The Vegetation Mapping Project (Lubinski *et al*. 2003) recognizes a total of 53 vegetation types in the ACAD region. Approximately one half (24/53) of vegetation types are wetland types. Of the 24 wetland types, 13 fall within the broad group of herbaceous wetland vegetation types, while six are shrub / dwarf shrub vegetation types.

Birds: Lakes, ponds and wetlands are important habitat for a number of bird species. Of the 205 resident bird species in the ACAD region, 29 are considered to be 'marsh' taxa (Table 8, Appendix 6). For most (25) of these species, data are insufficient to document temporal trends in population size. Four species on MDI appear to have expanding populations (Table 8).

The annual Maine Audubon loon count has documented common loon (*Gavia immer*) adults, chicks and nests on MDI since 1983. According to Evers *et al*. 2003 (cited by Bank *et al*. 2007), loon recruitment on MDI is below the level needed to maintain populations. Furthermore, according to Kahl *et al*. (2000), MDI lakes appear to have fewer loons compared to other lakes in Hancock County. However, analysis of Maine Audubon data suggest that the average numbers of loon adults on MDI lakes over the period 1983-2004 appear to be similar to those observed on other Maine lakes (Figure 26, upper panel). Other data indicate that the productivity of loons on MDI is very similar to loons elsewhere in Maine (approximately 0.5 fledged chicks per nesting pair; D. Lamon, Somes-Meynell Wildlife Sanctuary, unpublished data). The Audubon data demonstrate that there is significant inter-annual variation in loon densities on MDI (Figure 26, lower panel).

Mammals: Wetlands in the ACAD region are used by a diverse group of mammals, including beaver (*Castor canadensis*), river otter (*Lutra canadensis*), mink (*Mustela vision*) and other taxa that would be considered primarily terrestrial. Beaver have played a dominant role in the creation or modification of many wetlands on MDI (Calhoun *et al*. 1994). Although extirpated from MDI in the early 1900s, beaver were re-introduced in the early 1920s. Numbers remained low until the 1947 fire after which regenerating aspen stands created ideal habitat and thence a rapidly expanding population. The number of ponded wetlands at ACAD increased by 89% between 1947 and 1997 (Cunningham *et al*. 2006). More recently, the beaver population has decreased by

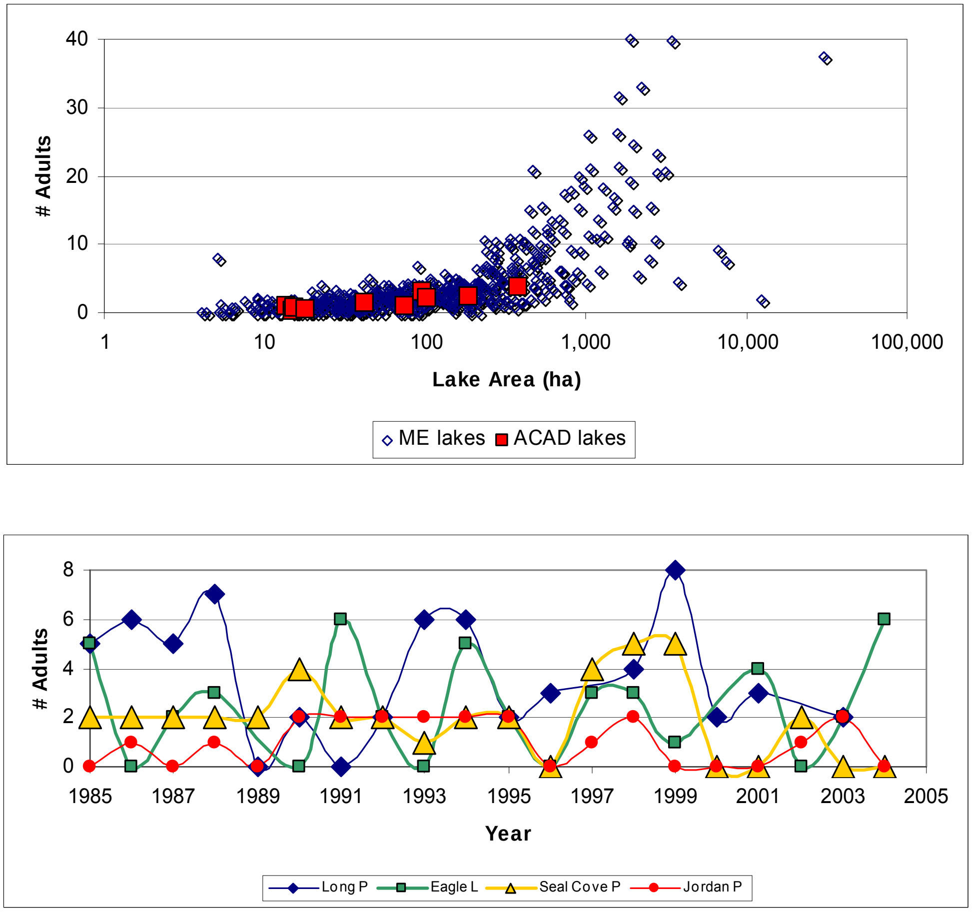


Figure 26. Loon populations on Maine and ACAD lakes. Upper panel shows average number of adults counted during July loon census as a function of lake area (data are for the period 1983-2004; the number of years with data varies among lakes). Lower panel shows temporal patterns in adult numbers on four ACAD lakes. Data source: Maine Audubon data accessed at www.pearl.maine.edu.

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approximately two thirds (Calhoun *et al*. 1994), with the result that many beaver dams are currently not maintained (Figure 27).

Beaver-created wetlands are used by other species. The river otter, in particular, is closely associated with these wetlands, occupying abandoned beaver lodges and dams as den sites (Dubuc *et al*. 1988, 1990). Surveys in the 1980s demonstrated that otter were present in over half of MDI's watersheds. Otter provide a link between fresh and marine wetlands since they move between these two environments and feed on marine fishes in winter (Dubuc *et al*. 1991). Beaver-created wetlands also provide breeding habitat for amphibians (Cunningham *et al*. 2006).

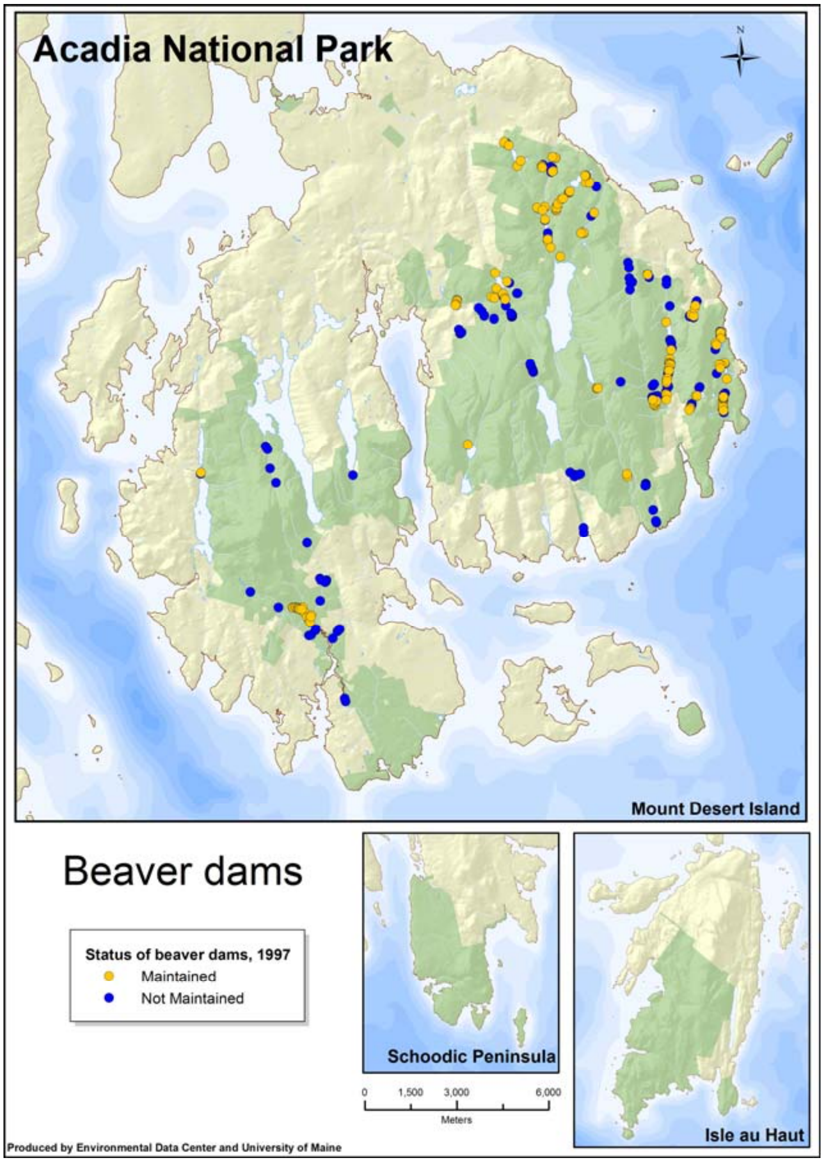


Figure 27. Location and status of beaver dams on MDI.
(Data source: ACAD Office of GIS, based on work of G. Mittelhauser and others)

Freshwater Fish: Lake and stream fish assemblages of ACAD were recently surveyed by Stone *et al*. (2007; see also Bowes *et al*. 1999). Using literature reviews and field sampling during 1998-1999, these authors concluded that 31 species of freshwater fishes have been recorded from ACAD and waters bordering the Park. Twenty-eight of these species are currently present (Table 12). One species (bridle shiner, *Notropis bifrenatus*) is known from just one collection in the 1990s and likely represents a bait introduction. One additional species, largemouth bass (*Micropterus salmoides*), is present in Hamilton Pond, which is outside the Park, and thus not included in the total of 28 species. Two species are generally considered estuarine taxa but were included in the list because they were collected in coastal streams.

Table 12. Freshwater fishes currently found in 24 lakes/ponds and 32 streams. Data are from Stone *et al*. (2007) and were compiled from past records and surveys conducted in 1998 and 1999.

Common Name	**Scientific Name**	**W/S***	**Native?**	**# Ponds**	**# Streams**
American eel	*Anguilla rostrata*	W	yes	17	17
Alewife	*Alosa pseudoharengus*	W,S	yes	5	0
Common shiner	*Luxilus cornutus*	W	no	5	2
Golden shiner	*Notemigonus crysoleucas*	W	yes	20	4
Bridle shiner	*Notropis bifrenatus*	W	no	0	1
Blacknose shiner	*Notropis heterolepis*	W	no	1	0
Northern redbelly dace	*Phoxinus eos*	W	yes	12	1
Creek chub	*Semotilus atromaculatus*	W	no	3	2
Fallfish	*Semotilus corporalis*	W	no	4	0
White sucker	*Catostomus commersoni*	W	yes	11	4
Brown bullhead	*Ameiurus nebulosus*	W	no	5	1
Chain pickerel	*Esox niger*	W	no	4	2
Rainbow smelt	*Osmerus mordax*	W	yes	12	0
Landlocked salmon	*Salmo salar*	W,S	no	7	0
Brown trout	*Salmo trutta*	S	no	4	0
Brook trout (landlocked)	*Salvelinus fontinalis*	W,S	yes	17	18
Brook trout (sea-run)	*Salvelinus fontinalis*	W	yes	1[b]	1[b]
Lake trout	*Salvelinus namaycush*	W,S	no	2	0
Banded killifish	*Fundulus diaphanus*	W	yes	18	3
Mummichog [a]	*Fundulus heteroclitus*	W	yes	0	2
Atlantic silverside [a]	*Menidia menidia*	W	yes	0	1
Fourspine stickleback	*Apeltes quadracus*	W	yes	1	3
Threespine stickleback	*Gasterosteus aculeatus*	W,S	yes	6	3
Ninespine stickleback	*Pungitius pungitius*	W	yes	10	5
White perch	*Morone americana*	W	yes	4	0
Redbreast sunfish	*Lepomis auritus*	W	?	3	0
Pumpkinseed	*Lepomis gibbosus*	W	yes	15	5
Smallmouth bass	*Micropterus dolomieu*	W,S	no	5	0
Yellow perch	*Perca flavescens*	W	no	3	1

[*] W/S = wild / stocked populations

[a] Found in lower, freshwater stations of some coastal streams

[b] Confirmed in at least 1 pond and 1 stream, but reported in several other coastal streams

Note that one additional species, largemouth bass (*Micropterus salmoides*) is present in Hamilton Pond, which is outside of the Park.

The golden shiner (*Notemigonus crysoleucas*) is the most common species in lakes and ponds, while brook trout (*Salvelinus fontinalis*) is most common in streams (Table 12). Seven species were recorded from half or more (≥12) of the surveyed lakes, while two species were present in half or more (≥17) of the streams. Two species were present in just one lake, while five species were present in just one stream. Ten species found in lakes were not found in streams.

The number of fish species in each lake is shown in Figure 28. Only one pond is fishless (Sargent Mountain Pond). From its high-elevation location we can infer that it is naturally fishless. Its acidic waters likely are one reason why it remains fishless today even though there are anecdotal accounts of unauthorized fish introductions. According to Stone *et al*. (2007), 15 of the 28 fish species currently present in ACAD are native to MDI waters. Only the depauperate Duck Pond appears to have never supported any fish species that is a non-MDI native (Figure 28).

As expected, larger ACAD lakes tend to contain more fish species than smaller lakes (Figure 29). Compared to other lakes in southern Maine, fish species richness in ACAD lakes larger than about 50 ha is similar to the regional lake population. However, smaller ACAD lakes appear to be somewhat more species-rich than other lakes in the southern region of the State. As will be discussed in the *Assessment of Threats* section, higher species richness is not necessarily a desirable condition since it may reflect introductions of non-native species.

Fisheries management in the ACAD region lakes falls under the jurisdiction of the Maine Department of Inland Fisheries and Wildlife (MDIFW), although management is implemented collaboratively with NPS. Since 2000, 14 out of 27 lakes in the region have been stocked by MDIFW with one or more species (Table 13). Seven lakes have not been stocked since 1989, although three of these were stocked in previous years. The most commonly stocked species is brook trout; other species include landlocked salmon (*Salmo salar*) and lake trout (*Salvelinus namaycush*). All three species are native to Maine, although lake trout and salmon are likely not native to MDI. Brown trout (*Salmo trutta*) has been stocked in two lakes frequently over the past two decades; this species is not native to North America. Stone *et al*. (2007) note that, of the 31 total historical species, 10 have been stocked at some time; these include three species that are no longer present on the island. The issue of fish introductions is further discussed under *Threats: Exotic Species*.

Although several diadromous species exist in the ACAD region, it is likely that runs are much smaller today than historically (D. Lamon, Somes-Meynell Wildlife Sanctuary, pers. comm. August 2007). Four species are present as anadromous as well as landlocked populations: alewife (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax*), white perch (*Morone americana*) and brook trout (Stone *et al*. 2007). Letcher *et al*. (2006) are currently studying movement of brook trout between marine and fresh water at Stanley Brook, one of three or four systems on the island that are known to contain “salters” (sea-run brook trout). Final results from this research are not yet available. The catadromous species, American eel (*Anguilla rostrata*) is known from 17 streams in the ACAD region (Table 12).

Recent research studying the genetic structure of brook trout at ACAD (T. King, USGS-BRD, pers. comm. December 2004) has identified levels of relatedness among populations of minor drainages and has been able to detect the influence of past stocking events. Out of six brook trout populations studied on MDI, four have similar genetic structure (Marshall Brook, Jordan Stream, Stanley Brook and Hunters Brook), while two others appear relatively distinct (Lurvey and Hadlock Brooks). The final report from this study is not yet available.

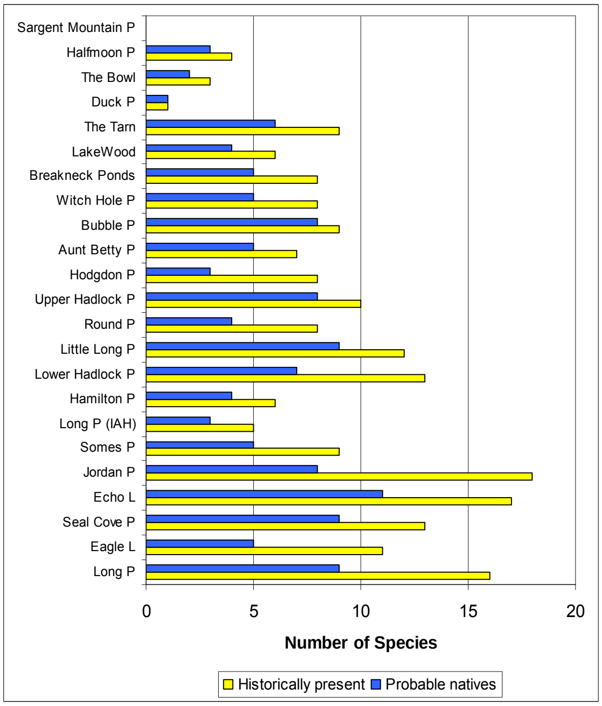


Figure 28. Fish species richness of ACAD area lakes and ponds. “Historically present” indicates all species known to have been present. “Probable natives” are species thought to be natives to the specific waterbody. Data from Bowes *et al.* 1999.

(Note that species totals do not always agree with those in the MDIFW database, from which data in Fig. 29 are derived. One reason is that some of the species recorded by Bowes et al. [1999] as being “historically present” are thought to be no longer present.)

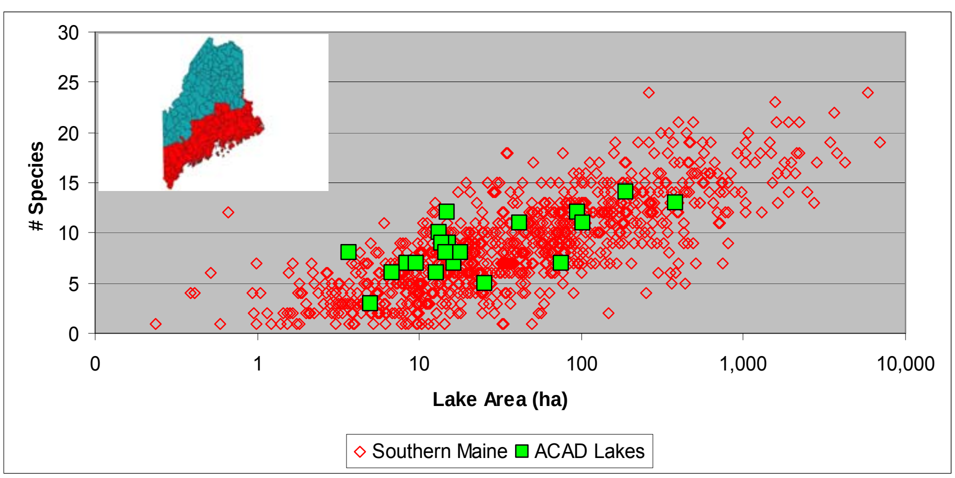


Figure 29. Fish species richness in ACAD area lakes compared to all surveyed lakes in southern Maine (red area in the inset map).

Note: Sebago lake [12,327 ha, 27 fish species] is excluded from this figure.

(Figure from Vaux [2005], based on data from ME Dept. of Inland Fisheries and Wildlife)

Table 13. Fish stocking history for lakes in the ACAD region. Data are number of years that species has been stocked during the period 1989-2006 and the most recent stocking year (through 2006). An asterisk (*) indicates that stocking occurred at some time during the period 1937-1988, but not since then.

Lake	**Brook trout**		**LL Salmon**		**Lake trout**		**Brown trout**		**Splake**	
	# years	*Most recent*	*# years*	*Most recent*	*# years*	*Most recent*	*# years*	*Most recent*	*# years*	*Most recent*
Long	15	2005	17	2005						
Eagle	17	2005	16	2006	3	1994				
Seal Cove	*						10	2003		
Echo	17	2005	14	2005	1	1994				
Jordan	*		16	2004	3	1991				
Somes										
Long P (IAH)										
Hodgdon										
Hamilton										
Upper Hadlock	13	2005					*		1	2001
Lower Hadlock	17	2006					15	2005		
Round	17	2005								
Little Long	*		*							
Bubble	14	2006								
Aunt Betty	5	1993								
Witch Hole	17	2005								
Lower Breakneck	17	2005								
Lake Wood	8	2005								
Little Round	*									
Upper Breakneck	17	2005								
Duck	*									
Halfmoon	17	2005								
The Tarn	11	1999								

Data are from ME Dept. of Inland Fisheries & Wildlife, as accessed on PEARL Website (www.pearl.maine.edu). 2006 data are from MDIFW Website.

Amphibians and Reptiles: Streams, wetlands and the littoral zone of some lakes are important habitat for many of ACAD's amphibians and reptiles. These taxa have been discussed as a group under the section on *Biological Resources of Terrestrial Systems*.

Freshwater Macroinvertebrates: Three of Maine's 11 freshwater mussel species are known from MDI: triangle floater (*Alasmidonta undulate*), eastern elliptio (*Elliptio complanata*) and eastern floater (*Pyganodon cataracta*). None of these three species is listed as threatened or endangered by the State of Maine.

Odonates (dragonflies and damselflies), mayflies and rotifers are perhaps the most well-documented groups of freshwater-associated invertebrates in the ACAD region. Over 100 of Maine's ca. 160 dragonfly and damselfly species have been recorded from MDI (data source: Maine Damselfly and Dragonfly Survey data as compiled in the Maine Aquatic Biodiversity Project database [Vaux 2005], including data of White [1989]). Just over one third (~58/~151) of Maine's known mayfly species are known to occur on MDI (Burian and Gibbs 1991; Mack 1998). The freshwater rotifers of MDI were thoroughly inventoried during a decade of field work by F. Myers during the 1920s and 1930s (see Kahl *et al*. 2000 for reference list).

Macroinvertebrate assemblages in nine streams on MDI have been surveyed by ACAD and MDEP staff to evaluate the extent to which these streams attain their designated water quality class. The streams are: Duck Brook, Lurvey Spring Brook, Richardson Brook, Marshall Brook, Otter Creek, Hunters Brook, Stanley Brook, Heath Brook, and Lake Wood outlet stream. All streams are designated class AA, the highest quality class for streams in the State of Maine. Only two streams (Stanley Brook and Richardson Brook) attained the AA designation in all samples (Table 14). Heath Brook and Otter Creek had the poorest attainment rates. Biodiversity data (taxon lists and guild representation) for selected samples are available from MDEP's biomonitoring Web site (http://www.maine.gov/dep/blwq/docmonitoring/biomonitoring/data.htm).

There are baseline data on the benthic macroinvertebrates of the two major estuarine / marsh areas on MDI: Bass Harbor Marsh (Doering *et al*. 1995) and Northeast Creek (Keats and Osher 2007). In both systems there is, as expected, a spatial gradient from freshwater to marine communities. In the case of Northeast Creek, the spatial arrangement of this gradient varies seasonally since the system is dominated by freshwater inflow in the spring, but by marine waters later in the year. Estuarine macroinvertebrate data are further discussed under the assessments of threats and conditions.

Marine / Coastal Systems

Physico-Chemical Environment of Marine / Coastal Systems

The Acadia region has 4,818 ha of marine wetlands and 2,575 ha of estuarine wetlands (Calhoun *et al*. 1994). Using the Cowardin system of classification, marine and estuarine wetlands comprise 37.5% and 20%, respectively, of the total wetland area in the Acadia region (Calhoun *et al*. 1994). Park lands include 81 ha of intertidal areas and 38 ha of coastal salt marsh

Table 14. Stream water quality attainment based on macroinvertebrate biomonitoring data*.

Site	Number of samples for which site attains designated class** of AA (total # of samples)	
Duck Brook	Site S-854: 0 (1)	Site S-322: 8 (11)
Richardson Brook	2 (2)	
Lurvey Spring Brook	4 (9)	
Marshall Brook	5 (7)	
Hunter's Brook	5 (8)	
Stanley Brook	11 (11)	
Heath Brook	1 (6)	
Otter Creek	1 (6)	
Lake Wood outlet	0 (1)	

* Most samples were collected during the period 1997 – 2004; number of samples varies per site. Data are from Maine Department of Environmental Protection's biomonitoring Web site, accessed July 2008: http://www.maine.gov/dep/blwq/docmonitoring/biomonitoring/data.htm
Class descriptions may be found in MDEP (2004).

** Stream Class is a legal designation adopted by MDEP. All ACAD streams are designated class AA, which is the highest quality designation possible. Macroinvertebrate samples are collected to measure the extent to which actual stream quality attains designated quality.

(Mitchell *et al*. 2006). Fee ownership lands include extended sections of coastline in six areas of the Acadia region: (i) the southeastern section of MDI, from Schooner Head to Hunters Brook; (ii) east and west mid-sections of Somes Sound; (iii) the southern tip of western MDI; (iv) the Schoodic peninsula; (v) approximately one third of Isle au Haut; and (vi) several smaller islands, including Baker, Schoodic and Long Porcupine (Figure 2).

With a total perimeter of about 208 km, MDI is the third largest island on the east coast of the United States and the largest in Maine. As described by Mathieson *et al.* (1998), MDI's "diverse and irregular coastline ranges from exposed and semi-exposed open coastal sites, to hectares of protected waters, extensive mudflats, and salt marshes. …. Protected open coastal habitats are interspersed among the exposed ones, particularly within the embayed waters behind the Cranberry Isles, Somes Sound, Seal Harbor, Northeast Harbor, Southwest Harbor and Manset Harbor". Mean tidal ranges are between 2.83 m on Isle au Haut and 3.23 m at Bar Harbor (Calhoun *et al.* 1994). Spring tidal ranges are approximately 0.5 m greater.

While Somes Sound is often viewed as the only fjord on the east coast of the United States, it resembles other Maine estuaries in terms of hydrology and stratification (Pettigrew *et al.* 1997). Calhoun *et al*. (1994) provide a detailed overview of the geography, structure and hydrology of marine and estuarine wetlands in the Acadia region. There are two major freshwater / estuarine wetland complexes on MDI: Northeast Creek and Bass Harbor Marsh. More information on both these systems is provided under the *Assessment of Threats*.

Although marine waters beyond low tide are outside National Park Service jurisdiction, they are an integral part of the park's setting (Kahl *et al*. 2000). Frenchman Bay is a relatively enclosed body of water to the northeast of MDI. Blue Hill Bay, to the west, is a "sheltered and often muddy location fed by several large brooks and the Union River" (Mathieson *et al*. 1998). Waters to the south of MDI are more exposed. Marine sediments to the south of MDI are typically gravel, while those to the east of MDI (and, presumably, in Blue Hill Bay) are generally finer (Figure 30).

Ocean currents along the mid-Maine coast typically run east to west (Figure 31), although finer level patterns can be more complex (e.g. Xue *et al*. 2000). Circulation patterns in the Blue Hill Bay region are of particular interest from the perspective of evaluating impacts from existing and future aquaculture operations (see *Threats: Nutrient Enrichment*).

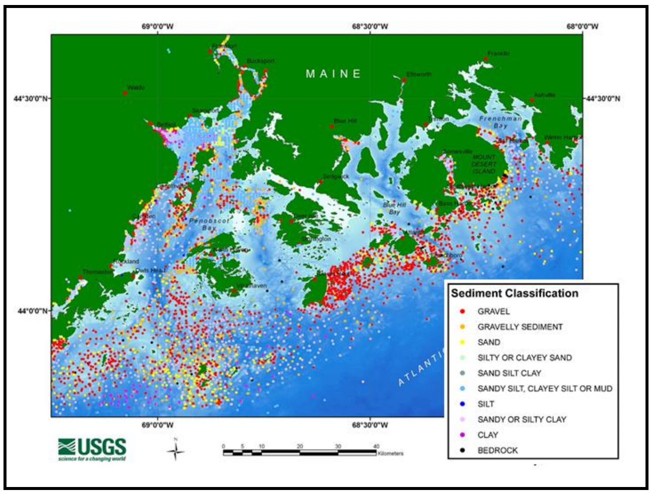


Figure 30. Sediment characterization in the Penobscot Bay to Frenchman Bay region of Maine. (Map generated from usSEABED database [Reid et al. 2005])

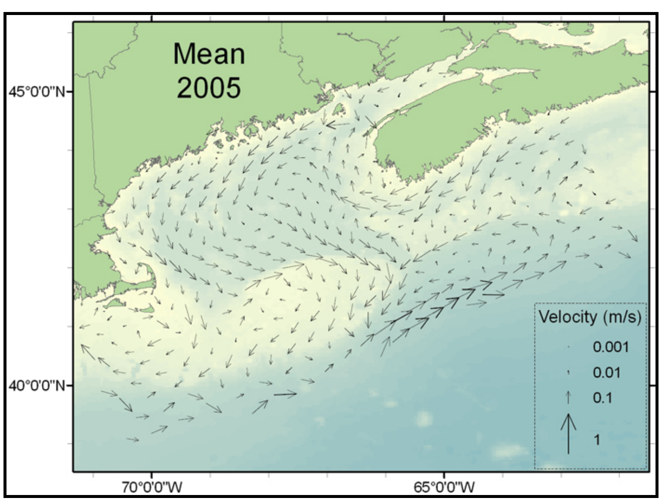


Figure 31. Circulation patterns in the Gulf of Maine. Data show mean 2005 surface current velocity vectors and are from the Gulf of Maine Princeton Ocean Model. Mount Desert Island is just west of center.

Biological Resources of Marine / Coastal Systems

Marine Plant Communities: Calhoun *et al*. (1994) provide an overview of algal and vascular plant communities in the marine and estuarine wetlands of the ACAD region. Plant communities include:

Marine system:

- Aquatic beds – developed on an outstanding variety of substrates in the inter-tidal region.

Estuarine system:

- Intertidal flats (unconsolidated bottom) – expansive because of the high tidal range.
- Estuarine aquatic beds – dominated by eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*).
- Estuarine emergent wetlands (salt marshes) – three common communities in the region are (i) tidal stream salt marshes (e.g. Bass Harbor Marsh), (ii) fringe salt marshes (associated with steeply sloping coves and embayments), and (iii) transitional marshes. An example of the latter is where freshwater wetlands are inundated by rising sea level. With a sea level rise of 3 mm/year, this type of salt marsh may be occurring at a number of locations in the ACAD region.

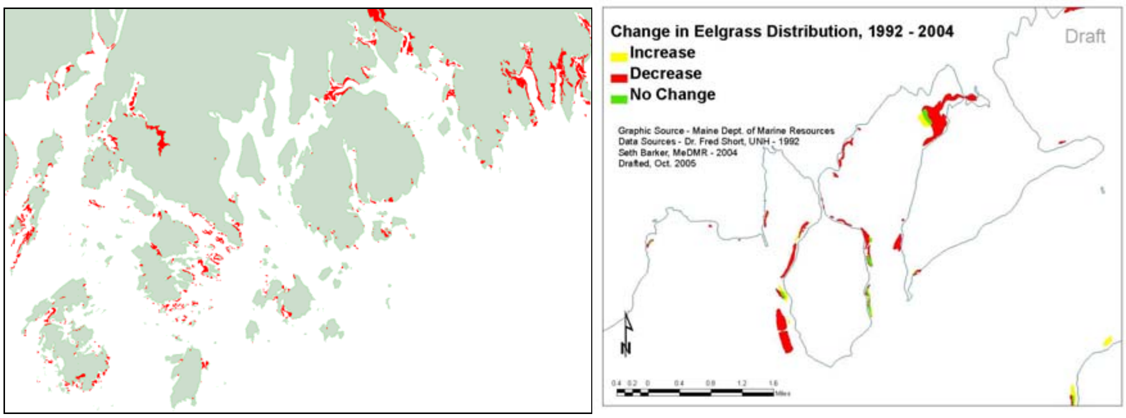
These authors note that zonation patterns in the salt marshes of the Acadia region more closely resemble marshes in the Bay of Fundy than those farther south. They also note that "study of salt marsh community development, plant community composition and distribution, hydrology, and wildlife value has been very limited in the region" (Calhoun *et al*. 1994). Most of the available information on salt marshes of the Acadia region comes from studies on Bass Harbor Marsh, research that was done in part because of the marsh's proximity to the Worcester Landfill. Doering *et al*. (1995) and Kinney and Roman (1998) summarize this research, which is further discussed in the section *Threats: Nutrient Enrichment.*

Research by Mathieson *et al*. (1998) provided the most detailed information available on the marine aquatic beds at ACAD. These authors studied the composition and zonation patterns of macroalgal communities at a series of high and low wave energy sites around MDI. A total of 113 taxa were collected by these researchers in the 1990s; this total was compared to 121 taxa that had been recorded during previous studies. Combining data from all studies, a total of 146 taxa have been recorded from the ACAD region (Table 5). Approximately one third of these species were represented by each of the major groups of seaweeds: green, brown and red algae. Highest species richness occurred in exposed areas (Otter Cliffs and Seawall), while sheltered sites exhibited the lowest diversity.

Benchmarked collections made in 1928 from Otter Cliffs (Johnson and Skutch 1928a, b, c) allowed Mathieson *et al*. (1998) to compare zonation patterns for different species over a ca. 60-year time period. There has been a marked reduction in the upper distributional limit for 13 species. In contrast, no species showed an upward expansion. The reasons for this change in distribution are unknown, although the authors speculate that the general warming trend in the Gulf of Maine may be a factor.

Ongoing research (Olson 2007) is documenting the flora (and fauna) of rocky intertidal habitats on the Schoodic Peninsula, perhaps one of the most pristine examples of this habitat in the State of Maine. The data will serve as a baseline from which to evaluate the impacts of visitor trampling. In addition, researchers at Northeastern University (J. Long and G, Trussell) are developing a rocky intertidal monitoring program for ACAD (development in 2008 and 2009, implementation in 2010); this program will also look at trampling impacts (B. Mitchell, NETN, pers. comm. January 2008). Muhlin *et al.* (2008) studied reproduction and genetic variation in focus around two peninsulas in Maine, one of which was the Schoodic peninsula. Coleman and Brawley (2005) also researched algal genetics and dispersal at SCH.

Figure 32A shows the distribution of eelgrass (*Zostera marina*) in the Acadia region during the 1990s. Eelgrass beds were most expansive in the upper part of Frenchman Bay and to the east of the Schoodic Peninsula. There were relatively few eelgrass beds around MDI, possibly as a result of coastline morphology. Quantitative time series data on eelgrass distribution are available only for around Sears Island, to the west of the main ACAD region. In that area, eelgrass cover decreased between 1992 and 2004 (Figure 32B). Similar kinds of time-series evaluations of eelgrass distribution are needed for waters in the vicinity of MDI[5].



(A) (B)

Figure 32. (A) Occurrence of eelgrass in the Acadia region. (B) Changes in eelgrass distribution in the Sears Island area between 1992 and 2004 (top left corner in [A]).

Data in panel (A) are a section of a statewide coverage developed from work done between 1992 and 1997. In this region, mapping was conducted using photography from:
1992 - Most of Penobscot Bay except for the Fox Islands (North Haven & Vinalhaven)
1993 - Pen Bay around the Fox Islands
1997 - East of Schoodic Point
1996 - Everything else (MDI, Isle au Haut, Blue Hill Bay, Frenchmans Bay, Deer Isle, Swans Island etc.)
Data sources: (A) Maine Office of GIS (http://megisims.state.me.us/metadata/megrass.htm). (B) S. Barker, Maine DMR, unpublished data.

[5] Two eelgrass GIS coverages are available at ME Office of GIS (http://megis.maine.gov/catalog), dated 1997 and 2005. Comparison of these coverages reveals that eelgrass areas around MDI are identical. Metadata suggest that the MDI area was not re-surveyed during the 2004 survey – the Penobscot Bay was, however, re-surveyed.

Marine Birds: Approximately 20% of the resident bird species of the ACAD region, as well as a number of migrant species, are associated with marine habitats (Table 8). Birds are discussed above, under Terrestrial Systems.

Marine Mammals: The list of ACAD mammals includes two marine species: gray seal (*Halichoerus grypus*) and harbor seal (*Phoca vitulina*). The full species list, developed from the NPSpecies database, may be found at www.pearl.maine.edu. According to Richardson (1973), an area of 500 square nautical miles in the ACAD region supported an estimated resident population of 1,600 harbor seals and an estimated seasonal population of 40 gray seals. At the time of that study, an absence of historical quantitative data prevented any conclusions being made about trends in population densities.

Because most other marine mammals generally do not utilize Park lands, they are outside the scope of this report.

Marine Fish: In their study of the Bass Harbor Marsh system, Doering *et al*. (1995) reported that 30% of the 23 fish species recorded from this estuary were marine taxa (Table 15). Jordaan (2006) conducted an extensive study of fish community structure on the coasts of MDI, SCH and neighboring areas. A total of 12 species were collected from tidepools, 50% of which were considered to be residents and 50% transients. Twenty species were collected from estuarine habitats, including Bass Harbor, Somes Sound and Northeast Creek sites.

Although we do not focus on off-shore marine species in this report, it should be noted that there is quite extensive information on marine fish populations in the MDI area and elsewhere along the Maine coast. Coastal waters in the ACAD region provide spawning habitat for a number of species, for example cod and haddock (Ames 1997, 2004; Figure 33). Sherman *et al*. (2005) summarize data from a comprehensive bottom trawl survey of groundfish and other species for Maine and New Hampshire's inshore waters. Sampling included many trawl sites around MDI. Trawl data are available for >70 fish species as well as some invertebrates. Figure 34 shows a selection of their data. Neal *et al*. (2003) reported on spawning habitat and temporal trends in spawning by Atlantic herring (*Clupea harrengus*) in the Gulf of Maine. One of their sampling sites was off Islesford. Herring is one of the keystone species in the Gulf of Maine and populations appear to have decreased over the past two decades.

Table 15. Groups of fishes recorded from Bass Harbor marsh (Doering *et al*. 1995).

Life History Group	Number of Species	Examples
Freshwater	4	Minnows and brook trout
Diadromous	1	American eel
Nursery	4	Clupeids, atherinid, mullet
Resident	7	Mummichog, sticklebacks
Marine	7	Hake, haddock, pollock, flounder, mackerel

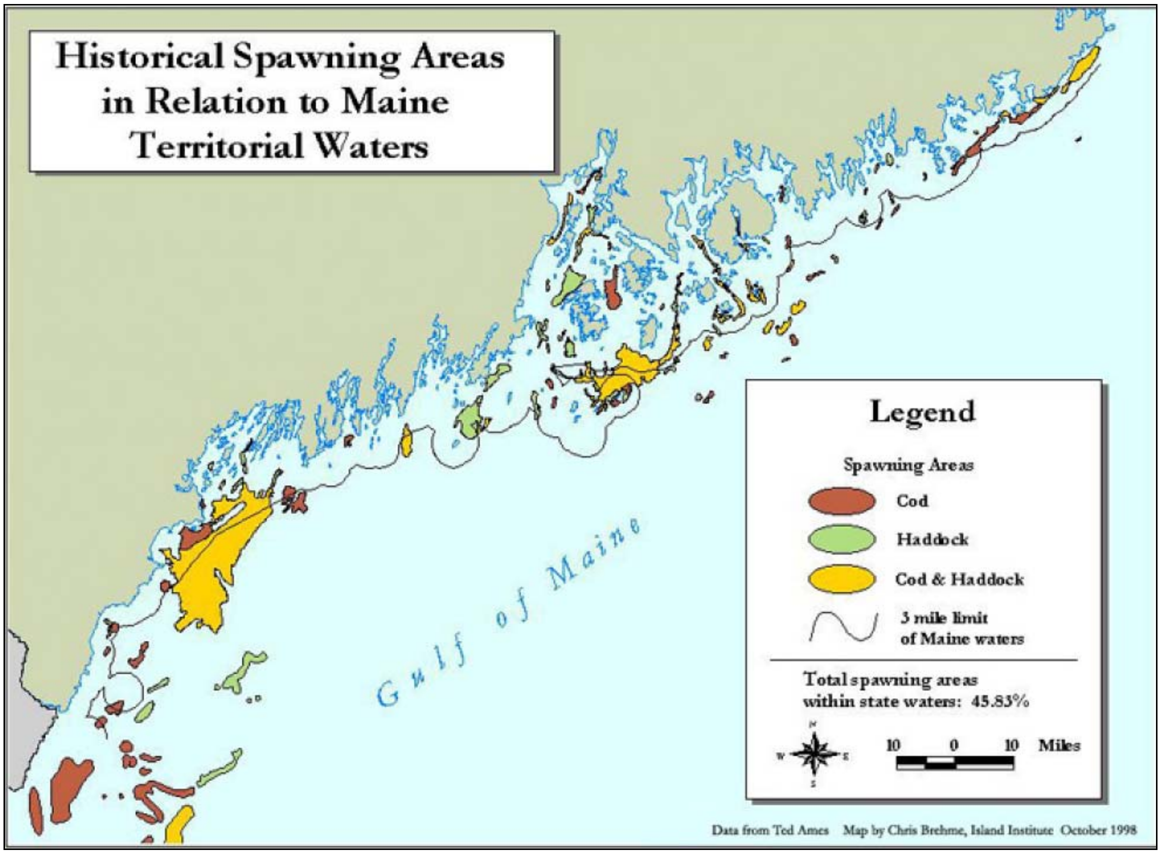


Figure 33. Historical spawning areas of cod and haddock in Maine territorial waters. Map based on data in Ames (1997).

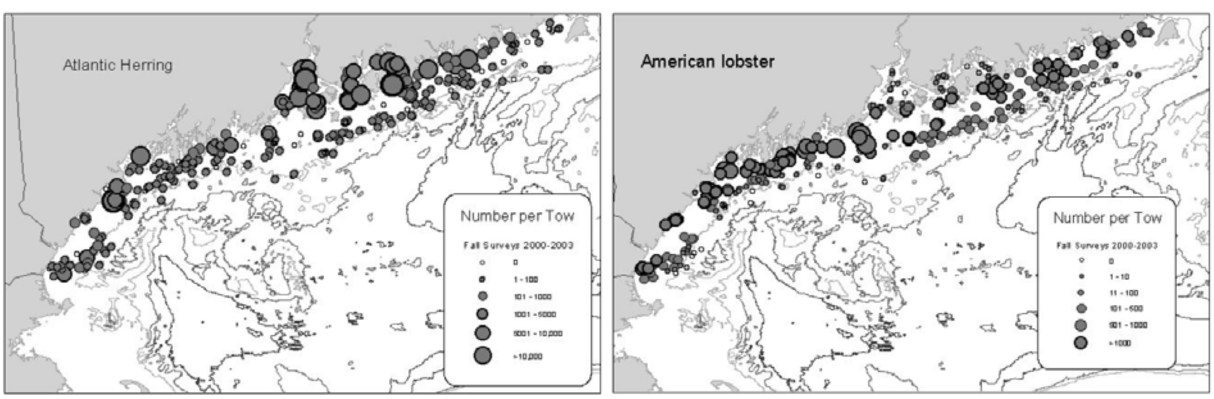


Figure 34. Density of Atlantic herring and American lobster in fall benthic trawl surveys. (Figure from Sherman *et al*. 2005).

Marine Reptiles: Three marine turtles occur along the Maine coast as vagrants: leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*) and Atlantic ridley (*Lepidochelys kempii*). Although all three are federally listed as threatened or endangered species (Hunter *et al*. 1999), none are known to use habitat within or bordering ACAD.

Marine Macroinvertebrates: There are limited inventories of marine macroinvertebrates in the intertidal and sub-tidal regions of ACAD, and few time series monitoring data. Procter (1933) conducted an inventory of marine invertebrates at subtidal and intertidal sites in Frenchman and Blue Hill Bays from 1926 to 1932. His work documented a total of 668 species and represents the most complete survey of invertebrates in marine waters surrounding ACAD (Procter 1933, Mittelhauser and Kelly 2007). In 1929, Procter collected the eelgrass limpet (*Lottia alveus*) off Mount Desert Island. This species is now believed to be extinct (Carlton *et al*. 1991).

Fefer and Schettig (1980) provide a detailed review of the invertebrate populations of coastal Maine mudflats and their ecological role. Cammen and Larsen (1992) sampled intertidal macrofauna at high-energy rocky shore sites and on low-energy mudflats at Thompson Island, Compass Harbor, Thunder Hole and Otter Cove. Their data include taxonomic composition and an analysis of seasonal and inter-annual variability. They recommended repeat monitoring of their sites every 10 years using identical protocols. Doering *et al.* (1995) sampled benthic invertebrates in Bass Harbor Marsh and concluded that the communities were typical of the region and paralleled mudflat data reported by Cammen and Larsen (1992). Doering and Roman (1994) noted that baseline data are lacking on the benthic invertebrates of Somes Sound.

Rocky intertidal areas in the Schoodic Peninsula unit of ACAD may represent some of the most pristine shoreline habitat in the State of Maine (S. Brawley, University of Maine, pers. comm.). This is because much of the area was off-limits to the public during occupation by the U.S. Navy. It has been identified as a Maine Critical Area for its high macroinvertebrate diversity (Doggett *et al*. 1978). Although detailed baseline data do not currently exist for this intertidal area, the ongoing research of Olson (2007), as well as the intertidal monitoring protocol mentioned previously, include detailed floral and faunal inventories and should help to fill this information gap.

A further source of information on marine macroinvertebrates in the Acadia region includes the Massachusetts Institute of Technology Marine Invader Tracking Information System (http://chartis.mit.edu/mitis/), which in turn contributes to the International Nonindigenous Species Database Network (http://www.nisbase.org/nisbase). While reporting is targeted toward invasives, some of these monitoring efforts provide a limited amount of time-series data on endemic marine species in the ACAD region as well.

Assessment of Threats

Introduction

This section discusses the threats and stressors[6] that are affecting, or thought to be affecting, natural resources at ACAD. An individual stressor can have multiple interacting causal factors. For example, changes in surface water and groundwater hydrology can result from increased residential use and/or residential development, changes in the proportion of runoff to infiltration, reduced precipitation, and other factors.

We focus on threats/stressors that have anthropogenic associations. In some cases, the action of an essentially natural factor has been influenced by human-associated events. An example is the disturbance regime caused by beaver colonization. Although a natural process, it has been influenced on MDI by re-introduction of this species and the major fire of 1947.

To organize our examination of threats, we developed a resource-stressor matrix to indicate which stressors are associated with each ecological system. Matrix content was based on conversations with ACAD scientists and other researchers, as well as a study of the comprehensive bibliographic database maintained at ACAD. Each cell in the matrix contains information on the extent or scale of a stressor and its impact on biotic or abiotic components of a resource. An example cell is:

Resource:	Terrestrial systems
Stressor:	Invasive species
Extent:	Spatial / temporal distribution
Impact(s):	Documented or inferred affects on other taxa.

For each cell in the resource-stressor matrix, the extent of the problem was categorized as follows:

- Existing problem (EP): convincing recent (since 1980) evidence, or earlier evidence plus reason to be fairly confident that the problem still occurs.
- Potential problem (PP): either i) evidence external to the Park suggests there may be a problem at ACAD, (ii) there is earlier evidence for the problem but we are not certain that it still occurs, or (iii) what we know about the Park suggests the problem could be occurring but is currently undocumented.
- Historic problem (HP): documented to have occurred >30 years ago, and there are no new data suggesting continuation.
- Problem unlikely (OK): the issue has been investigated and it does not seem to represent a problem based on available data, which may be limited.
- Unknown (Unk): not enough data to determine if problem exists at ACAD.

[6] We use the terms ‘threat’ and ‘stressor’ almost interchangeably in this report. Threat is sometimes viewed as a potentially problematic environmental trend while stressor is the process whereby the threat impacts the target system.

We assigned a confidence value to each problem evaluation by characterizing the extent of the information base: Good, Fair, Poor, Inferential. The latter category was used when we based conclusions about a problem at ACAD entirely on information derived from outside the ACAD region.

For each threat, we first describe the sources and magnitude of the threat. We then review how that threat is affecting the terrestrial, freshwater and marine resources at ACAD. Where possible, we compare and contrast ACAD data with regional or national data. Discussion of each threat is preceded by a summary matrix that lists (i) the key issues to be discussed, (ii) the scale of the problem, and (iii) the extent of supporting information about the issue. The threat assessment section concludes with a presentation of the complete resource-stressor matrix that summarizes the extent to which the full suite of stressors is acting on all ecosystems in the Acadia region.

Some stressors incorporate multiple sub-topics each of which may be characterized differently with respect to the scale of the problem and information richness. While the matrices simply record the multiple characterizations (e.g. EP / PP), the main text addresses each sub-topic, and the associated scale of problem and extent of information.

Ultraviolet Radiation

Key Issues	*Extent of Problem*	*Information Base*
UV dose to and flux in wetlands	PP	Good
UV impacts on amphibians	PP	Inferential

Reduced stratospheric ozone levels have resulted in increasing amounts of UV-B radiation reaching the earth's surface. Higher levels of UV-B radiation can be detrimental to human health and biological resources, including amphibians, and marine and freshwater plant and animal populations. The EPA UV-Net program has operated a network of spectrophotometers across the U.S. to measure full-sky solar radiation in the UV-B and UV-A bands (http://www.epa.gov/uvnet/). Fourteen of the monitoring sites were located in National Parks as part of the PRIMENet program. The ACAD site was active from 1998 to 2004 (Table 16).

As part of a larger study to measure UV-B radiation in wetlands of six national parks, Diamond *et al*. (2005) collected dosimetry data at ACAD between 1999 and 2001 (Figure 18). The research was designed to assess the role of UV-B as a stressor affecting amphibian health. The UV dose is the amount of radiation arriving at the wetland surface. The flux of UV radiation is the amount of radiation transmitted through the water column; it is influenced by the surrounding landscape and attenuation by the water. Mean UV-B dose at ACAD was lower than at the other five parks (Figure 35). Lowest values of UV-B flux were also observed at ACAD, in part because of relatively high dissolved organic carbon in ACAD wetlands (Diamond *et al*. 2005).

Table 16. Monitoring of physical and chemical parameters at ACAD.
CM = Cadillac Mountain, MH = McFarland Hill.

Parameter	Location	Start Year	End Year
Meteorology[(1)]	CM, MH	1995 (CM), 1981 (MH)	present
Wet deposition[(2)]	MH	1981	present
Dry deposition[(3)]	MH	1998	present
Mercury deposition[(4)]	MH	1995	present
Ozone	CM	1995	present
	MH	1982	present
	Schoodic	2003	present
Sulfur dioxide	CM	1988	1990
Nitrogen oxides	CM	1991, 1993, 1995-	present
VOCs[(5)]	CM	1991, 1993, 1995-	present
Carbon monoxide	CM	2002	present
UV	MH	1998	2004
Particulate matter	MH	1988	present
Teleradiometer[(6)]	MH	1980	1986
Transmissometer[(6)]	MH	1987	1994
Nephelometer[(6)]	MH	1993	present
Web camera[(7)]	CM	1999	present
Surface water chemistry[(8)]	19 park lakes	1997[(9)]	present

(1) Includes wind speed, wind direction, temperature and relative humidity
(2) National Atmospheric Deposition Program / National Trends Network
(3) Clean Air Status and Trends Program
(4) Mercury Deposition Network
(5) Volatile organic compounds
(6) Used to monitor visibility impairment
(7) Used to interpret current visibility conditions
(8) Acidification and eutrophication parameters
(9) Some data exist prior to this date.
(Data from Maniero and Breen 2004)

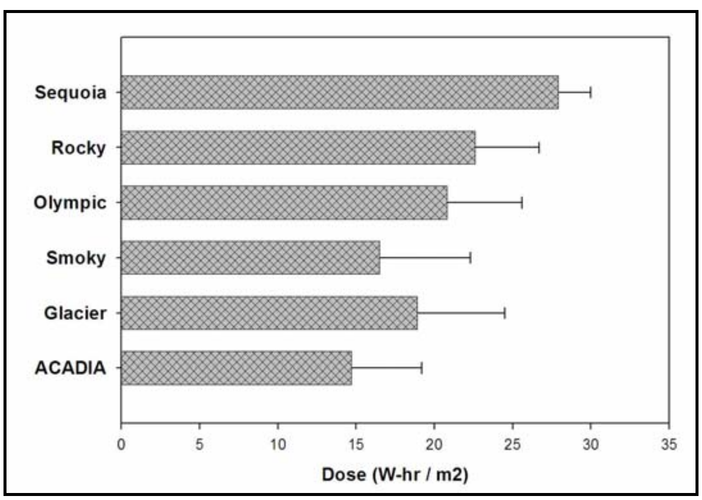


Figure 35. Mean dose of UV-B radiation at six national parks. Figure uses data from Table 2 of Diamond *et al*. 2005.

Current research on some ACAD lakes is investigating the association between UV-B radiation and zooplankton populations (E. Whitmore, University of Maine, pers. comm. June 2007).

Visibility Impairments

Key Issues	***Extent of Problem***	***Information Base***
Visibility at ACAD, primarily an issue for visitors/residents.	EP	Good

Visibility and haze monitoring has been carried out at ACAD since the 1980s as part of the IMPROVE program (Table 16). Selected visibility-related data are presented in Figure 36. The standard visual range in the ACAD region is greater than in most of the eastern part of the country, but is lower than in the western U.S. Visibility at ACAD depends on air trajectories – days with highest visibility are those when air masses derive from the north, while lowest visibility occurs when trajectories are from the south and southwest.

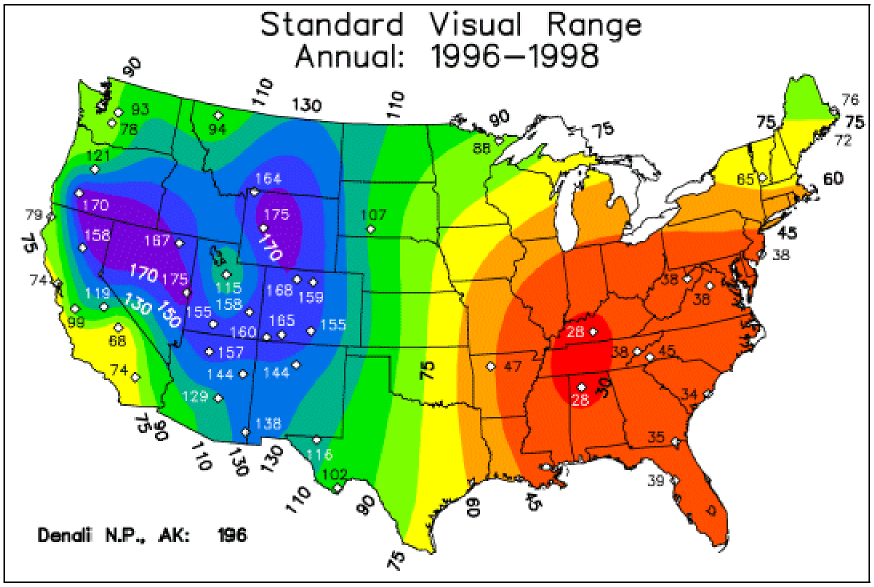
Ozone

Key Issues	***Extent of Problem***	***Information Base***
Ozone concentrations	EP	Good
Impacts on terrestrial plants	EP	Good

Atmospheric Ozone Levels

Tropospheric (ground level) ozone has been monitored on MDI since 1982 and at SCH since 2003 (Table 16). Information on park ozone monitoring is available on the Web site of the NPS Air Resources Division (http://www2.nature.nps.gov/air/monitoring/network.cfm).

Urban-derived plumes of ozone (and other pollutants) have been tracked from the Boston and New York areas to coastal Maine. Ozone levels in coastal areas are higher than those at inland Maine sites (Jagels *et al*. 1989). The annual number of 8-hour ozone exceedances at ACAD since 1983 has ranged from 1 to 17 (Table 17). Ozone concentrations are consistent with values documented from other non-urban sites in New England (Maniero and Breen 2004). Like many other NPS sites, ozone concentrations (both 1-hour and 8-hour) at ACAD showed an increasing trend between 1992 and 2002 (Maniero and Breen 2004). However, the most recent NPS Air Quality Division report on air quality trends in national parks concluded that there was no significant trend in tropospheric ozone concentrations (measured as the average 3-year, 4th highest, 8-hour ozone concentration) during the period 1996-2005 (NPS 2006). Ozone condition at ACAD was considered “moderate” and stable. In 2004, EPA designated ACAD as a non-attainment area for the 8-hour National Ambient Air Quality Standard of 0.85 ppm.



(A)

(B)

(C)

Figure 36. Visibility at ACAD.
(A) Standard visual range (km) for the U.S. Data are average values for the period 1996-1998 (figure from the IMPROVE program, http://vista.cira.colostate.edu/improve/).
(B) Air trajectories on days with the 20% best visibility at ACAD, 1997-1999.
(C) Air trajectories on days with the 20% worst visibility at ACAD, 1997-1999.
Air trajectory figures provided by D. Manski, ACAD, and originated from MANE-VU (Mid-Atlantic/Northeast Visbility Union, www.mane-vu.org).

Table 17. Annual number of 8-hour ozone exceedances at six park units. Data for individual years are shown for ACAD, only.

	ACAD: MH	ACAD: CM	CACO	GRSM-LR	ROMO	SHEN	YOSE-TD
Mean	**5.2**	**4.6**	**9.1**	**11.7**	**2.7**	**6.6**	**9.7**
Max.	**17**	**9**	**25**	**37**	**7**	**24**	**31**
Min.	**1**	**1**	**2**	**2**	**1**	**1**	**2**
# years with data	**19**	**10**	**19**	**21**	**7**	**20**	**15**

Year	ACAD: MH	ACAD: CM
1983	11	--
1984	7	--
1985	3	--
1986	3	--
1987	6	--
1988	17	--
1989	2	--
1990	4	--
1991	7	--
1992	1	--
1993	3	--
1994	--	--
1995	5	2
1996	2	1
1997	1	5
1998	4	8
1999	5	4
2000	--	3
2001	9	9
2002	6	8
2003	2	3
2004	--	--
2005	--	3

Legend

ACAD: MH – Acadia – McFarland Hill.
ACAD: CM – Acadia – Cadillac Mountain.
CACO – Cape Cod National Seashore.
GRSM-LR – Great Smoky Mountains NP – Loon Rock.
ROMO – Rocky Mountain NP.
SHEN – Shenandoah NP.
YOSE-TD – Yosemite NP – Turtleback Dome.

Ozone Impacts on Terrestrial Vegetation

Extensive research has evaluated ozone effects on terrestrial vegetation at ACAD. Maniero and Breen (2004) provide an excellent synopsis of much of this research. Some of the more recent studies are summarized below.

Kohut *et al.* (2000) examined 32 plant species exposed to ozone under experimental conditions to identify potential bioindicator taxa at ACAD. Species injured at ambient ozone levels were black cherry (*Prunus serotina*), quaking aspen (*Populus tremuloides*), white ash (*Fraxinus americana*), jack pine (*Pinus banksiana*), big-leaf aster (*Aster macrophyllus*), and spreading dogbane (*Apocynum androsaemifolium*). Red maple (*Acer rubrum*), pin cherry (*Prunus pensylvanica*), mountain ash (*Sorbus americana*), mountain holly (*Nemopanthus mucronatus*), and flat-topped aster (*Doellingeria umbellata*) were also injured at ambient levels. Species that showed foliar injury at >150% of current ambient levels were gray birch (*Betula populifolia*), small sundrops (*Oenothera perennis*), and bunchberry (*Cornus canadensis*), suggesting their ability to tolerate somewhat higher than ambient ozone levels. Some species were not injured even at twice the ambient levels of ozone, including paper birch (*Betula papyrifera*), eastern white pine (*Pinus strobus*), pitch pine (*Pinus rigida*), red spruce (*Picea rubens*), northern white cedar (*Thuja occidentalis*), northern red oak (*Quercus rubra*), Canada bluejoint grass (*Calamagrostis canadensis*), wild radish (*Raphanus raphanistrum*), and Canada mayflower (*Mianthemum canadensis*). Due to characteristic injury patterns big-leaf aster (*Aster macrophyllus*), spreading dogbane (*Apocynum androsaemifolium*), quaking aspen (*Populus tremuloides*), white ash (*Fraxinus americana*), flat-topped aster (*Doellingeria umbellata*), and black cherry (*Prunus serotina*) were recommended by Kohut *et al.* (2000) as reliable ozone-indicator species. They further suggested that these species should be the core of any bio-monitoring program designed to assess the incidence and extent of ozone injury at ACAD.

Plants are seldom exposed to only one stressor and the interaction of multiple stressors can have significant effects on plants. Much of the vegetation at ACAD is frequently exposed to fog, some of which may be acidic (see further discussion under *Threats: Acidity and Related Chemisty*). The combined effects of ozone and acidic deposition should be explored in further detail (Jagels *et al.* 2002).

Kohut (cited by Maniero and Breen 2004) used multiple ozone exposure metrics to identify ozone-sensitive species and determine the likelihood of injury. These 16 species include the reliable ozone-indicator species listed above.

Another study (Eckert *et al.* 1997) examined the effects of ozone at ACAD by quantitatively sampling natural populations of big-leaf aster and spreading dogbane for visually detectable symptoms of ozone injury. The authors concluded that ozone injury in big-leaf aster in 1996 occurred at more sites than in 1993-1994 and one fewer site than in 1995. Ozone injury for spreading dogbane occurred in 25% of populations examined, contrasting with the virtual absence of injury noted in previous surveys (1993-1995) by these authors. This difference may be associated with increased precipitation in 1996 relative to other years. Wetter conditions may have promoted enhanced stomatal opening, thus permitting greater uptake of ozone (Eckert *et al.* 1997).

Bartholomay *et al*. (1997) showed that white pine radial growth at ACAD is inversely related to ozone level and duration of exposure. Seven of eight stands observed in their dendroclimatic survey documented negative associations between tree-ring indices and ozone levels. This association was stronger than any modeled association between tree-ring indices and climate factors. Short-term, high-level ozone events were shown to have the greatest negative association with tree-ring widths. The study showed stand (habitat) level variation suggesting that micro-ecological characteristics could affect tree response to ozone pollution. The authors note that trees growing on better sites could be more susceptible to ozone damage because they have higher rates of photosynthesis.

Wenner and Merrill (1998) concluded that ozone tissue damage on white pines is rare, contrary to what was believed in earlier years. According to these authors, observed foliar damage in this species is more likely the result of needle blight associated with a fungal infection, rather than elevated ozone levels.

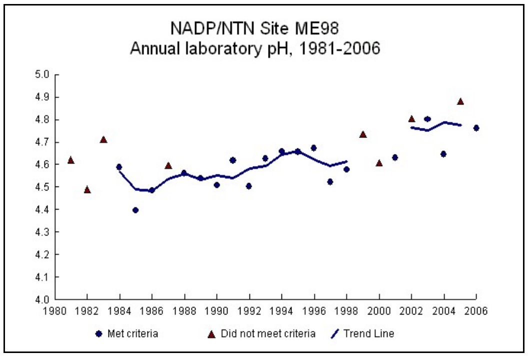
Chappelka and Samuelson (1988) reviewed ambient ozone effects on forest trees of the eastern United States. Appendix 12 presents their data for eight species found at ACAD. Ozone had no effect on growth for five of these species, although there were effects on some physiological measures. For the other three species, ozone levels reduced growth rates and/or height or tissue biomass.

Theisen *et al*. (1994) used fluorescence to study the physiological response of white pine to short-term ozone exposure at ACAD. They concluded that photosynthetic processes partially recover within 48 hours following ozone exposure.

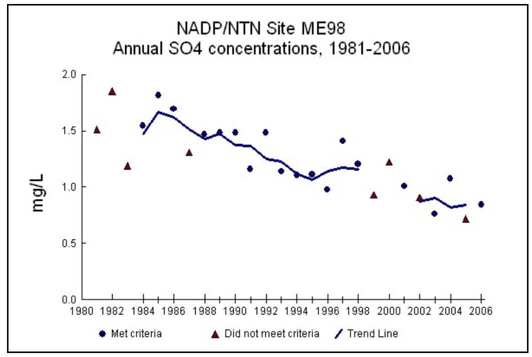
Atmospheric Deposition (Acidity and Related Chemistry)

ACAD "is uniquely located downwind of major pollution sources and, as a result the watersheds receive some of the highest levels of air pollutants … in the northeastern United States" (Haines and Webber 1999). Atmospheric deposition contributes acidity (hydrogen ions), nitrogen, sulfur and other constituents to terrestrial and aquatic systems. It has been the subject of extensive research at ACAD. In this section, we first provide an overview of deposition chemistry at ACAD. We then discuss this chemistry from the perspective of the Park's terrestrial and aquatic systems. A subsequent section of this report (*Threats: Nutrient Enrichment*) focuses on the issue of nutrient enrichment in aquatic systems. This separation is somewhat artificial – nitrogen, while contributing to acidity, is also a nutrient, and atmospheric deposition is a significant source of this element.

Key Issues	***Extent of Problem***	***Information Base***
Precipitation chemistry	EP	Good
Fog chemistry	EP	Fair
Impacts of acidity on terrestrial vegetation	EP	Good
Impacts of N on terrestrial vegetation	EP	Fair + inferential
Impacts on freshwater chemistry	EP	Good
Impacts on freshwater biota	PP	Poor
Impacts on marine/coastal systems	PP	Fair



(A)



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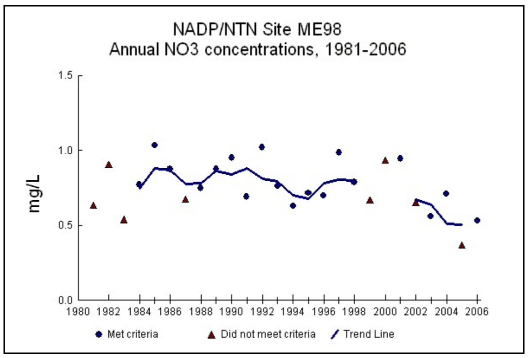

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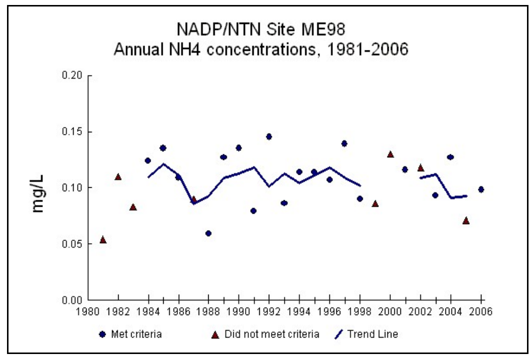

(D)

Figure 37. Precipitation chemistry at the McFarland Hill NADP site, 1981-2006. (A) pH, (B) sulfate, (C) nitrate, (D) ammonium.

Atmosphere: Deposition Chemistry

During the period 1981-2006, the annual average pH of precipitation at ACAD ranged from 4.4 to 4.9 (Figure 37A). These pH levels are considered to be three- to four-times more acidic than pre-industrial precipitation chemistry in eastern North America (see references in Kahl *et al*. 2000). Annual average values of precipitation pH suggest a possible increasing trend in recent years (Figure 37A). Previous analyses of data from the period 1981-1993 suggested a slight pH *decrease* (increase in acidity) (Kahl *et al*. 2000).

Sulfur (S) and nitrogen (N) compounds both contribute to acidity, although the former have been the major acidifying substances in acid rain in Maine (Kahl *et al*. 1991). Primary anthropogenic sources of atmospheric S and N include power plants, other industrial sites and vehicle emissions. Natural sources of atmospheric S are volcanoes (SO_2) and emissions from organisms and decaying matter (dimethyl sulfide), which are subsequently oxidized in the atmosphere to sulfuric acid (H_2SO_4) (Turco 2002). Deposition of atmospheric S and N occurs through precipitation (wet deposition), dry deposition and ground-level cloud/fog. Because of its proximity to the ocean and the marine origin of some sulfate (SO_4), ACAD received 20% to 40% more SO_4 in wet deposition annually than inland sites in Maine during 1997-2001 (NADP 2007).

Because S has a short residence time (days) in the atmosphere and is readily scavenged by wet deposition (Turco 2002), emissions reductions following implementation of the 1990 Clean Air Act Amendments had immediate effects on S deposition (Kahl *et al*. 2004). Across the Northeast, a region strongly affected by acidic deposition, SO_4 in wet atmospheric deposition declined ~39% between 1993 and 2003 (Kahl *et al*. 2004). At ACAD, annual average SO_4 concentrations in wet-only deposition measured at the NADP site suggest a similar decline (Figure 37B). In contrast, N deposition through the early 2000s did not decline to the same extent. Recent data, however, suggest that nitrate (NO_3) concentrations may be trending lower than levels observed during the most of the 1980s and 1990s while ammonium (NH_4) deposition appears to remain more constant (Figure 37C, D). Kahl *et al*. (2004) observed that continued N deposition may contribute to the lack of recovery in acid neutralizing capacity (ANC) of surface waters.

Using NADP SO_4 data from 2006 as an example, ACAD wet deposition values were comparable to those recorded from other NADP sites in Maine (Figure 38). They were lower than values reported from sites in the Midwest and Mid-Atlantic, and higher than values for Western sites.

Wet-only deposition underestimates total deposition for some ions, such as S. The chemistry of throughfall provides a reasonable estimate of total deposition to a watershed for more conservative ions (Grigal 2002, Rea *et al.* 2000, Lovett 1994, Rustad *et al.* 1994, Lindberg and Lovett 1992).

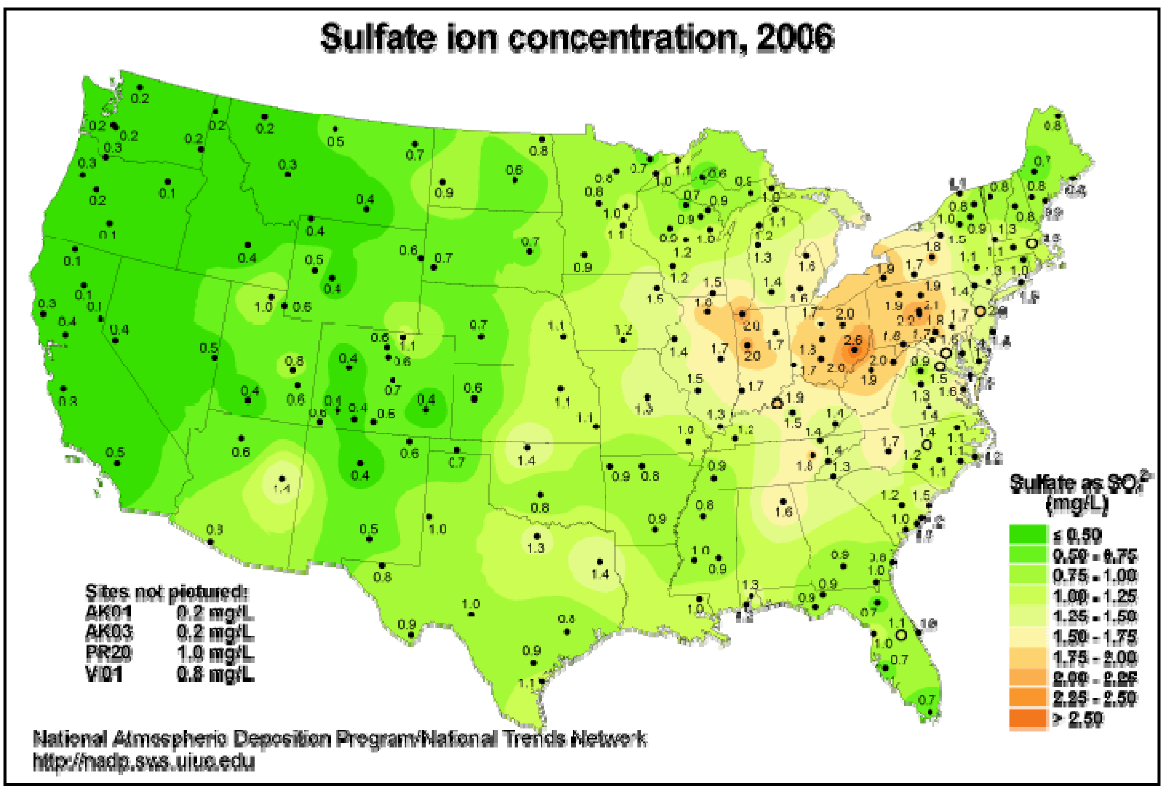

Figure 38. 2006 sulfate concentrations in wet deposition (from http://nadp.sws.uiuc.edu/).

Two recent projects have quantified throughfall deposition of S at ACAD: an MDI-wide study that used resin beads to collect S data (Simkin *et al*. 2004, Weathers *et al*. 2006), and a paired watershed study that quantified S mass balances (Nelson 2002, Kahl *et al*. 2007b). Both studies found that S deposition as throughfall was dependent on landscape factors, with elevation and vegetation type driving differences in enhancement of S across the heterogeneous landscapes. Weathers *et al*. (2006) reported modeled S deposition hotspots up to 25 kg/ha/yr (Figure 39), while Kahl *et al*. (2007b) found maxima of only 13 kg/ha/yr, based on data collected from smaller watersheds. However, both models suggest relative hotspots of S deposition in conifer-forested and in high-elevation areas. Regardless of the differences in magnitude, both studies clearly demonstrate that wet-only deposition represents less than half of total S inputs at sites that have forest canopy cover.

In contrast to S, N tends to be under-represented by throughfall measurements because the forest canopy takes up N as it is deposited, reducing the amount of N that appears below the forest canopy. Weathers *et al*. (2000, 2006) used relationships developed for S to scale up N wet deposition to model total deposition of N. Using such relationships, these authors report a range for total N deposition at Acadia from 3.0-13.5 kg/ha/yr (Figure 39). These model-based estimates of total N deposition are an average of 70% greater than those derived from summing wet

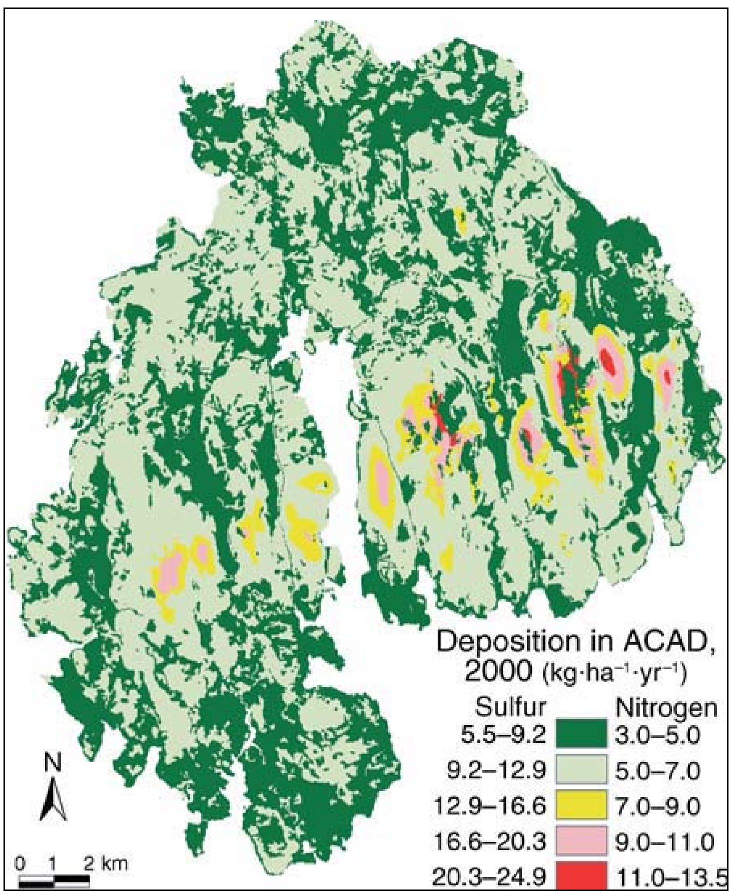

Figure 39. Modeled total atmospheric deposition of S and N to MDI for the year 2000.
(Image from Weathers *et al*. 2006, used with permission)

(NADP) and dry (CASTNET) deposition data. Because much of ACAD is under coniferous and mixed forest canopy (the forest types that are associated with the highest total depositional inputs of N), continued N deposition is a threat to the park's freshwater and marine resources.

Although fog is a common phenomenon in coastal areas of Maine, few research projects have examined fog acidity and chemistry at ACAD. Weathers *et al*. (1986) conducted one of the first acidic fog research projects and documented fog pH, nitrate, and sulfate across the eastern U.S., including Bar Harbor (Figure 40). The Bar Harbor site had the greatest SO_4 concentration of all sites sampled during the August 1984 cloud/fog event. For all sites, fog pH was extremely low, ranging from 2.8-3.09, considerably lower than the average pH of rain in the region. The lowest pH value was measured in Bar Harbor.

Jagels *et al*. (1989) and Kimball *et al*. (1988) provide additional data on fog and cloud chemistry.

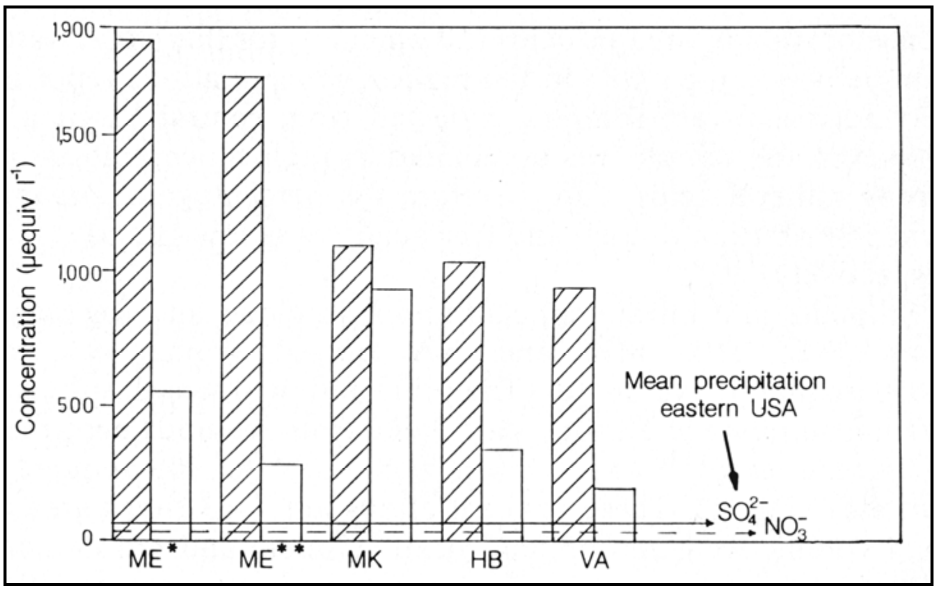

Figure 40. Sulfate (shaded bars) and nitrate (open bars) concentrations of acidic cloud/fog events in Bar Harbor compared with other sites.
Site ME is Bar Harbor; MK is New York; HB- Hubbard Brook, NH; VA is Virginia. Mean precipitation data are from Whiteface Mountain, NY; Ithaca, NY; Hubbard Brook, NH; and Charlottesville, VA.
* Bar Harbor sample collected on 7-8 August 1984; ** Bar Harbor sample collected on 8-9 August 1984.
(Figure from Weathers *et al*. 1986, used with permission)

Impacts of Atmospheric Acidity on Terrestrial Systems

An extensive literature review on potential impacts of acid precipitation by Anderson (1984) examined the susceptibility of vegetation and other biota to acidic deposition, sulfur dioxide[7] (SO_2), and other contaminants. Plant species are listed based on relative sensitivity to SO_2 (see Tables III and IV in Anderson 1984).

Jagels *et al*. (2002) studied differential sensitivities of red spruce (*Picea rubens*) and white pine (*Pinus strobus*), two common species at ACAD, to acid fog. The major symptom observed on coastal red spruce was upper surface chlorosis of needles older than the current year (Jagels *et al*. 1989). White pine is a frequent cohort of red spruce stands at ACAD, yet pine show sensitivity to ozone but not to acid fog (Kohut *et al.* 1990, but see Wenner and Merrill 1998). Symptoms of red spruce decline in Maine were observed at sites which received both acid fog and acid rain, but not at locations which received only acid rain (Jiang and Jagels 1999). The greatest symptom development was in mid-coast Maine where ACAD is located (Jagels *et al.* 1989). Differential sensitivities of red spruce and white pine to acid fog and ozone could be explained by differences in physiological responses with respect to photosynthetic gas exchange patterns (stomatal conductance). Research on red spruce at Isle au Haut and other sites in Maine indicated that acid fog enhanced epicuticular wax production and calcium leaching from needles (Percy *et al*. 1993, Jiang and Jagels 1999).

The recently established Northeastern Temperate Network (NETN) long-term forest monitoring sites are beginning to produce baseline data to evaluate long-term trends in soil and vegetation characteristics at ACAD. This program uses the ratio of calcium to aluminum (Ca:Al) in soil or soil solution as an indicator of acidification stress to forest vegetation. Initial Ca:Al ratio data from NETN soil plots indicate that 46% of plots show ratios that may be considered to be of "significant concern", while 37% were rated "good" (Table 18).

Impacts of Atmospheric Nitrogen on Terrestrial Vegetation

Nitrogen deposition in forests of the northeastern U.S. has led to changes in forest species composition and increased N leaching into surface waters (Aber *et al.* 2003). High levels of forest floor N can lead to foliar nutrient imbalances in many species, as well as reduced cold tolerance and increased freeze injury to foliage. Such stresses can in turn reduce sugar reserves and increase the potential for secondary stressors that cause tree mortality (McNulty *et al.* 1991). Drought, aluminum toxicity, and nutrient leaching from the forest floor could act synergistically with N saturation to increase the potential for tree mortality. These factors could also lead to a shift in species composition to stands of birch (*Betula* spp.) and sugar maple (*Acer saccharum*) and a faster N-cycling ecosystem (McNulty *et al.* 1991).

Tree species common to ACAD have very different patterns of N cycling (Finzi *et al.* 1998) and may respond differently to increased N deposition. There are significant relationships among N deposition, soil C:N ratio, and nitrification, but the strength and significance of these

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[7] The form of S that is typically emitted and dominates in the atmosphere; dissolved in water it becomes sulfuric acid and is typically measured as sulfate in precipitation.

Table 18. Forest plot-level data for four condition metrics. Data are number of sites at each rating value, by park region*.

Metric / Rating		Region			
		IAH	MDI-West	MDI_East	SCH
CWD**:	*Sig. concern*	5	17	19	4
	Caution	2	9	7	1
	Good	1	4	10	0
Tree condition:	*Sig. concern*	1	1	2	0
	Caution	1	13	11	2
	Good	6	16	24	3
Ca:Al ratio:	*Sig. concern*	3	16	16	2
	Caution	3	5	9	1
	Good	3	9	12	2
C:N ratio:	*Sig. concern*	1	1	0	0
	Caution	1	4	8	0
	Good	6	25	29	5

*Data provided by B. Mitchell, May 2008
** CWD = coarse woody debris

relationships differ among forest types and soil horizons (Aber *et al.* 2003). Lovett *et al*. (2004) showed that five species, *Fagus grandifolia*, *Betula alleghaniensis*, *Acer saccharum*, *Tsuga canadensis*, *Quercus rubra*, all occurring at ACAD, varied markedly in their N cycling characteristics. Their work suggested that tree species can exert a strong influence on N cycling in forest ecosystems and that this influence is generally mediated by the quality of the organic matter they produce. Hence, N cycling in forest ecosystems could be patchy and dependent on the dominant trees in the patch. As a result, species-specific processes and stressors such as selective harvesting, pests/pathogens, global warming, and pollutants could substantially alter N cycling. For example, beech bark disease, targeting American beech (*Fagus grandifolia*), could potentially result in an increase in sugar maple (*Acer saccharum*), currently uncommon at ACAD (Greene *et al*. 2005), as both beech and sugar maple coexist in similar habitats. Dominance of sugar maple could then result in an increase in N enrichment in forest soils. Lovett and Mitchell (2004) listed sugar maple as a unique and critical species with regard to N cycling and retention in northeastern forests because sugar maple-dominated stands generally have higher rates of nitrification and nitrate leaching into surface waters. In some areas, sugar maple may be increasing due to the population decline of its primary competitor, American beech. Alternately, any threats to sugar maple (e.g. pests, acidic deposition, *etc*.) could drastically alter nutrient cycling. Hence, population dynamics of this species could have major impacts on forest composition and processes, and should be carefully monitored at ACAD.

Parker *et al.* (2001) conducted a study at ACAD looking at effects of N enrichment, wildfire, and harvesting on soil C and N pools at the paired-watersheds (Cadillac [burned] and Hadlock [unburned]) and other watersheds outside the Park that were characterized by different disturbance regimes (harvesting, N enrichment). Although no soil data for either C or N prior to disturbance were available, it was clear that all three disturbances can have long-term impacts on soil C and N, particularly on C pools in forest floor. They concluded that the shifts in species composition that might result from such forest disturbances (harvesting, N enrichment, and fire) could be at least as important in determining soil C and N content as the level of removal or additions of C and N from the disturbance itself.

Using a variety of biogeochemical, landuse and nutrient uptake data, Miller (2006) evaluated the sensitivity of forests across the Northeast to N and S deposition. Figure 41 shows the areas of Maine where deposition rates were greater than critical loads estimated from other data. According to this model, ACAD forests were not designated as sensitive.

Monitoring recently initiated by the NETN is using carbon to nitrogen (C:N) ratios in soil as a primary indicator of forest nitrogen status and the impacts of atmospheric deposition. Initial results from soil plots suggest that although most have favorable C:N ratios, some plots have C:N ratios that potentially indicate some ecological concern (Table 18).

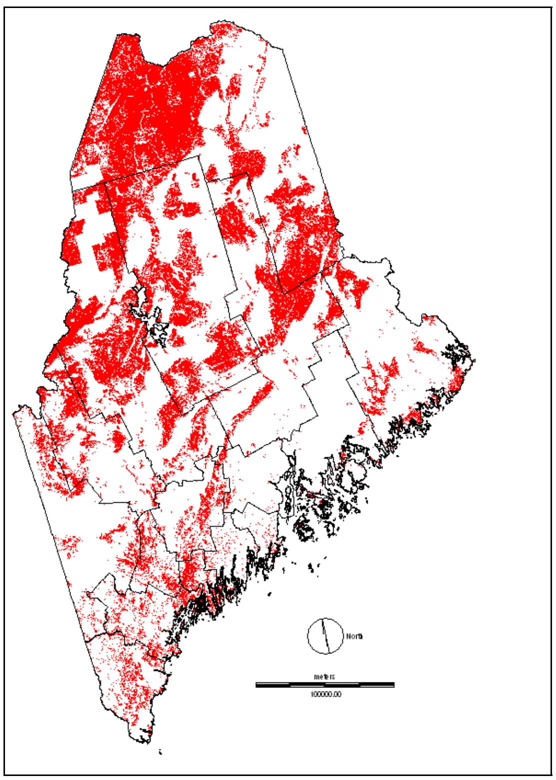


Figure 41. Forested areas of Maine that are sensitive to the negative effects of combined atmospheric sulfur and nitrogen deposition. Red areas indicate current sulfur and nitrogen atmospheric deposition rates greater than the critical load. The critical load is influenced by land use. Land use information was obtained from Maine Office of GIS in 2003 and may not accurately represent present or future land use.
(Figure and legend from Miller 2006)

Forest stand composition and age, along with soil structure, are key factors at ACAD influencing both atmospheric deposition of N, S and other elements, and the movement of these substances into surface and groundwaters. The legacy of major fires on MDI continues to influence vegetation structure, soil characteristics and, in turn, stream water chemistry (Campbell *et al*. 2004, Kahl *et al*. 2007a, Johnson *et al.* 2007, Nelson *et al.* 2008). Surface water chemistry is discussed below.

Acadia is one of the few remaining areas in the Northeastern U.S. with a diverse assemblage of macro-lichens (N. Cleavitt, Cornell University, pers. comm. March 2008). Several studies have investigated air pollution impacts on lichen assemblages. Wetmore (1984) and Sullivan (1996) both concluded that lichens at ACAD were not being adversely influenced by air pollution. In contrast, Stubbs *et al*. (1988, 1990 [cited in Maniero and Breen 2004]) suggested that air pollution (and red spruce health) has reduced lichen diversity in both coastal and inland sites in Maine – including Isle au Haut. Recent research provides evidence that the vertical dimension is a critical factor influencing the extent of air pollution impacts on lichens. Tree canopies at high elevations receive higher volumes of more acidic cloud water than trees at lower elevations. Pollution effect gradients are vertical and at the scale of individual trees, with the result that impacts tend not to be detectable using site-based assessment protocols (N. Cleavitt, Cornell University, pers. comm. March 2008). The impacts of air pollution on lichen assemblages depend on tree species, elevation, and forest assemblage type.

Impacts of Atmospheric Deposition on Freshwater Systems

Lakes: Kahl *et al*. (2000) and Seger *et al*. (2006) summarize surface water quality at ACAD, including pH status. Most surface waters are poorly buffered, low in nutrients and potentially vulnerable to acidification. As previously discussed, only two ponds at ACAD are acidic (Figure 20). One (Duck Pond) is part of a naturally acidic wetland complex, while the other (Sargent Mountain Pond) is acidic because of atmospheric deposition and the characteristics of its watershed.

A few studies have addressed temporal patterns in acidity-related (and other) water quality parameters for surface waters on MDI. Kahl *et al*. (1993, cited in Kahl *et al*. 2000) compared sulfate and acid-neutralizing capacity (ANC) of 22 lakes and ponds on MDI for the period 1982-1985. Most of the lakes exhibited a trend toward increased ANC and decreased sulfate (although none of these changes were statistically significant because of the small number of samples involved). However, for the period 1990-2000, Kahl *et al*. (2004) documented significant decreases in sulfate and base cations in ACAD lakes (Table 10), presumably in response to decreased atmospheric S deposition that occurred following S emissions reductions legislated in the Clean Air Act Amendments (Figure 37). Sulfate in ACAD surface waters declined 10% during this period. In the broader population of sensitive Maine lakes, sulfate declined by 10 to 25%. Kahl *et al*. (2004) suggested that input of sulfate from marine aerosols could explain the modest response in ACAD lakes as compared to lakes in the broader northeast region. There was a trend (insignificant) toward higher acidity (hydrogen ion concentration) in ACAD lakes during this period, apparently slowing or reversing the trend toward decreasing acidity observed during the 1980s in Maine.

There appear to be no studies that have investigated the impact of N loading on lake productivity or other aspects of ecosystem functioning.

Streams: Streams at ACAD tend to be dilute (Figure 23), suggesting they could be susceptible to the effects of acid deposition. Heath *et al*. (1993) compared ANC and sulfate concentrations in ACAD streams over the period 1982-1990 and were unable to document any significant changes (Heath *et al*. 1993). In contrast, recent analyses of composite stream water quality data suggest decreased sulfate concentrations between the 1980s and the present (S. Nelson, University of Maine, unpublished; Figure 42). Although statistical trend analyses from these data are not yet available, the decline appears to be particularly marked for fall samples.

Streams at ACAD exhibit episodic acidification (defined as an ANC decline of ≥50 μeq/L, or 50%) following precipitation events, with pH values as low as 4.7 (Kahl *et al*. 1992, Heath *et al*. 1993). Episodic acidification results from a number of factors,

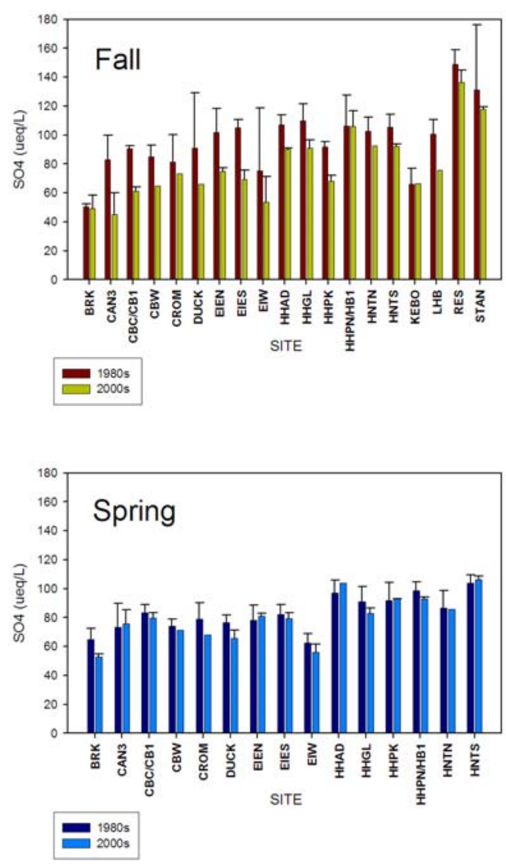


Figure 42. Spring and fall stream sulfate concentrations measured in the 1980s and 2000s. Data are from Heath et al. (1993) and Kahl et al. 2007b).

including sulfuric and nitric acids from precipitation and natural sources, organic acids from soils and wetlands, and hydrochloric acid derived from salt-effect reactions within watershed soils.

The role of sea salt exchange in episodic acidification has been documented for the Hadlock Pond watershed (Heath *et al.* 1993). At ACAD, salt inputs from atmospheric deposition were greatest during winter (Nelson 2007, NADP 2007). Road salt used for de-icing can contribute sodium (and calcium) chloride to streams, making early spring/snowmelt season the most vulnerable to this type of acidification. Whitaker (1999) found significantly higher road salt at sites below roads as compared to those above roads in six catchments at ACAD. Nelson (2006) reported similar findings; however, the salt signal was attenuated just a few hundred meters downstream of roads in the Downeast region of Maine. At ACAD, chloride concentrations in streams across the park do not show clear linkage with road density, which is generally low throughout the Park area. Other landscape factors (e.g. elevation) may play a role mediating sea salt inputs to terrestrial systems. There is also evidence that salt concentrations measured during high-discharge episodes during 1999-2003 were greater than those during 1988-1989 (S. Nelson, unpublished data).

As discussed above, ACAD receives moderate to low amounts of NO_3 and NH_4 in wet-only atmospheric deposition. However, the forested landscape results in enhanced dry deposition (e.g., Weathers *et al*. 2000, 2006). The undisturbed status of many spruce-fir forests at Acadia leads to increased leaching of N from the terrestrial system to surface waters, where it may cause eutrophication and acidification. Nitrate concentrations in some streams in the Park are chronically elevated (Nelson *et al.* 2008), a condition that suggests N saturation of older growth forested watersheds. Nitrogen saturation may occur across the Northeast as well as at ACAD (Aber *et al.* 1998, Aber *et al.* 1989, McNulty *et al*. 1990, Nelson *et al.* 2007).

Several controls on N in streamwater have been proposed, including the initial N status of a site, history of disturbance by harvesting and fire, vegetation composition, and hydrology (Aber *et al*. 1998, Campbell *et al*. 2004). Studies of the paired Cadillac and Hadlock Brook watersheds at ACAD have shown that the export of inorganic N from a burned watershed (Cadillac) was about one tenth of the export from an unburned watershed (Hadlock) (11.5 eq/ha/year vs. 92.5 eq/ha/year; Kahl *et al*. 2007a, Nelson *et al*. 2007). Furthermore, N retention at Cadillac was among the highest in a regional assessment of N input-output budgets (Campbell *et al*. 2004).

An MDI-wide study conducted during 1999-2000 found that other landscape-level factors can mask the effect of fire (Nielsen and Kahl 2007). The study found no significant difference between streams located in watersheds that had burned as compared to those that were undisturbed by fire. However, the authors reported that watersheds entirely *inside* the Park boundary exported significantly *less* total N than watersheds partly or entirely outside the Park boundary (Figure 43). These findings suggest that different factors could control N retention inside as compared to outside the Park.

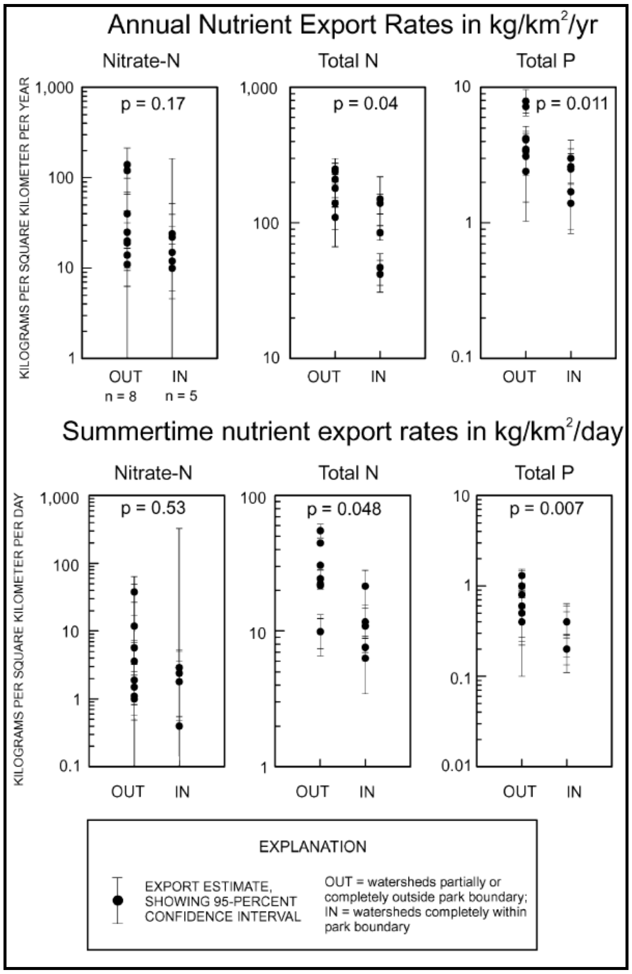


Figure 43. Nutrient export rates for MDI watersheds inside and partially or completely outside ACAD.
(Figure from Nielsen and Kahl 2007, used with permission)

In summary, threats to the Park's streamwater N status include natural disturbances such as fire, non-point source pollution (continued elevated levels of N deposition), and a potentially anthropogenic stressor related to a watershed's location with respect to Park boundaries. It is unclear whether this stressor may be related to roads (automobile emissions of N), management of riparian buffer areas, issues with septic systems and other discharges, or other as yet unidentified factors.

Modeling of the Northeast Creek system has been used to predict the effects of total N loading (i.e. from all sources) on the ecology of this system; for extended discussion of this topic, see *Threats: Nutrient Enrichment*.

Acidic precipitation can mobilize toxic aluminum in surface waters (Munson and Gherini 1991a, 1991b), cause leaching of base cations from soils (Fernandez *et al*. 2003), and it may directly damage vegetation through contact with leaf surfaces or inhibition of transpiration (Turco 2002). Aluminum dynamics are influenced by complexation with fluoride and organic carbon – which may both increase aluminum in solution and also decreasing toxicity to aquatic organisms. No information exists regarding whether biota are affected by aluminum at ACAD.

Organic materials (dissolved organic carbon, DOC) also contribute acidity to freshwater systems. There is little published research regarding the status of organic acidity in ACAD lakes and streams. As discussed above, the acidity in Duck Pond (one of two naturally acidic lakes on MDI; Figure 20) is mostly from natural organic matter (Kahl *et al.* 1989). There are two potential threats or stressors related to DOC levels in surface waters at the Park. First, Nelson *et al*. (2007) concluded that DOC is correlated with mercury, and thus freshwaters with high levels of DOC may be potentially at risk for mercury contamination (see *Threats: Mercury* section). Second, Kahl *et al*. (2004) and Stoddard *et al*. (2003) found statistically significant increases in DOC in lakes across the northeastern US in an EPA assessment of 20 years of water chemistry data. The source of this increased DOC and implications of rising DOC levels are currently an active area of research. At ACAD, further research is necessary to determine both the temporal change in DOC at the Park (if any) and the potential interaction with Hg in freshwaters and biota.

Atmospheric Nitrogen Deposition to Coastal and Marine Systems

Nitrogen fluxes from watersheds in the Northeast United States have increased 3-8 fold since the early 1900s (Jaworski *et al*. 1997; note that all watersheds discussed by these authors are to the south of Maine). Evidence strongly suggests a linkage between increases in cultural eutrophication (higher productivity) and the increase in N emissions from fossil fuel combustion.

Nielsen *et al*. (2002b) developed a water budget and estimated nitrogen loads to Northeast Creek. Direct deposition to the creek surface represented a small proportion of total N loading to this system from all sources. Total atmospheric N deposition (wet and dry, inorganic and organic) across the entire watershed was estimated to be 510 kg/km^2/year. This estimate of atmospheric deposition can be compared to total-N <u>yields</u> to Northeast Creek from its various sub-watersheds of 130-270 kg/km^2/year (Nielsen *et al*. 2002b). These data suggest that N processing and uptake by biota are major sinks for N in this system.

In their study of Bass Harbor Marsh, Doering *et al*. (1995) did not explicitly model atmospheric input, but rather assumed that it was accounted for in overall loads from freshwater sources.

Studies of estuaries on the east coast of the U.S. (the closest to ACAD is Casco Bay in southern Maine) have shown that total atmospheric N deposition (direct deposition plus surface runoff) accounts for 15-42% of the total N loading to these systems (Castro and Driscoll 2002). The value for Casco Bay was in the middle of this range: 24%. In some estuaries, direct deposition to the water surface represented a significant proportion (35-50% of the total atmospheric input). Roman *et al*. (2000) concluded that atmospheric deposition represented an average of approximately 70% of total nitrogen loading to four Maine esturaries (Penobscot Bay, Sheepscot Bay, Casco Bay and Saco River). In more urbanized watersheds, atmospheric loading represented generally <50% of total nitrogen loading because more was derived from agricultural runoff and/or wastewater treatment facilities.

The impacts of nitrogen loading on the ecology of the Northeast Creek system are discussed below, under *Threats: Nutrient Enrichment*.

Mercury

Key Issues	Extent of Problem	Information Base
Atmospheric sources	EP	Good
Hg in terrestrial systems	EP	Good
Hg in freshwater – abiotic components	EP	Good
Hg in biota	EP	Fair
Hg in coastal sediments	OK ?	Good

Atmospheric Sources

Mercury (Hg) is atmospherically deposited in regions remote to its origin (Haines and Webber 1999). Atmospheric Hg is delivered to ecosystems by rain, snow, dry, and occult (cloud and fog) deposition. Where total deposition of Hg has been measured, dry deposition (particles and gases) equals or exceeds wet deposition (Hg in rain and snow) and is likely the largest vector of Hg input from the atmosphere to terrestrial ecosystems (Lindberg *et al.* 2007, Miller *et al.* 2005, Grigal 2002).

At ACAD, dry deposition of Hg equals or exceeds wet-only deposition, during both the growing season and in winter (Figure 44). Recent research regarding snow Hg deposition indicates that total deposition was much greater than previously thought during winter (Nelson 2007); however, much of the Hg that is deposited in snow is volatilized and emitted back to the atmosphere as snowpack matures. Snow research at ACAD suggests future work to determine the processes leading to snowpack Hg burdens and the fate of re-emitted Hg. A regional model for dry deposition of Hg that incorporates enhancement of Hg deposition by vegetation type suggests that total Hg deposition in the ACAD region is at least twice the reported value for wet-only deposition (Miller *et al*. 2005) (Figure 45).

Evidence from the Canadian Maritimes suggests that fog could be enriched in Hg as well as in S and N. Ritchie *et al*. (2006) observed Hg concentrations in fog ranging from 2 – 435 ng/L along a geospatial gradient from an ocean island (Grand Manan, high concentration) to an inland site (Fredericton NB, low concentration). At these sites in Canada, Hg concentrations were greatest on days with stationary fog banks. Because of its coastal location and frequent fog immersion, these data suggest that future research regarding fog contributions to both Hg and acid loading to the Park's ecosystems is warranted.

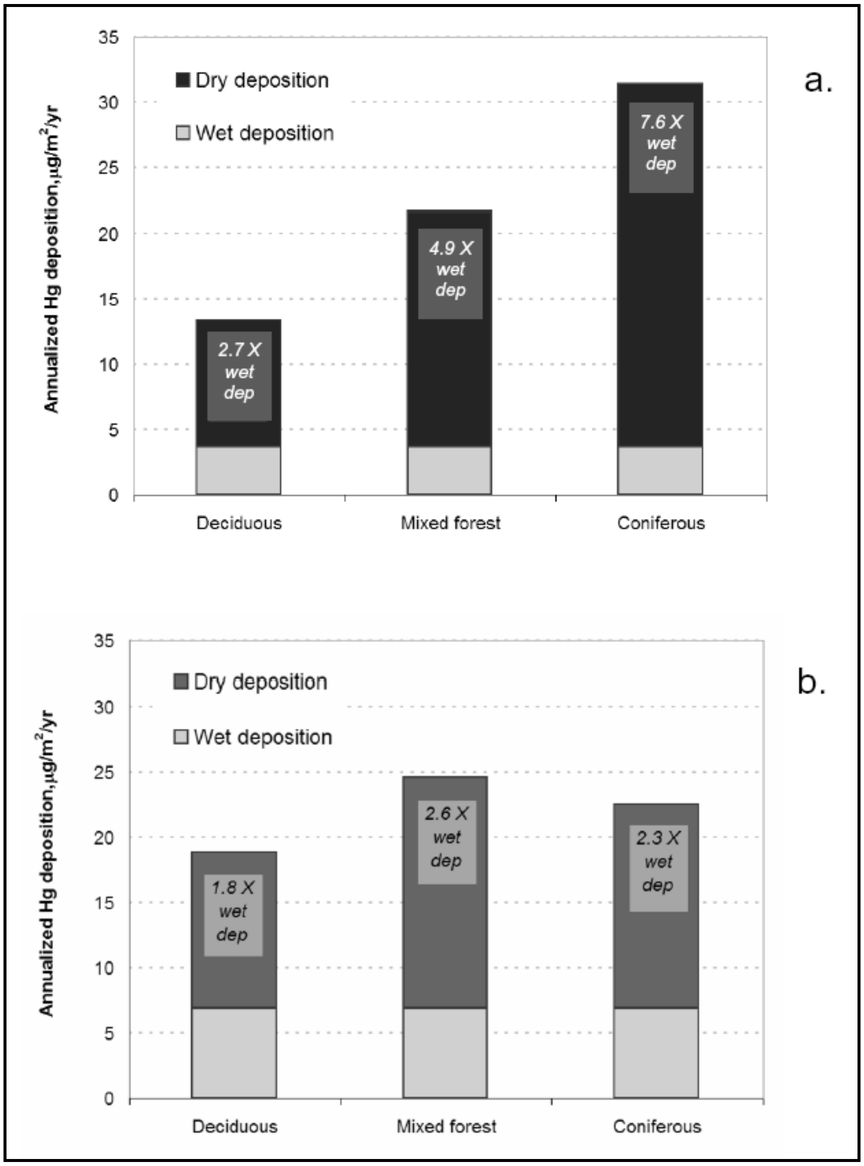
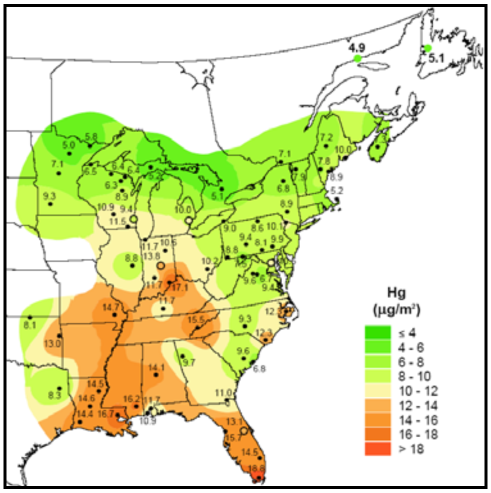
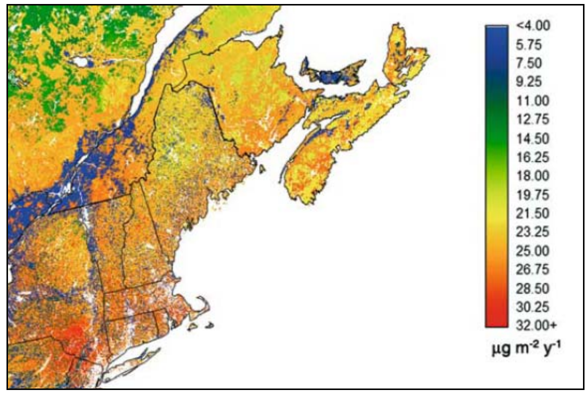


Figure 44. Winter (a) and growing season (b) mercury (Hg) deposition measured in throughfall in ACAD. Bars show the contribution of Mercury Deposition Network wet-only deposition, plus the amount of dry deposition inferred from throughfall measurements. Winter throughfall was measured December 15, 2004-March 16, 2005, and growing season throughfall was measured from May 28, 2004-November 17, 2004. The graph shows estimates from these measurements annualized to per year rates, for comparison.
(Source: Nelson 2007)



(A)



(B)

Figure 45. Wet-only and total mercury deposition in eastern North America. (A) 2006 wet deposition, (B) estimated total mercury deposition (wet + dry) to rural areas.

Image sources: (A) Mercury Deposition Network (http://nadp.sws.uiuc.edu/mdn/ accessed September 2007). (B) Miller *et al*. 2005. Note that "deposition was not estimated for areas with urban or residential land cover. Mercury deposition is likely to be much greater than depicted here in the immediate vicinity of urban areas and emissions sources."

Mercury in Terrestrial Systems

Forest cover enhances Hg deposition because forests act as filters that scavenge dry particles and gases from air masses (Rea *et al.* 2000, Lindberg *et al.* 1994). Forest canopies also take up Hg and can re-emit Hg previously deposited on the canopy (Graydon *et al.* 2007). Wet deposition and the net remaining Hg deposited on forest canopies via dry deposition subsequently are washed by precipitation as throughfall to the forest floor or deposited later as litterfall (Rea *et al.* 2000, Lindberg *et al.* 1994).

Mercury in throughfall at ACAD is dependent on vegetation type and watershed aspect. In a network of 52 study sites distributed throughout Hadlock and Cadillac watersheds, throughfall deposition was, on average, 1.6 (deciduous), 2.3 (coniferous), and 2.6 (mixed) times higher at forested than open sites during 1999-2000 (Johnson 2002). Site aspect also influenced Hg concentrations in throughfall. Southwest and west aspects had significantly higher Hg deposition than other aspects studied (Figure 46). Higher deposition at west-facing sites has been attributed to the dominant wind direction, which typically tracks through the Midwest before reaching the Northeast (Johnson 2002).

Sheehan *et al*. (2006) estimated Hg fluxes through the Cadillac and Hadlock watersheds, and compared them to precipitation and throughfall inputs. Litterfall contributed as much Hg as total deposition to the study watersheds (Sheehan *et al*. 2006), and presumably represented Hg that was scavenged from the atmosphere and trapped in or on leaves (Grigal 2002).

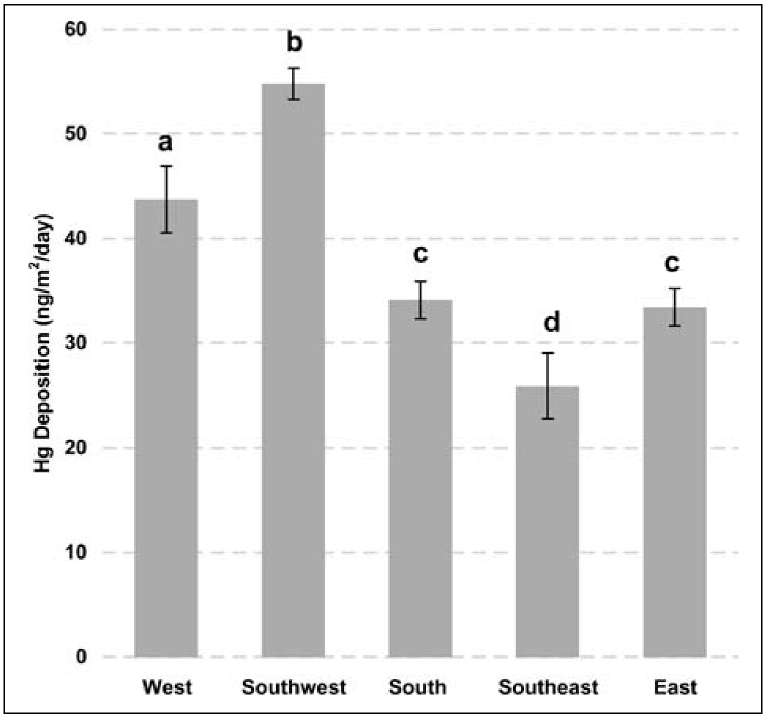


Figure 46. Hg deposition stratified by site aspect for the period May-November 2000, at Cadillac and Hadlock watersheds study sites. Matched letters are not significantly different (ANOVA, P > 0.05). Error bars represent standard error.
(Figure from Johnson 2007)

Mercury in Freshwater Systems (Abiotic Components)

The relationship between landscape factors and Hg in fresh waters has been the subject of ongoing research in the Park since 1998 (Kahl *et al*. 2007a).

Mercury (measured as total dissolved Hg) was collected in streams across MDI during two surveys in 1999-2000 and in 2004 (Figure 48; Kahl *et al*. 2006, Peckenham *et al*. 2007). The greatest Hg concentrations were found in Squid Cove Brook, Oak Hill Stream, Hodgdon Brook, and Whalesback Brook. Hodgdon Brook is a tributary to Hodgdon Pond, the waterbody where the greatest Hg concentration in a Maine fish was found in 1995 (Burgess 1997). Streams draining unburned watersheds tended to have higher Hg concentrations that those draining burned watersheds (this trend was not statistically significant).

The influence of fire history on mercury dynamics was further explored during the Acadia paired watersheds project (see Kahl *et al*. 2007a for an overview of this project). The research was designed to compare ecosystem processes in the Cadillac Brook watershed that burned in 1947 and the Hadlock Brook watershed that has been largely undisturbed for at least 300 years (Schauffler *et al*. 2007). The project hypothesis was that fluxes of Hg from the unburned watershed would be higher because: i) mature coniferous forest in the Hadlock watershed would enhance dry deposition, in turn resulting in higher total Hg deposition; ii) elemental Hg pools in

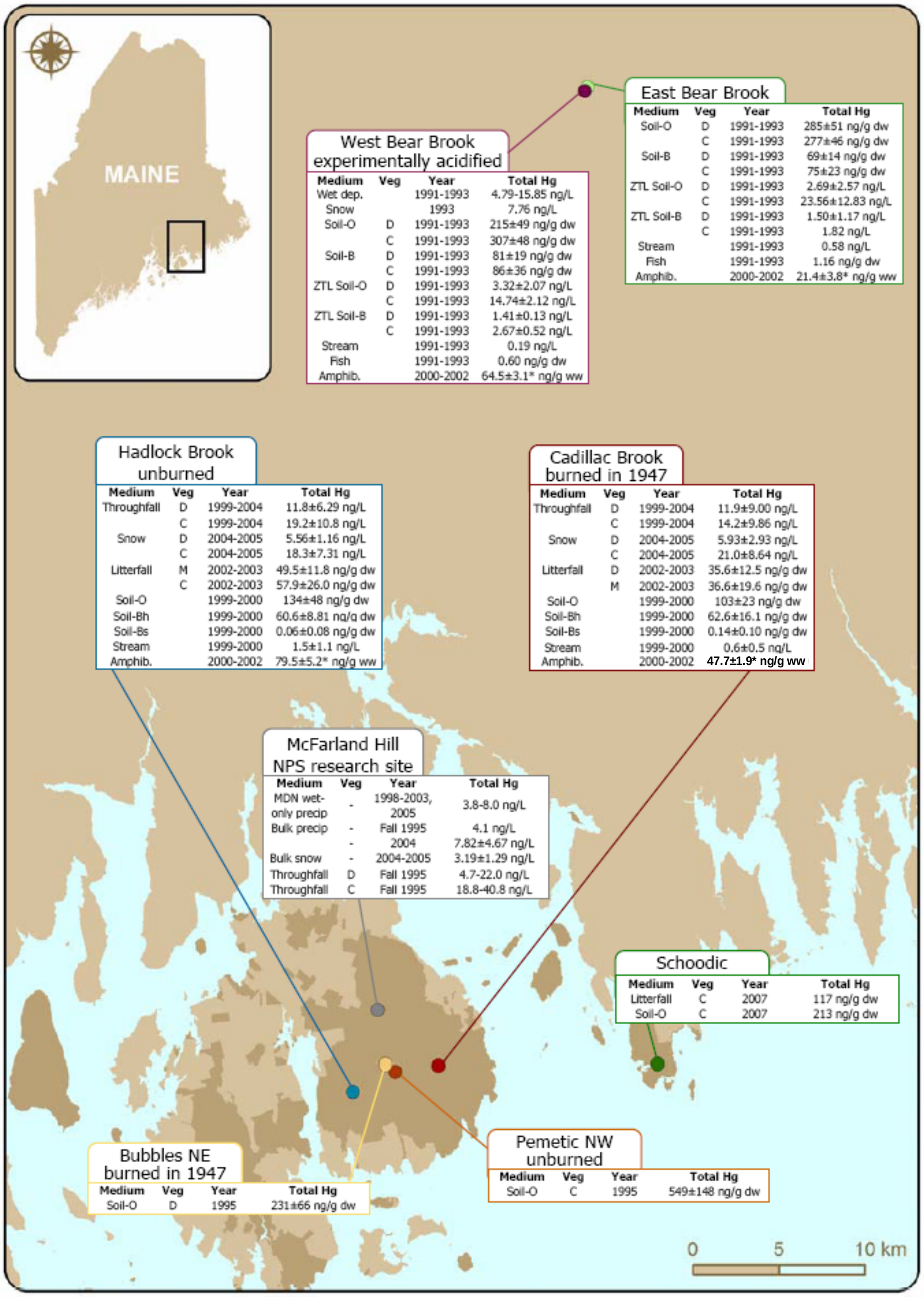


Figure 47. Summary of Hg concentrations in environmental media from established research sites in upland, forested sites at Acadia National Park and Bear Brook Watershed in Maine. Values for total Hg are means or ranges, with standard deviations. The * denotes that standard errors were reported rather than standard deviation.
(From Nelson 2007)

Hadlock watershed soils would be higher compared to the burned soils of the Cadillac watershed (Nelson *et al*. 2007).

Discharge-weighted Hg in streamwater draining the unburned watershed was twice that in streamwater draining the burned watershed (Kahl *et al*. 2007a, Nelson *et al*. 2007, Johnson 2002) (Figure 47 – see 'streams' data). Soils in Cadillac (burned) watershed were more able to bind Hg, keeping it from moving through ecosystems and into water (Kahl *et al.* 2007). Approximately 13% (burned watershed) and 5% (unburned watershed) of total mercury deposition was exported in streamwater (Nelson *et al*. 2007) – although scientific debate is ongoing whether the Hg in streamwater is new (recently deposited) Hg or old (stored in soils) Hg (e.g., Hintelmann *et al.* 2002).

Mercury concentrations measured in MDI streams fall within the range of concentrations documented from a study of 58 Maine rivers (Peckenham *et al*. 2003 - none of those river sites were in the ACAD area). The average concentration measured in this statewide survey was 1.80 ng/L (range = 0.093 – 7.01 ng/L). The highest MDI stream mercury concentrations (Figure 48) were approximately 70% of the maximum values observed in the statewide survey. Although MDI data therefore fall within the statewide range, Hg levels in MDI streams are unusually high from a more regional basis. According to Hg contour maps presented by Peckenham *et al*. (2003), the ACAD region falls within a broader coastal / Downeast zone of minimal Hg concentrations, typically <1 ng/L (in contrast, highest values occurred in the northern and western parts of the state). The higher values measured on MDI therefore suggest that MDI represents a hotspot of elevated Hg concentrations within the regional context of coastal and Downeast Maine.

Norton *et al*. (1997) reported that accumulation rates of Hg to sediments in Big Heath Bog and Sargent Mountain Pond during the 1980s were substantially higher than would be expected from measured wet-only atmospheric deposition. This observation reinforces the likely contribution of dry deposition.

Mercury in Terrestrial and Freshwater Biota

Mercury is converted by micro-organisms to methymercury (MeHg). In this form, Hg is biologically active and toxic to animals. Mercury is not actively taken up by most plants. Consequently it is unlikely that the elevated Hg levels at ACAD are affecting vegetation.

A number of studies have documented Hg and MeHg levels in the biota of ACAD. Bank *et al*. (2007a) reviewed available data on Hg levels in biota of ACAD and vicinity. Bank *et al*. (2005 and 2007b) reported data on mercury levels in ACAD amphibians, and Longcore *et al*. (2007a, b) provide data on tree swallows. Table 19 presents a synthesis of these data. Figure 49 shows spatial patterns of mercury levels in two-lined salamanders and Figure 50 compares Hg in trees swallows at three ACAD lakes with levels at other Maine and Massachusetts sites. Table 20 summarizes some key conclusions from these publications. Although ACAD fauna clearly display elevated tissue Hg concentrations, the physiological and ecological implications of these body burdens are unclear.

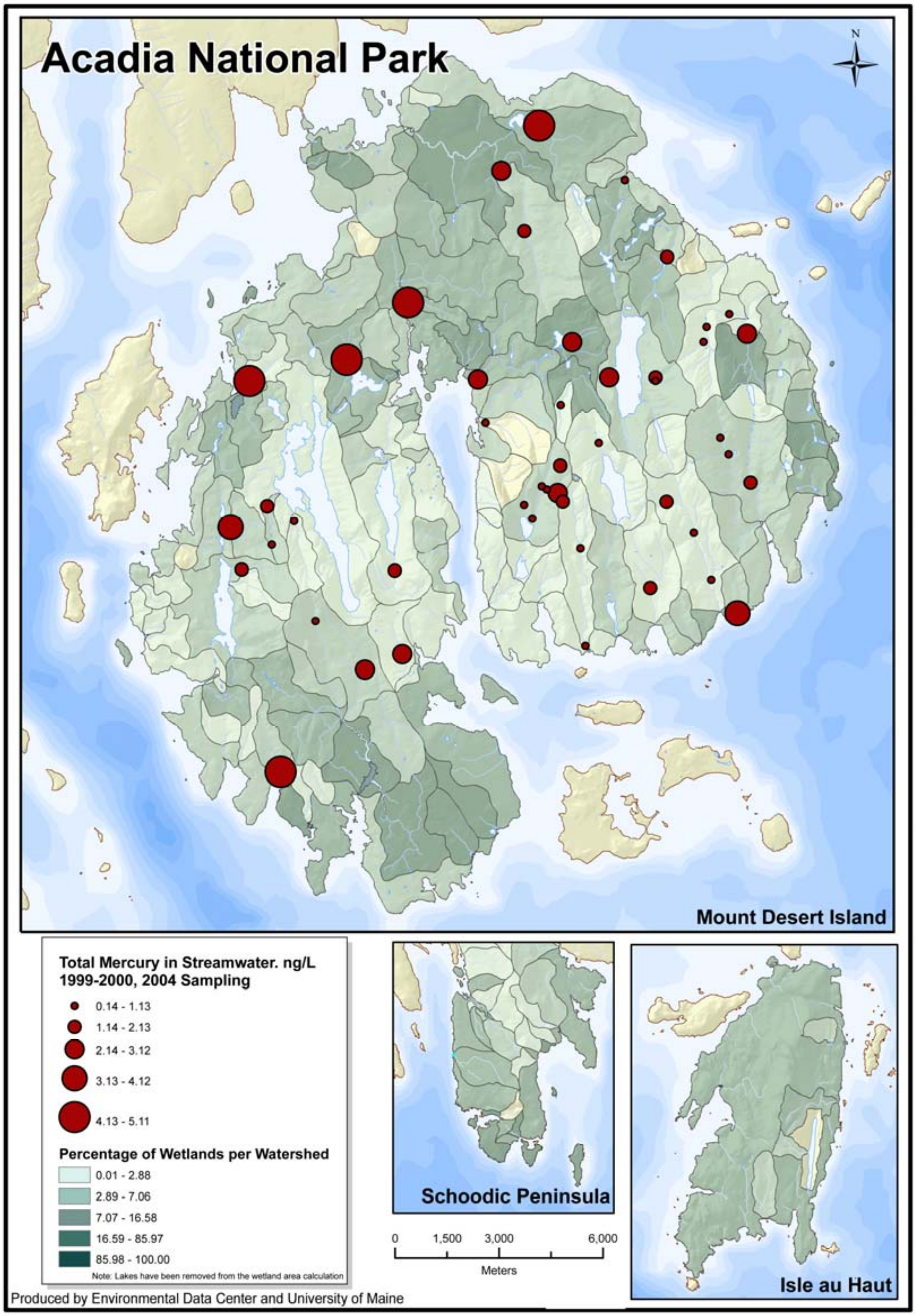


Figure 48. Mercury in streams and wetlands extent in watersheds. Stream surveys were conducted in 1999-2000 and 2004 to characterize total mercury (average values are shown). Wetlands data are derived from data in Lubinski *et al*. (2003) and are presented as watershed-level summaries.

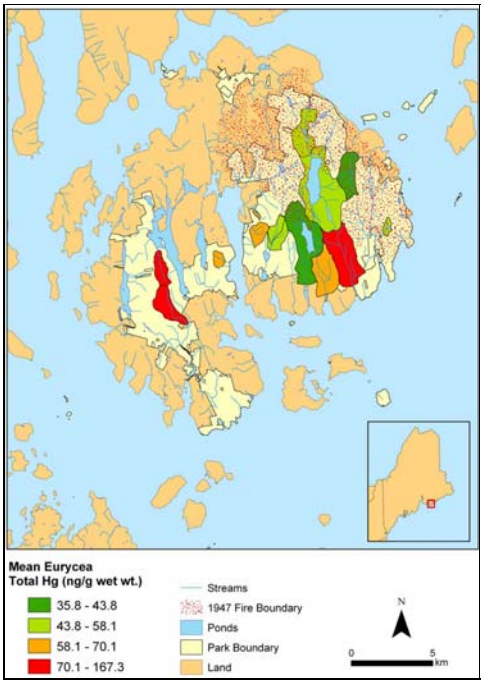


Figure 49. Average concentrations of total mercury (ng/g wet wt.) in two-lined salamanders (*Eurycea bislineata bislineata*) larvae, June-July 2001-2002. Note that samples were not collected in all MDI watersheds.
(Figure from Bank *et al*. 2006, used with permission)

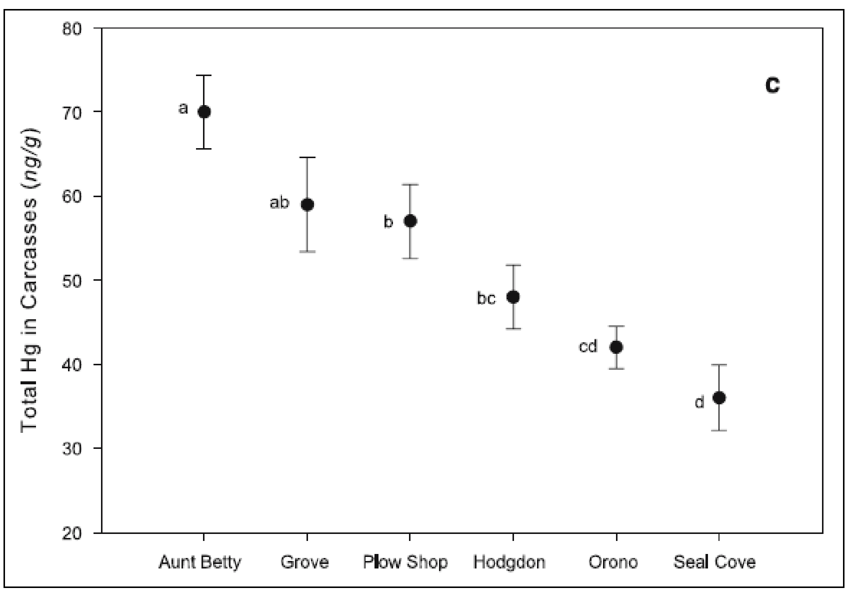


Figure 50. Mean (SE) concentrations of total-Hg in tree swallow carcasses at three ACAD lakes (Aunt Betty, Hodgdon and Seal Cove) compared to another Maine site (Orono) and Massachusetts superfund sites (Grove and Plow Shop), 1997-1999. Different letters indicate statistical differences of means.
(Figure from Longcore *et al*. 2007b, used with permission)

Mercury in Marine Systems

Mercury contamination in the Gulf of Maine is widely recognized as an important regional issue (Jones and Wells 2002). However, Hg concentrations in marine sediments around the MDI area appear low when compared to the entire Maine coast (Figure 51).

The mercury content of intertidal and subtidal species has been studied recently by C. Chen and B. Mayes (Dartmouth College, NH) at a series of sites on MDI, including Northeast Creek, Salisbury Cove, Seal Cove, and Somes Sound. Although published results are not yet available, this study documented that, although sediments around MDI are relatively uncontaminated with Hg, this contaminant does become biomagnified in marine fauna at higher trophic levels (C. Chen, Dartmouth College, pers. comm.). D. Kopec (University of Maine) is currently investigating Hg in seals and their prey in offshore areas near the Park, such as near Mount Desert Rock.

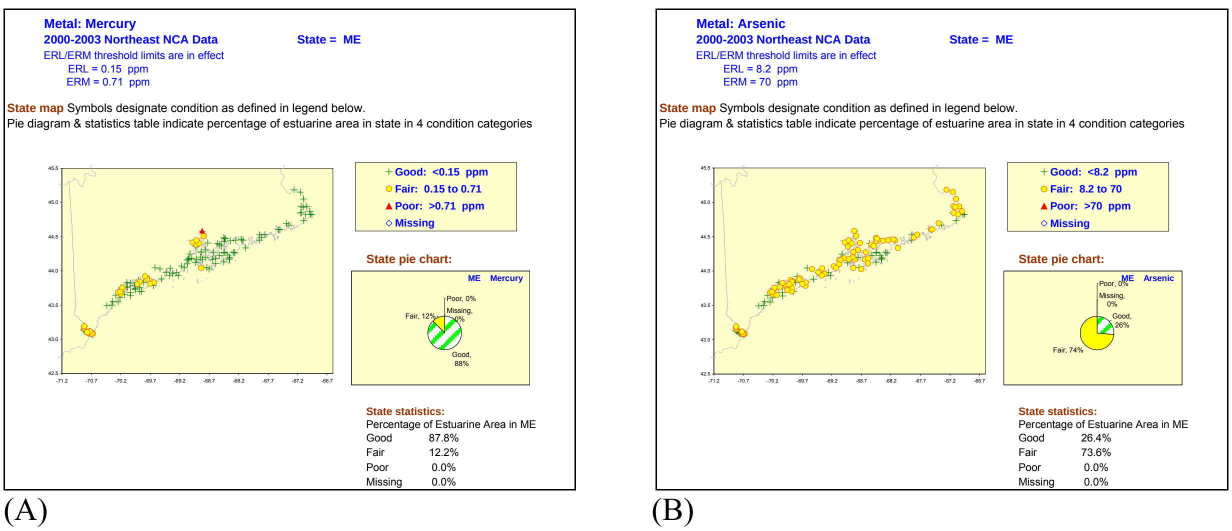


Figure 51. Mercury (A) and arsenic (B) concentrations in coastal sediments of Maine. (Data and plots from EPA National Coastal Assessment database)

Table 19. Mercury concentrations in biota: a summary of data presented by Bank *et al*. (2007a, b).

Group	*Site*	*Total Hg: Mean (st. dev.) µg/g DRY weight* [(2)]	*Original Source*
Plankton [(1)]	Hodgdon P.	0.53 (0.14)	Burgess 1997
Plankton [(1)]	Seal Cove P.	0.51 (0.22)	
Anisoptera [(1)]	Hodgdon P.	0.45 (0.17)	
Anisoptera [(1)]	Seal Cove P.	0.32 (013)	
Isopoda [(1)]	Hodgdon P.	0.38 (0.10)	
Amphipoda [(1)]	Hodgdon P.	0.21 (0.40)	
Amphipoda [(1)]	Seal Cove P.	0.39 (0.09)	
		Total Hg: Mean (range) of lake means. µg/g WET weight	
Predator fishes - fillets	11 lakes	0.54 (0.15 – 1.72)	Burgess 1997
Predator fishes – whole body	10 lakes	0.27 (0.14 – 0.51)	
Forage fishes (yellow perch) – whole body [(3)]	2 lakes	0.14 (0.12 – 0.18)	
		Total Hg: Mean (st. dev.). µg/g WET weight [(2)]	
2-lined salamanders, 1-3 yr old larvae	14 streams	0.066 (0.003)	Bank *et al.* 2005
Green frog tadpoles	9 ponds	0.025 (0.001)	Bank *et al*. 2007b
Bullfrog tadpoles	9 ponds	0.019 (0.007)	Bank *et al.* 2007b
		Total Hg: Mean (range) of sample values. µg/g WET weight	
Bald eagles (6-8 wk old):	5 small island and MDI sites		Welch 1994
-- feather		5.21 (2.8 – 6.5)	
-- blood		0.10 (0.03 – 0.15)	
		Total Hg: Range of sample values. µg/g fresh (fur) and wet (liver) weights	
River otter and mink fur	Long and Round Ponds	1.14 – 9.90	BioDiversity Research Institute, unpublished data
River otter and mink liver	Long and Round Ponds	0.48 – 0.86	

(1) Plankton and macro-invertebrates: composite of spring (May-June) and summer (Aug-Sept) samples.
(2) Data from plankton, invertebrate and amphibian samples have been converted from ng/g (Bank *et al*. 2007a, b) to µg/l for consistency within this table.
(3) Yellow perch data include both spring and summer samples and exclude the young-of-young data presented by Bank *et al*. (2007).

Table 20. Mercury in terrestrial and freshwater biota: selected observations.

METHYLATION AND BIOCONCENTATION

- All trophic levels at ACAD have elevated levels of Hg and MeHg [(1)].
- Bioconcentration factors[(8)] from pond water to amphibian tadpoles are within the ranges of 2.7-4.0 (total Hg), and 3.6-5.2 (MeHg). These levels are comparable to those observed in amphipods from other ACAD lakes [(3)].
- The ratio of MeHg to total Hg in tadpoles from nine ACAD lakes ranges from about 5% to almost 20%, with four of nine study ponds showing a methylation efficiency of >10% [(3)].
- Methylation efficiency is enhanced by acidification, higher temperatures, elevated DOC, among other factors [(3)]

TISSUE CONCENTRATIONS

- ACAD plankton Hg and MeHg levels tend to be higher than values in Wisconsin meso-oligotrophic lakes [(1)].
- ACAD invertebrate Hg concentrations are comparable to values observed elsewhere [(1)].
- Higher Hg concentrations in 2-lined salamanders, relative to frogs, likely reflect invertebrate vs. grazer diets, respectively [(2)].
- Salamanders from undisturbed watersheds (e.g. Hadlock) exhibit higher Hg levels than animals from burned watersheds (e.g. Cadillac) [(2, 8).] (Figure 49)
- Non-salmonid fish species on MDI generally have similar or lower Hg concentrations than statewide averages for these species [(1)].
- Chain pickerel on MDI had much lower Hg concentrations than the statewide mean, although this comparison may be influenced by size of sampled fish.
- Smallmouth bass on MDI had higher Hg concentrations than the statewide average [(1)].
- Highest Hg concentrations in MDI fish fillet samples were recorded from Hodgdon Pond (smallmouth bass) [(1)].
- The State of Maine mercury consumption advisory recommends that the sensitive human population not eat fish containing > 0.27 µg/L Hg. All 11 lakes samples for fish Hg levels had at least one fish sample for which the fillet concentration exceeded the advisory [(6)].
- Tree swallow chicks and eggs from ACAD are at least as contaminated with Hg as birds living at a Hg-contaminated Superfund site in Massachusetts [(5)]. (Figure 50)
- Loon blood Hg levels are highly correlated to prey fish Hg levels on breeding lakes [(1)].

ECOLOGICAL IMPACTS

- The risk of negative effects from MeHg in fish and amphibians is likely higher than in birds, mammals and reptiles which store MeHg in body parts away from vital organs [(1)].
- Hg levels in bald eagles reflect upper trophic level biomagnification. However, when compared to levels in juvenile eagles elsewhere, MDI marine habitats do not pose a risk to eagles [(1)].
- Compared to Hg exposure levels elsewhere in Maine and across North America, Hg exposure on the larger MDI lakes represents a low risk to breeding loons. While loon recruitment is below sustainable levels on MDI (Evers et al. 2003, cited by Bank et al. 2007), Hg levels are not thought to be a contributing factor [(1)].
- Although early growth rate in weight in tree swallows was negatively associated with MeHg levels in feathers, long-term growth appeared to be unaffected by MeHg body burdens [(4)].
- Limited mammal (mink and otter) data from MDI suggest potential low risk from Hg [(1)].
- Research suggests that commonly observed levels of Hg increase vulnerability of golden shiners to predation. They do not appear to influence mortality or growth rates [(7)].

KEY INFORMATION GAPS

- No reptiles have been sampled for Hg exposure on MDI. Amphibian data are available for only three species [(1)].
- There are many gaps in knowledge of the factors influencing exposure to and toxicological effect from Hg. In particular, a better understanding is needed of the interaction between Hg and other anthropogenic stressors [(1)].
- More research is necessary at ACAD to determine whether wetlands are hotspots for Hg methylation and transport [(3)].

[(1)] Bank *et al*. 2007a. [(2)] Bank *et al*. 2005. [(3)] Bank *et al.* 2007b. [(4)] Longcore *et al*. 2007a. [(5)] Longcore *et al.* 2007b. [(6)] Haines and Weber 1999. [(7)] Webber and Haines 2003. [(8)] Bank *et al.* 2006. [(9)] Log(biota concentration / water concentration), based on composite samples.

Nutrient Enrichment

Key Issues	*Extent of Problem*	*Information Base*
Atmospheric N loading to terrestrial systems	EP	Good
Nutrient loading to lakes and streams	PP	Fair
Nutrient loading to wetlands and estuaries	EP / PP	Good
Nutrient issues for coastal/marine systems, incl.algal blooms, aquaculture, sewage	PP	Fair

Nutrient Enrichment: Terrestrial Systems

Atmospheric deposition includes elevated concentrations of nitrogen derived from industrial and other emissions. The effects of nitrogen enrichment on forest ecosystems at ACAD have been discussed above (*Threats: Atmospheric Deposition: Acidity and Related chemistry*).

Nutrient Enrichment: Lakes and Streams

Freshwaters and estuaries in the northeastern U.S. are increasingly at risk of eutrophication as a result of elevated nutrient loading rates (e.g. Nielsen and Kahl 2007, Roman *et al*. 2000, Kinney and Roman 1998, Jaworski *et al*. 1997). Excessive nutrient enrichment may lead to dense algal growth, decreased dissolved oxygen concentrations, reduction in submerged vascular plant beds and deterioration of habitat for finfish and shellfish (Rohweder *et al*. 2004). Even though MDI watersheds are relatively unaffected compared to many in the Northeast, accelerated nutrient enrichment is a concern in the ACAD region. Nutrient loading to aquatic systems has been identified as a key resource management issue at ACAD.

According to Nielsen and Kahl (2007), nutrient export from 13 small watersheds across MDI is relatively low. Nevertheless, their data suggest that land-use may be influencing stream nutrient levels. Watersheds partially or completely outside the Park boundary exported more total N and phosphorus (P) than those entirely within the Park (Figure 43). The three watersheds with the highest nitrate exports were Marshall, Stony, and Stanley Brooks. All have relatively high human populations. There is a capped landfill in the Marshall Brook watershed and there are near-stream septic systems in the Stanley Brook watershed (Nielsen and Kahl 2007). Even though these authors detected a possible land-use signature in nutrient export rates, atmospheric deposition was considered to be the greatest single source of nitrate in the studied watersheds.

Atmospheric deposition has resulted in elevated flux of N in wet and dry precipitation across the Northeast (see above). Atmospheric N loading has typically not been thought to result in eutrophication of lakes because P is the nutrient that most commonly limits primary production in north temperate systems (Bergstrom *et al*. 2005). However, there is a growing body of evidence to suggest that P limitation in relatively unproductive lakes is a derived characteristic that has resulted from increased atmospheric N loading over the past several decades (Goldman 1988, Bergstrom *et al*. 2005).

Most lakes and ponds in and around ACAD are nutrient-poor and unproductive (Kahl *et al.* 2000; Table 9). There is a positive association between total phosphorus and chlorophyll concentrations in Maine lakes as well as in the subset of ACAD lakes (Figure 52). This relationship is indicative of the fact that many lakes are P-limited. Nitrogen to phosphorus ratios suggest P-limitation in at least some ACAD lakes. For example, using 2007 (June and August) water chemistry data collected by the NETN monitoring program (data provided by B. Gawley, NPS), we calculated two sets of ratios for 11 lakes - total N:total P and dissolved inorganic N:dissolved inorganic P. Ratios were not calculated when either N or P samples were below detection. Total N:P ratios were between 19:1 and 53:1. Dissolved N:P ratios were between 38:1 and 104:1. Typically, N:P ratios of >7:1 on a mass basis suggest P limitation (Redfield 1958). To our knowledge, there has been no attempt to use nutrient bioassays to document whether ACAD lakes are limited by N or P. These bioassays would provide important background information relating to eutrophication risk in ACAD lakes.

Although cultural eutrophication (human-associated productivity increase) is a concern in many Maine lakes (Nieratko 1992), there is little evidence of this process occurring in ACAD lakes. In some lakes, water transparencies (Secchi depths) appear to have actually increased over the past several years and trophic state index values have decreased.

Nutrient enrichment, and the resulting elevated rates of primary production, can increase the extent and severity of hypolimnetic oxygen depletion in lakes. In addition to reducing the amount of habitat available to aquatic organisms, anoxia triggers internal loading of phosphorus from lake sediments, in turn further increasing primary production. The hypolimnia of

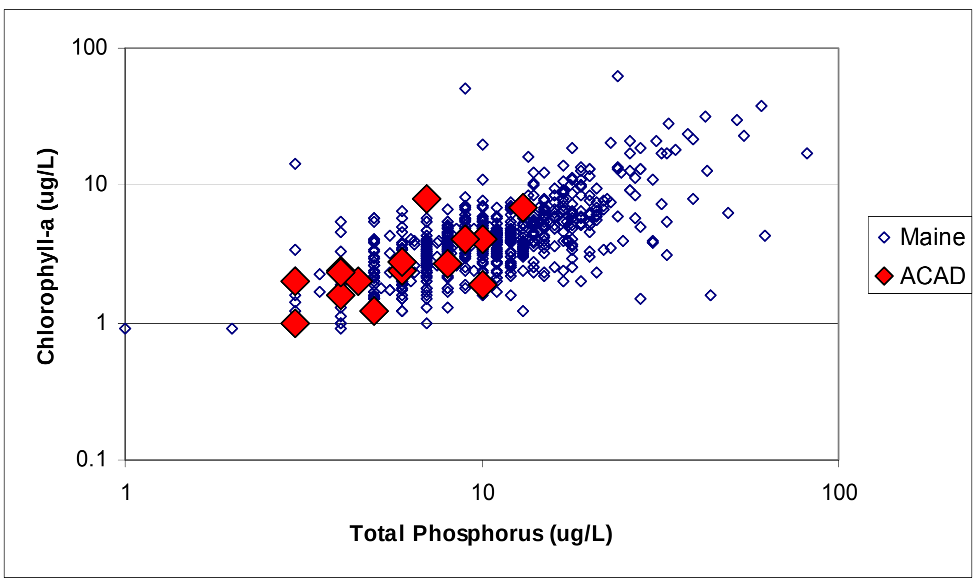


Figure 52. Relationship between total phosphorus and chlorophyll concentrations in Maine and ACAD lakes. Data are overall averages for each lake, calculated by MDEP and accessed at www.pearl.maine.edu. Where data were available for >1 basin / lake, data were averaged across basins. Original water quality data for ACAD lakes were provided to MDEP by ACAD staff.

mesotrophic (moderately productive) ACAD lakes (e.g. Seal Cove, Witch Hole and Upper Hadlock) exhibit reduced oxygen levels or complete anoxia during summer months (Seger *et al*. 2006). This is likely a natural – or at least long-standing – feature of these lakes. Many exhibited similar reductions in hypolimnetic dissolved oxygen over 60 years ago (Figure 53; Fuller and Cooper 1946). Oligotrophic lakes remain well-oxygenated throughout the growing season.

Although there is currently no evidence of eutrophication affecting ACAD lakes, the potential for this exists, particularly in lakes whose watersheds are not completely within ACAD. The excellent water quality of many ACAD lakes with respect to nutrient concentrations highlights the need to ensure their future protection. Current monitoring at ACAD includes collection of water quality data from a set of lakes potentially at risk of eutrophication (Seger *et al*. 2006). This monitoring is essential for early detection of changing conditions, at a time when it may be possible to mitigate the effects of nutrient enrichment.

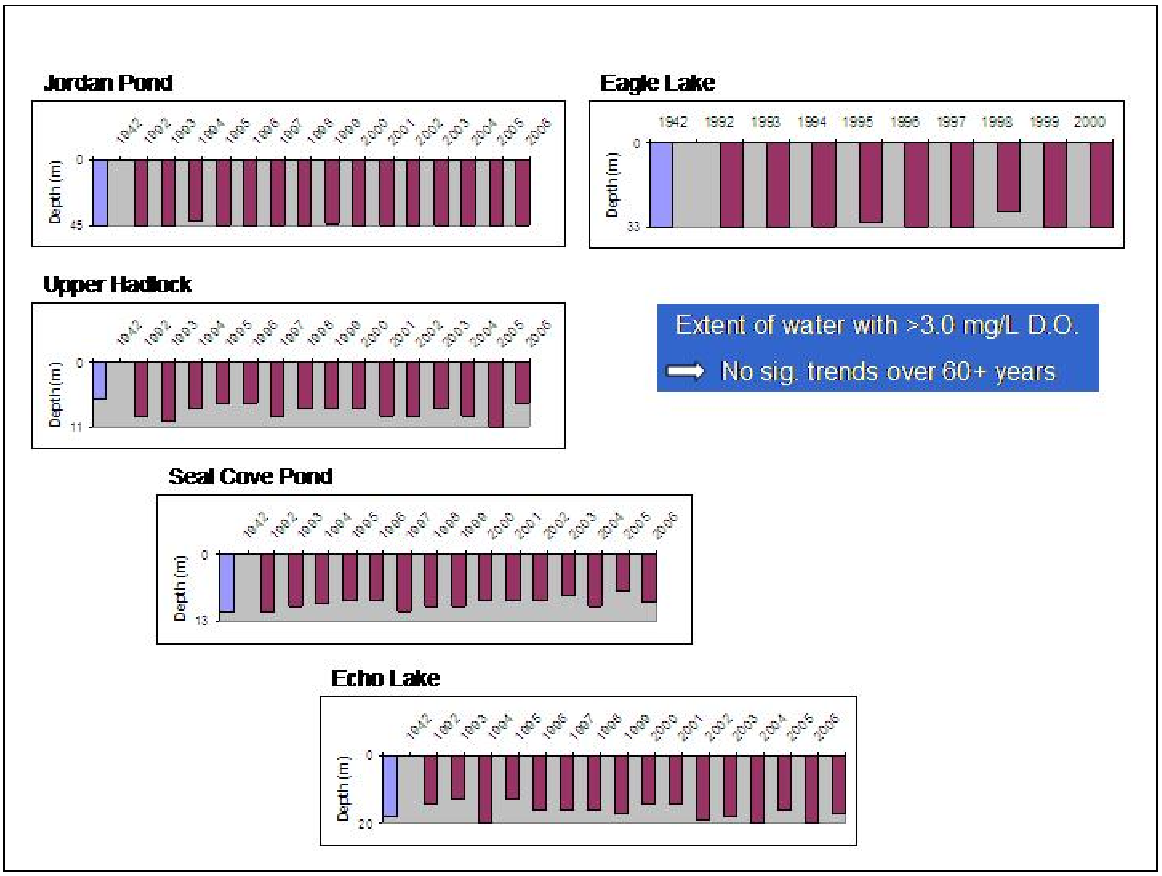


Figure 53. Dissolved oxygen concentrations at depth in four MDI lakes: 1942 and 1992-2006. Bars show the depths at which there was > 3.0 mg/L dissolved oxygen in August samples. Data from 1942 are from Fuller and Cooper (1946); more recent data are from ME Dept. of Environmental Protection, as accessed at www. pearl.maine.edu.

Nutrient Enrichment: Wetlands and Estuaries

Water quality degradation resulting from eutrophication is a particular concern for the estuaries at ACAD. Evidence of eutrophication has been observed at Bass Harbor Marsh (Doering *et al*. 1995, Kinney and Roman 1998, Farris and Oviatt 1999). Although water quality problems have not yet been documented in Northeast Creek (Culbertson *et al*. 2007), there is concern that increasing residential development in this watershed could adversely affect estuarine water quality. Compared to inputs of phosphorus, anthropogenic inputs of dissolved inorganic N likely represent a much greater risk to the estuaries of the ACAD region (Culbertson *et al*. 2007).

Water quality and nutrient loading have been studied in three coastal ecosystems on MDI: Bass Harbor Marsh, Northeast Creek and Somes Sound.

Bass Harbor Marsh: In response to qualitative observations of increasing macroalgal biomass and a decreasing recreational (brook trout) fishery in Bass Harbor Marsh, Doering *et al*. (1995) implemented water quality surveys in the early 1990s. They addressed N and P loading from freshwater and ocean sources; atmospheric deposition was assumed to be incorporated into the freshwater component. Ocean and freshwater sources contributed approximately equal loads of inorganic N, whereas most of the inorganic P loading came from the ocean. Of the freshwater inputs, Marshall Brook provided the most dissolved inorganic N (Figure 54, upper panel). This stream drains the closed Worcester landfill and has been the subject of extensive water quality investigations (see review in Haines and Webber 1999).

In general, nutrient concentrations of streams draining into Bass Harbor Marsh were similar to those observed in tributaries to Somes Sound. According to Doering *et al*. (1995), a future decrease in nutrient loading from Marshall Brook to levels characteristic of more pristine streams would likely lead to an upstream shift in the boundary between N-limited and P-limited primary production.

Kinney and Roman (1998) compared Bass Harbor Marsh to other shallow estuaries in the Northeast[8] (Figure 54, lower panel). Watersheds of these other estuaries are much more urbanized than the Bass Harbor Marsh watershed. While nitrogen loading rates and macroalgal biomass in Bass Harbor Marsh were lower than at the two most highly eutrophic sites (CR and MC1), Bass Harbor Marsh displayed productivity patterns similar to other sites in the Northeast, all of which are in urbanized watersheds and are considered relatively degraded. Kinney and Roman (1998) considered biomass of widgeon grass (*Ruppia maritima*) in Bass Harbor Marsh to be similar to other estuaries except for those with high nutrient loading rates.

Characteristics of the macrofaunal benthic community of Bass Harbor Marsh provide uncertain evidence of enrichment – generally this community was considered healthy in the early 1990s (Doering *et al*. 1995).

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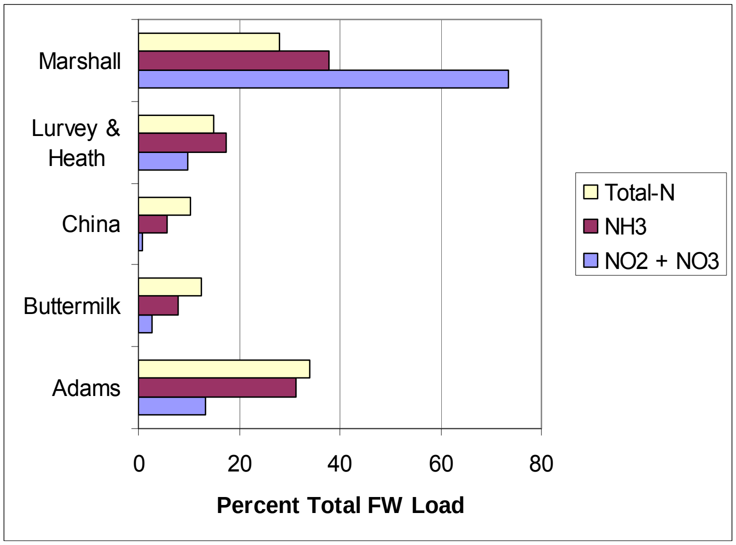
[8] Three estuaries (CR, QR and SLP) are all parts of the Waquoit Bay on Cape Cod. Three other three sites (GH, NP and PJ) are also in Rhode Island. Sites MC1 and MC represent Mumford Cove, CT, before and after sewage diversion, respectively.



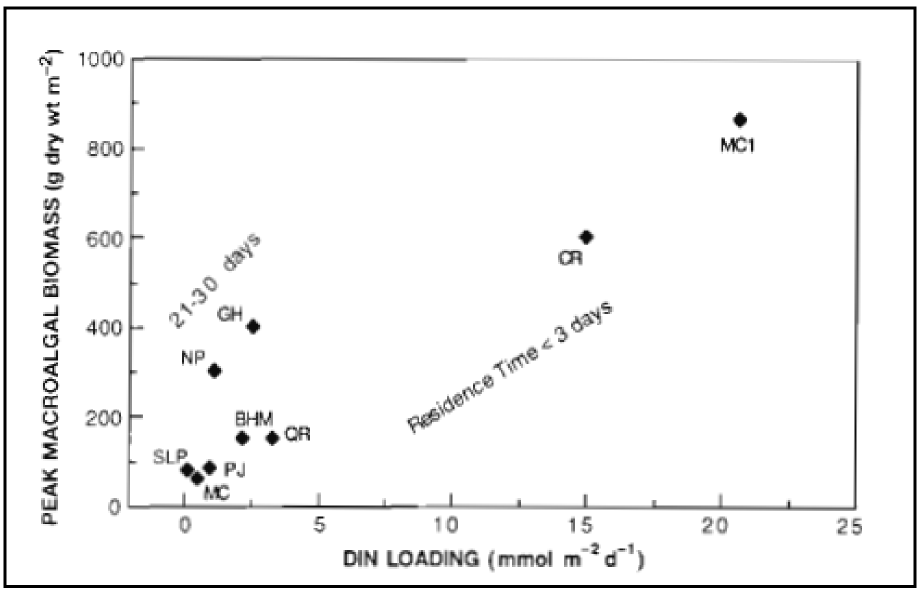


Figure 54. Nutrient loading and algal biomass in Bass Harbor Marsh.
Upper panel summarizes nitrogen loading from five freshwater inflows. Data show the contribution of each sub-watershed to total loads of nitrogen 'species' to the Bass Harbor Marsh. For each nitrogen form, loads total 100% across all tributaries.
Lower panel shows the relationship between peak green macroalgal biomass and dissolved inorganic nitrogen loading to Bass Harbor marsh (BHM) and eight other shallow estuarine sites in the Northeast. See text for more information.
(Figure from Kinney and Roman 1998, used with permission)
(Data from Doering *et al*. 1995)

Culbertson *et al*. (2007) used aerial thermal imaging of shallow groundwater discharge and water samples from seeps and wells to characterize nutrient enrichment of Bass Harbor Marsh (and Northeast Creek – see below) from groundwater sources. Concentrations of dissolved nitrogen in shallow groundwater were elevated relative to those of the adjacent estuary and surface water tributaries, indicating that the hyporheic zone (the region beneath and lateral to a stream bed) represented a nitrogen source to the estuary. Initial loading estimates suggested that shallow groundwater could be contributing a substantial percentage to the total N load of this system.

Although elevated N levels in shallow groundwater indicated that there may be contamination from septic systems, household wastewater-related compounds were generally at or below detection in bedrock wells. This observation suggested that septic sources were not contaminating the local aquifer.

Northeast Creek: Extensive research on the Northeast Creek (NEC) estuary and associated wetlands has investigated how increasing residential development in this watershed may affect nutrient loads. Since housing in this region of MDI is served by septic systems, there is concern that increasing development may contribute to accelerated eutrophication of the estuary. The population of the NEC drainage basin increased by almost 50% between 1981 and 1996 (Nielsen 2002a).

Nielsen (2002a) investigated the influence of nitrogen loads from septic system discharge on groundwater quality. Nielsen (2002b) developed a water and nutrient budget for the basin. Nielsen and Kahl (2007) studied nutrient export from 13 small watersheds on MDI, including NEC (see also Nielsen *et al*. 2002). Caron (2005) investigated groundwater contributions of water and nutrients in one sub-watershed of NEC – Aunt Betsey's Brook. A GIS-based decision support system (NLERT) was developed by the USGS for evaluating the effect of land-use changes on nutrient loading to NEC, and the responses of estuarine autotrophic communities to various levels of enrichment (Rohweder *et al*. 2004). This study used mesocosms to investigate the influence of nitrogen loading on vascular plants, phytoplankton, epiphytes and macroinvertebrates (e.g. Keats 2002). Recently, K. Anderson (ACAD Office of GIS, pers. comm. September 2007) used the NLERT model to estimate the impact of increasing residential development on the ecological condition of the NEC estuary. As noted above, Culbertson *et al*. (2007) included Northeast Creek in their study of nutrient enrichment from discharge of shallow groundwater on MDI. Twenty seven groundwater seeps were identified in NEC.

Key findings from these studies are summarized below. For discussion of water use and groundwater recharge issues, see section on *Threats: Altered Hydrology*.

Groundwater Nitrogen Concentrations

(i) Estimated groundwater NO_3-N concentrations were sensitive to the rate of recharge. In populated NEC sub-watersheds, estimated concentrations ranged from 0.3 mg/L (Stony Brook watershed, high recharge rate) to 11 mg/L (Liscomb Brook watershed, low recharge rate). Figure 55 shows nitrogen data and dilution factors for the medium recharge scenario. (Nielsen 2002a, b)

(ii) With the exception of the Liscomb Brook estimate, estimated NO_3-N groundwater concentrations in the NEC basin are below the human health limit of 10 mg/L (USEPA 2001). (Nielsen 2002b)

(iii) Dissolved N concentrations in hyporheic zone wells adjacent to NEC were elevated relative to NEC tributaries, suggesting that contamination from septic sources may be influencing the quality of shallow groundwater. (Culbertson *et al*. 2007)

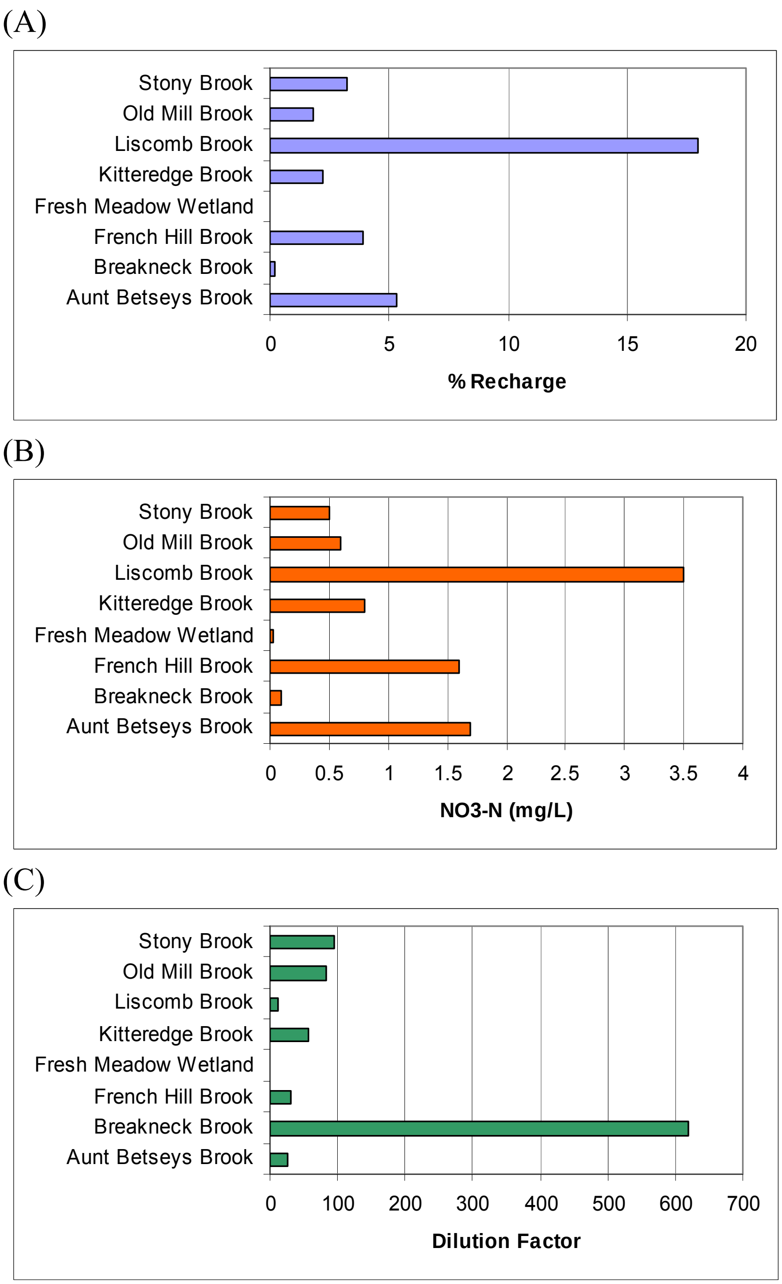


Figure 55. Groundwater use and nitrate concentrations in selected sub-watersheds of the Northeast Creek system. (A) Groundwater use as a percentage of recharge. (B) Estimated nitrate-nitrogen concentration in the bedrock aquifer. (C) Dilution factor. All data are for medium groundwater recharge rate of 9 in/yr. (Data source: Nielsen 2002b)

Nutrient Loading

(iv) Overall, nitrogen yields to NEC were lower than yields to eutrophic estuaries elsewhere on the East Coast. Most of the other estuaries are, however, in more urbanized settings. (Nielsen 2002b)

(v) The Stony Brook sub-watershed contributed 59% and 46% of the system's total non-marine load of nitrate (NO_3) and total N, respectively. This watershed has a higher population than any of the other NEC sub-watersheds. Slightly less than half of this watershed lies within the ACAD boundary. Even though its population has been relatively stable over the past 20 years, many of its houses are likely served by older septic systems. (Nielsen 2002b)

(vi) Recent population growth in the NEC basin has been greatest in the Old Mill Brook (about one third of the watershed is within ACAD) and French Hill Brook (entirely outside ACAD) sub-watersheds. Together, these contributed 23% of total NO_3 loading to the NEC system. (Nielsen 2002b)

(vii) Direct atmospheric inputs (i.e. to the creek surface) represented only 1% of the total N load and <10% of the inorganic N load. (Nielsen 2002b)

(viii) Nitrogen flux to Aunt Betsey's Brook from groundwater was insignificant relative to contributions from surface water loads. (Nielsen 2002b)

(ix) However, initial loading estimates from the work of Culbertson et al. (2007) suggest that shallow groundwater seeps could represent a substantial proportion of the total dissolved N load to the NEC system. Because groundwater seeps are likely to be less influenced by short-term drought that stream flow, the shallow groundwater load may be especially important during periods of low stream flow.

(x) Nitrogen loading from tidal inflow may be significant if the NEC system behaves similarly to the Bass Harbor Marsh (Doering *et al*. 1995).

(xi) In 13 watersheds across MDI (including the studied watersheds in the NEC basin), drainages entirely within ACAD exported significantly less total N and total P than did watersheds partially or completely outside the park. (Nielsen and Kahl 2007)

Ecosystem Response

(xii) Using results from mesocosm experiments, three classes of estuarine condition were defined (Rohweder *et al*. 2004). Average watershed loadings of dissolved inorganic nitrogen associated with each class are:

"Healthy": < 2.2 kg/ha/yr;
"Degrading": 2.2 – 4.4 kg/ha/yr;
"Degraded": > 4.4 kg/ha/yr.

(xiii) Based on 2001 land-use patterns, the estimated NEC nitrogen loading was 1.86 kg/ha/yr. This places the system in the "healthy estuary" class. Using 2004 data for building footprints and building permit records, the estimated loading would increase to 2.1 kg/ha/yr., still within the healthy class but approaching the modeled threshold to degrading. Land-use projections based on the draft Bar Harbor comprehensive plan suggest that the loading would further increase to 2.72 kg/ha/yr (K. Anderson, NPS, pers. comm. September 2007). This scenario would place the estuary within the "degrading" class.

Somes Sound: Nutrient loading to Somes Sound was investigated by Doering and Roman (1994). Six streams provide 86% of the freshwater inflow to the Sound. The Somesville water pollution control facility contributed < 0.1% of the freshwater input, but 37% of total dissolved inorganic N loading and 51% of the phosphate loading. Nutrient concentrations entering the Sound via freshwater sources were considered low compared to other estuaries – inorganic N and P loadings were two orders of magnitude lower than in other systems. Because of the importance of marine-derived nutrient loading, a 20% increase in nutrient loading from freshwater sources would have negligible impact on nutrient concentrations in Somes Sound. Overall, Somes Sound is relatively pristine, with low nutrient and chlorophyll levels. The water column is always oxygen saturated (Doering and Roman 1994).

Nutrient Enrichment: Other Coastal and Marine Areas

Eutrophication Assessments: The expression of eutrophic conditions within the ACAD region can be best evaluated using the NOAA National Estuarine Eutrophication Assessment (NEEA). Condition reports have been released three times over the past decade (NOAA 1997, Bricker *et al*. 1999, and Bricker *et al*. 2007). Methods have evolved with subsequent assessments, but are based in principle upon evaluating influencing factors (nutrient load, flushing, susceptibility), and the level at which eutrophic conditions and symptoms are expressed. Blue Hill Bay is among the 10 NEEA estuaries within the Gulf of Maine, and it has consistently expressed low-level eutrophic conditions. Assessments for 1999 and 2004 both predicted small deteriorations in condition within Blue Hill Bay due to anticipated changes in nutrient loading. However, the trend between these two assessments was actually a slight improvement in chlorophyll-*a* levels (Bricker *et al*. 2007).

Aquaculture: There are at least 20 permitted aquaculture lease sites around MDI covering 169.2 ha, but none within 2 km of ACAD lands (Figure 56). Most of the leased resource (148.3 ha) is permitted for shellfish aquaculture and presents no particular threat to exacerbating nutrient stresses on these waters since no fertilizer or feed is used. Three lease sites have been permitted for finfish aquaculture – all in the vicinity of Swans Island. Of these, two sites (13.3 ha) are currently leased into 2009, and the remaining (7.6 ha) is leased until 2014. Due to the necessary application of feed and medication, finfish aquaculture may adversely affect benthic habitat and water quality, and promote eutrophication (Jones and Wells 2002). Past interest in expanding finfish aquaculture into Blue Hill Bay has been unsuccessful, but prompted investigations into computer simulation modeling of dispersal of aquaculture wastes (e.g. Dudley *et al*. 2000). Pesticides used in finfish culture are a potential contaminant source (see below).

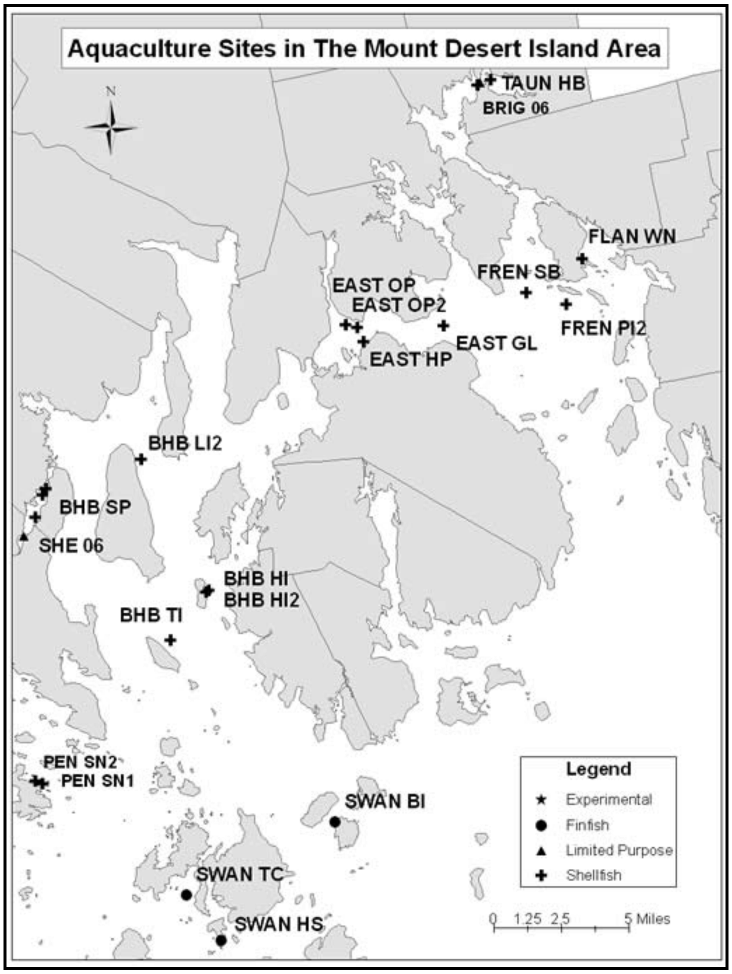


Figure 56. Aquaculture sites in the MDI area. Additional sites are pending permitting.
(Data from ME Division of Marine Resources)

Algal Blooms: Harmful and nuisance algal blooms are an important issue in the Gulf of Maine (Jones and Wells 2002). Blooms occur both near-shore and off-shore, and are often related to nutrient levels.

Blooms of the toxic dinoflagellate, *Alexandrium fundyense*, are common in the Gulf of Maine during summer months (Figure 57; Townsend *et al*. 2005). Blooms may be associated with relative concentrations of inorganic nitrogen and silicate, which are in turn influenced by oceanographic processes. The blooms can result in paralytic shellfish poisoning when infected shellfish are consumed by humans. Aside from this, however, it appears unlikely that these marine phytoplankton blooms have a direct effect on ACAD natural resources.

Sewage: Discharge of treated and untreated sewage is a recognized concern in the Gulf of Maine (Jones and Wells 2002). Along with municipal discharge of treated wastes, numerous direct overboard discharges of household sewage are still grandfathered by the state. While once common practice, the overboard discharge of untreated raw sewage from boats into the ocean is

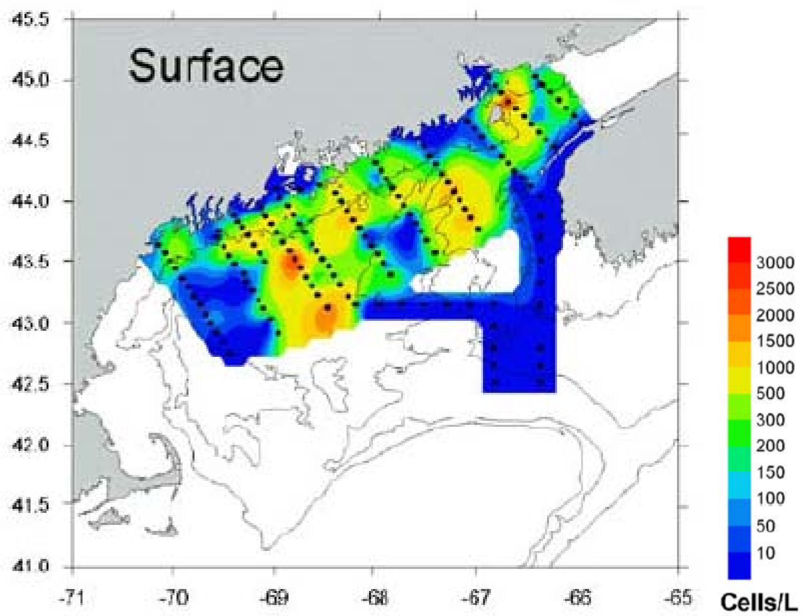


Figure 57. Cell densities of the toxic dinoflagellate *Alexandrium fundyense* in surface waters of the Gulf of Maine in June 2000. MDI is shown in mid-coast area.
(Figure from Townsend *et al*. 2005, used with permission)

no longer permissible within 3 miles of shore. However, vessel operators may still pump out sewage that has been treated to reduce bacteria and remove visible floating solids. In addition to its contribution to nutrient pollution, bacterial contamination from untreated or inadequately treated wastes poses significant health risks and can result in beach and shellfish closures around MDI (see below).

Microbial Contamination

Key Issues	***Extent of Problem***	***Information Base***
Bacteria contamination of beaches	PP	Good
Shellfish closures	EP	Good

Microbial contamination is primarily a human health issue and is not known to directly affect non-human biota at ACAD.

Bacterial contamination of beaches

Bacterial monitoring is carried out at Echo Lake, Lake Wood and Sand Beach by ACAD staff because of human health concerns. The Maine Healthy Beaches Program monitors other beach sites on MDI but outside the Park. Data from these surveys are shown in Figure 58. While most samples are within Maine standards, some bacterial counts exceed these criteria.

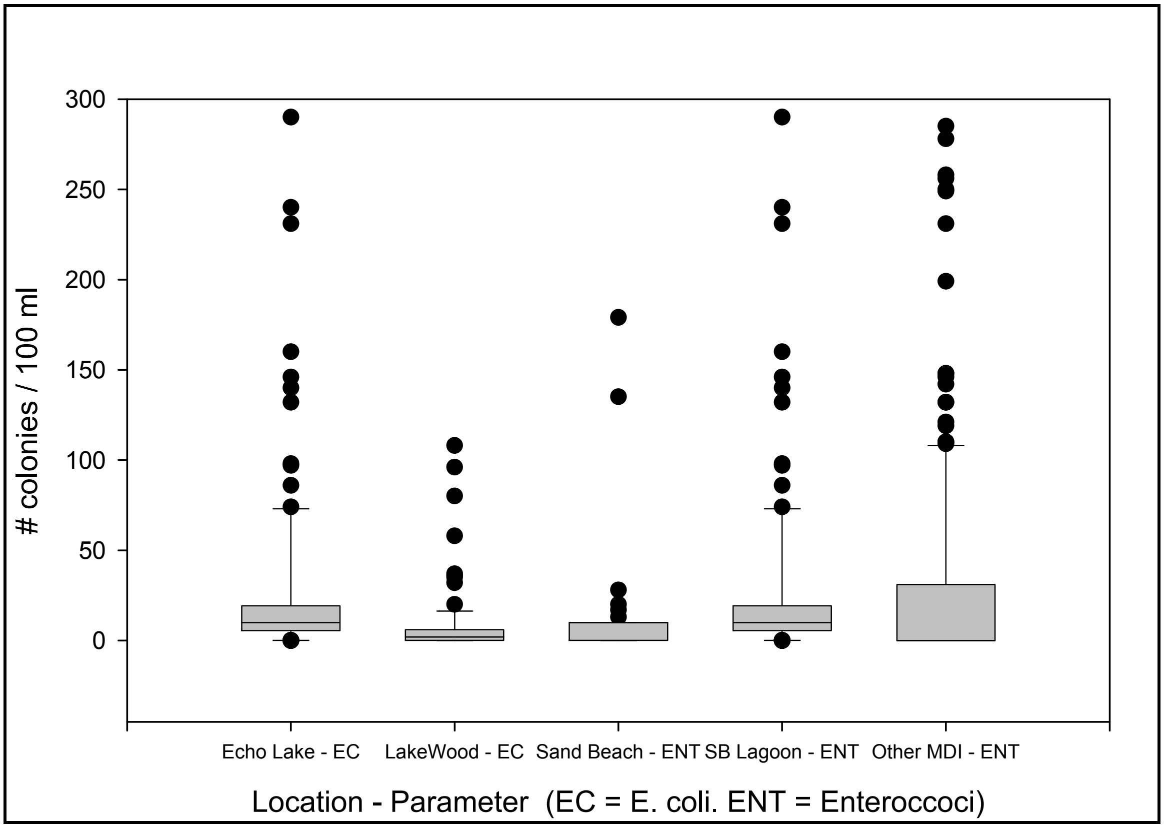
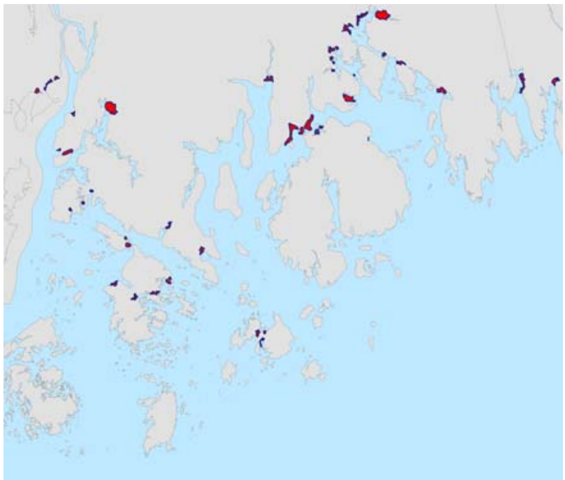


Figure 58. Bacteria concentrations at four ACAD beach sites: Echo Lake, Lake Wood, Sand Beach and Sand Beach lagoon. Also included are data from other MDI beach and stream (Stanley Brook) sites outside of, or bordering, ACAD.
ACAD data are from 1993-2006. Number of sampling dates vary with location. Data for other MDI sites are from 2004-2006.
Boxes indicate 25th and 75th percentiles, with median line; whiskers are 10th and 90th percentiles; dots are outliers.
Maine standards are: E. coli = 29 (geometric mean), 194 (single sample); Enteroccoci = 8 (geometric mean), 54 (single sample).

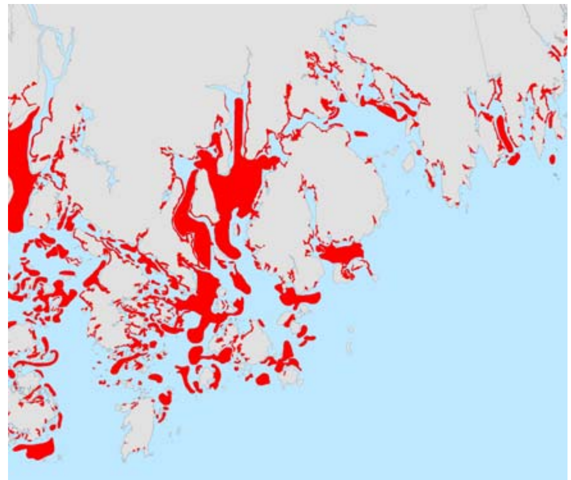
(Note that one unusually high value from Sand Beach Lagoon has been omitted from this plot.)

Shellfish closures

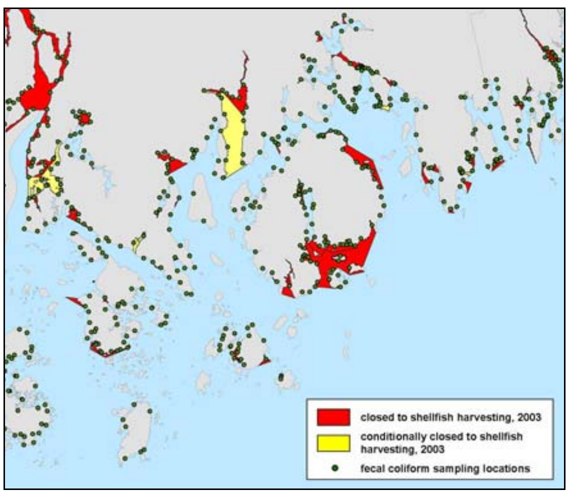
The Maine Shellfish Growing Area Classification Program follows National Shellfish Sanitation Program standards to judge the cleanliness of all the marine waters of the State of Maine (Figure 59). This is accomplished by monitoring water along marine shores in the vicinity of shellfish beds six times per year for bacterial contamination (green points in Figure 59C are current and historic shellfish monitoring stations) and by conducting shoreline surveys to determine the location and magnitude of potential sewage pollution problems. Updated legal notices for the Maine Shellfish Closed Area Inventory are available from Maine Division of Marine Resources (http://www.maine.gov/dmr/rm/public_health/closures/closedarea.htm).



(A)



(B)



(C)

Figure 59. Worm and shellfish habitat and shellfish closures in the ACAD region.

(A) Marine worm and (B) shellfish habitat in the 1970s.
Maps were produced from GIS data from Maine Office of GIS (http://megisims.state.me.us/metadata/worm.htm) and are based on original maps in Fefer and Schettig (1980).

(C) Areas closed (red) and conditionally closed (yellow) to shellfish harvesting as of July 2003. Note that this inventory does not include shellfish areas closed due to the presence of biotoxins (red tide).
The Maine Shellfish Growing Area Classification Program follows National Shellfish Sanitation Program standards to judge the cleanliness of all the marine waters of the State of Maine. This is accomplished by monitoring water along marine shores six times per year for bacterial contamination (green points) and by conducting shoreline surveys to determine the location and magnitude of potential sewage pollution problems. Vector digital data for closed areas (Maine Office of GIS *CLASS03E* dataset) are based upon descriptions from rules promulgated by the Maine Department of Marine Resources (DMR) current at the time of data publication. Updated legal notices for the Maine Shellfish Closed Area Inventory are available from Maine DMR (http://www.maine.gov/dmr/rm/public_health/closures/closedarea.htm). Point locations of water quality sampling stations were compiled from paper maps by the Maine DMR (Maine Office of GIS *NEWWQ* dataset).

Other Contaminants

Key Issues	***Extent of Problem***	***Information Base***
PCBs	EP	Poor
Sewage	PP	Poor
Schoodic naval base legacy	PP	Fair
Parking lot runoff	PP	Inferential
Boat traffic and oil spills	PP	Inferential
Aquaculture pesticides	PP	Poor
Landfills	EP	Fair
Road salt/sand	PP	Poor
Underground storage tanks	OK ?	Poor
Metals in stream water	PP ?	Good
Arsenic and radon in groundwater	PP	Poor
Metals in marine sediments	OK	Good
Fire retardants	PP?	Inferential
Trace metals and organics in mussels	PP (dep. on contaminant)	Good

Haines and Webber (1999) provide a detailed assessment of contaminant threats at ACAD. Their assessment concludes that the majority of the Park's pollutant load arrives via atmospheric transport. In this section we provide a brief overview of key findings from the Haines and Webber assessment as they relate to contaminants potentially affecting the ACAD region. For more information, and for source references, see Haines and Webber (1999). The overview is structured around the four transport mechanisms (pathways) described by the authors: air, surface fresh water, surface salt water, and ground water.

Following a review of the Haines and Webber (1999) assessment, we summarize additional information on freshwater, ground water, and marine contaminants.

Air Pathway

Four primary contaminants of concern were identified: ozone, acid rain, Hg and organochlorines. The first three have been discussed above under *Threats: Atmospheric Deposition* and *Mercury*. Organochlorine compounds are deposited in areas remote to their origin. Within 200 km of the Park, there are 130 facilities reporting emissions of air toxics. A 1993-94 survey of contaminants in fish throughout Maine did not record "appreciable" quantities of PCBs or pesticides in fish collected from ACAD lakes. In contrast, PCBs and DDE have been recorded in nesting bald eagles within and near the Park at concentrations high enough to cause damage to raptors. These contaminants probably were derived from marine organisms. The entire Park is at risk from organochlorines. Sensitive species are those with high percentages of fish in their diets and naturally low reproductive rates. Examples include loons and kingfishers. There is inadequate information on the extent of, and impacts from, contamination by organochlorine compounds at ACAD.

Freshwater Pathway

Pollutant sources of highest concern include: (i) RCRA hazardous waste generators (13 listed for MDI); (ii) CERCLA sites of gross environmental damage (none on MDI, but 19 in the Maine Coastal watershed); (iii) TRI (toxics release inventory) sites (none on MDI, SCH or IAH); (iv) pollution control facilities (3 on MDI; Bar Harbor and Mount Desert, each with three discharge points, and Southwest Harbor with one discharge point); (v) mining sites (1 listed for MDI, but likely inactive); (vi) local pesticide use (no aerial spraying occurs on MDI, SCH or IAH, but ground-based spraying occurs along power line routes); (vii) uncontrolled spills (six sites within five km of the Park); (viii) parking lots.

The two highest risk sources were considered to be the Mount Desert sewage outfall at Otter Creek and the former Naval Security Group at SCH. The Otter Creek sewage outfall has recently been closed – sewage is now pumped to Seal Harbor where it is treated at an upgraded facility. A key concern at SCH was contamination caused by capacitors that had been stored there for many years and some of which had ruptured. Both sources are probably today of much lower risk because of remediation actions that have been implemented over the past several years.

Parking lot runoff may be a source of non-point source pollution. Primary parking lots in the Park are at Echo Lake, Eagle Lake, Sand Beach, the Visitor Center and Jordan Pond. At Jordan Pond (one of the clearest lakes in the State of Maine), runoff from the boat ramp at Jordan Pond is a concern (D. Manski, NPS, pers. comm.).

Saltwater Pathway

Pollutant sources with greatest potential to damage Park resources are (i) oil spills (2 reported from MDI in the five years prior to the assessment of Haines and Webber [1999]); (ii) boat traffic (tour boats, smaller pleasure craft and fishing boats); (iii) merchant transport; (iv) bulk oil and hazardous material storage facilities (four on MDI, all of which are hazardous material storage, plus a more recently constructed bulk oil facility); (v) some aquaculture operations (Figure 56).

Fine-scale models of the circulation patterns in the Acadia region are limited to Blue Hill Bay (Dudley *et al*. 2000). Interest in information for this area was driven by concern over the possible expansion of finfish aquaculture in this area, as noted above. For the rest of the Acadia region, circulation models are based on coarser spatial and temporal domains (e.g. Xue *et al*. 2000). On average, one major oil spill (greater thatn 100,000 gallons) occurs in Maine each decade. Circulation models are an important component of the responses to manage oil spills. The State of Maine uses the Marine Oil Spill Information System (MOSIS) which is based on output from the General NOAA Ocean Modeling Environment (GNOME). Maine has also developed a detailed Marine Environmental Vulnerability Index (EVI) for the entire state to give first responders a tool for prioritizing and targeting protection strategies. Nonetheless, there is still great uncertainty as to how a major oil spill in the Penobscot Bay or neighboring waters might affect ACAD resources. The concern for potential future impacts is particularly strong around Isle au Haut, an area with regular tanker traffic. An additional concern is possible collisions and/or fuel spills from the large number of cruise ships that visit Frenchman Bay each year.

A study of ocean currents in the immediate ACAD area was carried out by Muhlin (2007) who focused on the influence of near-shore circulation patterns around Schoodic Point on gene flow in the brown alga *Fucus vesiculosus*. Using surface drifters, the study highlighted the dynamic association between near-shore coastal oceanography and population genetics.

Groundwater Pathway

Pollutant sources of highest concern are (i) landfills (see below); (ii) road salt and sand (only the Southwest Harbor pile is upstream of Park resources); (iii) underground storage tanks (approximately 80 on MDI and 19 at SCH) – all tanks are fitted with leak and corrosion detectors and are thus of low concern to the Park; (iv) shallow-well injection sites (16 wells listed for MDI; mainly waste pipes to streams, storm drains and soil from businesses such as garages and cleaners) – all are considered to be of low contaminant risk to Park resources on account of their location downgradient or distant from the Park.

There are four municipal landfills within five km of the Park. All are closed, but the Winter Harbor landfill is of high concern because of the presence of PCBs and hydrocarbons in surface and groundwater samples taken around the landfill. The Worcester landfill in Southwest Harbor is a private operation that operated from the 1930s to the early 1990s. Leachate from the landfill has affected water quality in Marshall Brook. This brook formerly supported large runs of sea-run brook trout. It is currently a high priority system for stream crossing restoration (see *Threats: Habitat Loss / Impairment*). There has been an extensive series of studies relating to Marshall Brook – see full list in Haines and Webber (1999).

Additional Contaminant Data

Surface Freshwaters: Peckenham *et al*. (2006) sampled streams and springs on MDI to investigate the impact of vehicular traffic on water quality. Samples were analyzed for volatile organic compounds (VOCs), polynuclear aromatic hydrocarbons (PAHs) and trace metals. VOCs and PAHs were below detection at all sites. Trace metals were detected in all samples (Figure 60), with the five most concentrated elements being aluminum, zinc, copper, molybdenum and arsenic.

Concentrations were below acceptable ecological limits but above amounts expected from local geology. Arsenic and molybdenum concentrations were statistically associated with traffic counts. However, enhanced metal levels also occurred distant from roads. This suggests that atmospheric transport of vehicle-derived contaminants is an important factor influencing their distribution in ACAD surface waters. Surprisingly, springs had elevated metal concentrations. Molybdenum was consistently high in Sieur de Monts Spring, while the higher elevation Birch Spring had relatively high total metal concentrations.

Lead contamination in loons and other freshwater taxa is a concern as a result of ingestion of lead sinkers (D. Lamon, Somes-Meynell Wildlife Sanctuary, pers. comm.). Although some loon tissues and unhatched eggs have been analyzed for lead and other toxins, data from these studies are not currently available.

Groundwaters: Analyses of water quality in domestic and bedrock monitoring wells in the Northeast Creek and Bass Harbor Marsh areas showed that, except for phenol, all household wastewater-related compounds were below detection at all sites (Culbertson *et al*. 2007). Phenol was detected in one well (domestic) in the Northeast Creek watershed and two wells (both bedrock monitoring wells) in the Bass Harbor watershed.

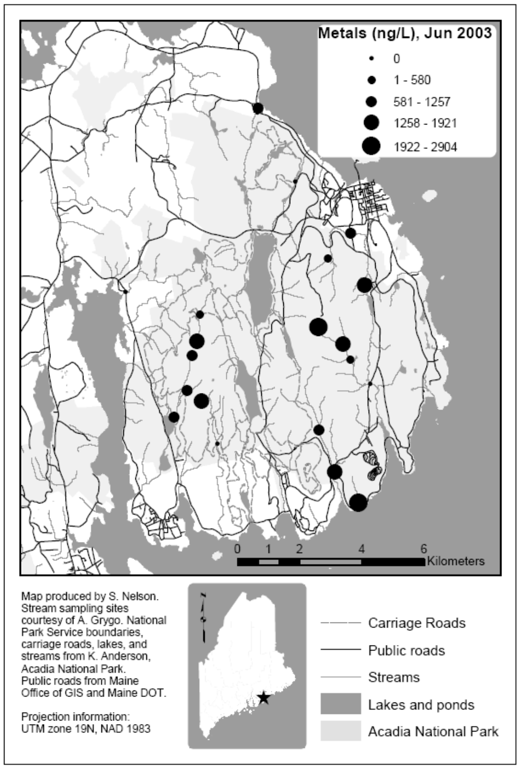


Figure 60. Total trace metal concentrations in streams and springs on MDI, June 2003. (From Peckenham *et al*. 2006)

Naturally occurring contaminants in well water supplies include arsenic and radon. Arsenic concentrations appear to be low on MDI – out of 117 well-water samples analyzed, 92 had <1µg/L arsenic while three had >30 µg/L (K. Bell, University of Maine, pers. comm.). Culbertson *et al*. (2007) detected arsenic in two domestic wells and two bedrock montoring wells in the Northeast Creek watershed. Concentrations in domestic wells were <5 µg/L, while those of bedrock wells were between 6.3 and 11.1 µg/L (the EPA maximum concentration in drinking water for arsenic is 10 µg/L.).

Data presented by Kahl *et al*. (2000) suggest that radon levels in some wells on MDI may be a health hazard to humans.

Marine Waters: Contaminant monitoring of coastal marine sediments indicates that contaminant concentrations in the MDI region are relatively low. Figure 51 displays data for Hg and arsenic.

The Gulfwatch program monitors spatial and temporal patterns of trace metal and organic contaminants in the Gulf of Maine using the blue mussel (*Mytilus edulis*). Most contaminant levels were lower in the Gulf of Maine than median concentrations from all National Status and Trends (NST) Mussel Watch data (Chase *et al*. 1997). However, Hg concentrations at > 80% Gulf of Maine sites exceeded the median NST value. There are two Gulfwatch sites on the southwest sector of the MDI coast (www.gulfofmaine.org).

Emerging issues: Recently, concern has been raised about previously un-studied contaminants. Two such examples are fire retardants and pharmaceuticals. There is no specific information regarding these groups – or other emerging contaminant groups – at ACAD, but they have been found to be fairly ubiquitous at some other sites and warrant further investigation.

Fire

Key Issues	***Extent of Problem***	***Information Base***
Impacts on terrestrial systems: vegetation composition, soil structure and chemistry, Hg, beaver populations	EP / PP / HP	Good

Impacts of Fire on Terrestrial Systems

Patterson *et al*. (1983) list 10 major fires in the ACAD region during the century from the mid 1800s. The largest of these burned approximately one third (6,875 ha) of MDI in 1947 (Figure 14). In addition, there have been many smaller fires, generally affecting areas < 5 ha. Between 1937 and 1974, for example, there were 136 documented smaller fires.

Forest stands at ACAD have been classified into five fire-response groups (Patterson *et al*. 1983):

- (i) Spruce and cedar stands, in which the natural fire cycle is tied to the maturation cycle of the dominant trees.
- (ii) Pine stands, composed of fire-adapted species for which fire enhances the establishment of seedlings.
- (iii) Birch-aspen stands – these often appear following fires which expose mineral soils.
- (iv) Red oak stands, which may benefit from moderate fires but are significantly affected by more intense fires.
- (v) Northern hardwood stands – these are less likely to burn than other forest types but, when ignited, are also more susceptible to forest damage.

ACAD soils have been classified into four groups according to their susceptibility to fire damage (Patterson *et al*. 1983). Classification is based on a series of properties (slope, drainage, permeability, depth, texture and erodibility) that characterize a soil's susceptibility to post-fire erosion and the rapidity with which revegetation would occur.

More recently Devine *et al*. (2006) developed fire fuel load maps of ACAD using data from the Acadia Vegetation Mapping Project (Lubinski *et al*. 2003) and field-collected fuel load data. Figure 61 depicts fire fuel loads for MDI and vicinity using a "complacent" fire fuels model (i.e. little vegetative seasonal drying or "curing"). Used with data on stand height, canopy cover, canopy bulk density, slope, aspect and elevation, these fire fuel load data will enable future simulations of fire growth behavior. This is particularly important given Park policy of not removing fuel.

Related topics: The 1947 fire affected extensive stands of softwood forests on eastern MDI and resulted in the regeneration of birch-aspen stands (Patterson *et al*. 1983). In addition to vegetation composition, the 1947 fire influenced beaver, river otter and deer populations (Dubuc *et al*. 1988, 1990, 1991; Cunningham *et al*. 2006; D. Manski, NPS, pers. comm.) as well as soil structure and Hg dynamics (Johnson *et al*. 2003). These issues are covered in other sections of this report.

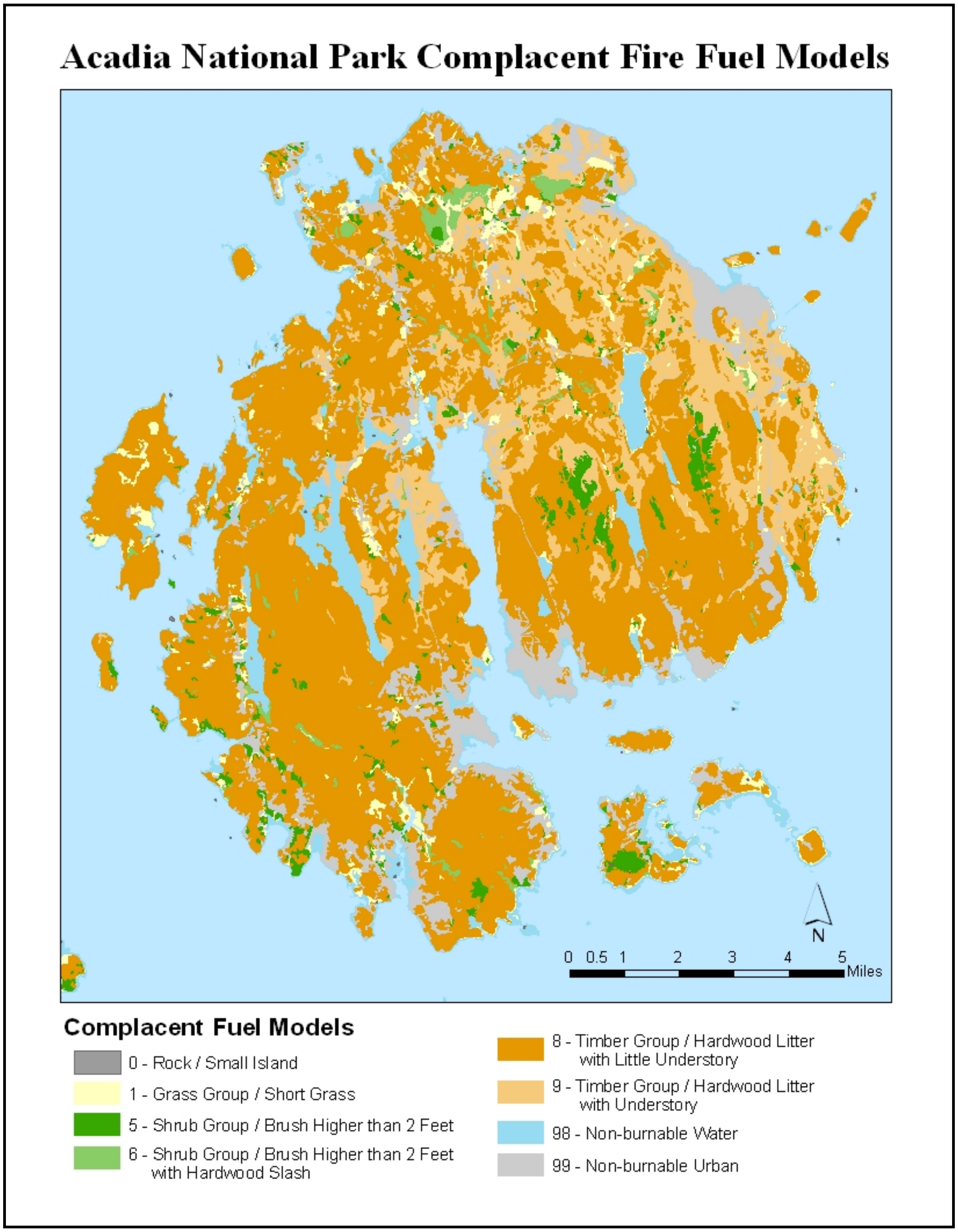


Figure 61. Fire model output for MDI region based on vegetation map data. (Image from Devine *et al*. 2006)

Altered Hydrology

Key Issues	*Extent of Problem*	*Information Base*
Lake water level fluctuations	OK	Good
- impacts on biota	UNK	Poor
Stream discharge	OK	Poor
Wetland hydrology	EP	Good
Groundwater levels	PP	Fair
- water availability & surface hydrology	PP	Poor

Lake Water Levels

Lake water levels are influenced by precipitation, evaporation and, in the case of four drinking water supply lakes, potable water demand. Use of water for fire control as well as human and beaver damming activity may also influence lake water levels (Seger *et al*. 2006). Stage data are available from eight lakes on MDI (Eagle, Bubble, Echo, Jordan, Seal Cove, Upper Hadlock, Witch Hole and the Tarn). The magnitude and pattern of lake drawdowns vary among years (Seger *et al*. 2006). Figure 62 shows stage data for MDI lakes in 2005, a year when there was relatively little rainfall during the summer months. Late spring-summer water level declines were greatest for Eagle and Echo Lakes (ca. 1.5 m) and least for Bubble and Upper Hadlock Ponds. Eagle Lake is a municipal water source, but Echo Lake is not. In years with greater summer precipitation (e.g. 2004, Seger *et al*. 2006), lake levels fluctuate less.

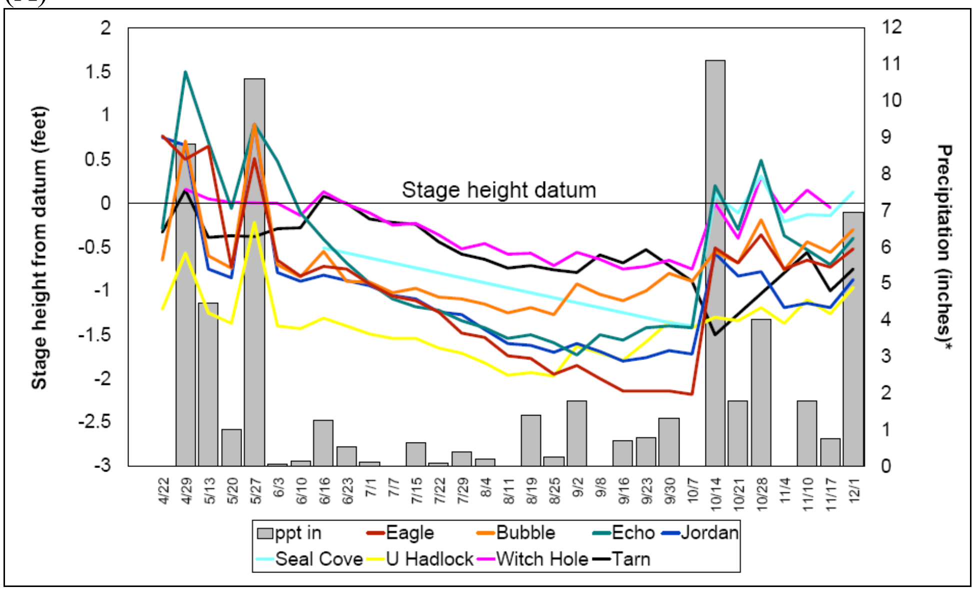
Water withdrawals for Eagle Lake in summer months are about double the winter level (Figure 62B), in part because of increased demand from the tourist population. The drought of 2001-2002 did not have substantial effects on either lake levels or water quality of Eagle Lake (Schmitt 2003).

There appears to be no information on the impacts of lake drawdown regimes on habitat quantity or quality for aquatic biota in ACAD lakes. Fluctuating water levels have been identified elsewhere as adversely impacting some bird species: black terns (*Chlidonis niger*), common loons (*Gavia immer*), pied-billed grebe (*Podilymbus podiceps*) – see Appendix 9 for more information. In some Maine lakes, human-influenced lower and/or fluctuating lake levels are known to negatively impact aquatic plant and fish populations (Vaux 2005). Instream flow below water control structures at lake outlets may be reduced when lake water levels fall below the outlet elevation (see below). Water level changes in lakes or wetlands, flooding, and frequent drying and wetting cycles increase the production of methylmercury (the toxic form of mercury) by increasing decomposition of organic matter and creating anoxic zones, both conducive to methylating bacteria (in the case of wetting) or oxidizing reduced sulfur (in the case of drying) which then leads to a spike in sulfur reduction when soils/sediments are subsequently re-wet (Munthe *et al.* 2007 and references therein).

Stream Discharge

The hydrological record for ACAD streams is insufficient to document any medium- to long-term trends in stream discharge. The longest-term records are for Cadillac and Hadlock Brooks, each with just seven years of data. There are also insufficient data to evaluate the effects of water control structures at lake outlets (Figure 9) on the hydrology of outflowing streams. Flows in the outlet stream from Long Pond may be too low to permit effective passage of anadromous fish – and may be lower than permitted flows (D. Lamon, Somes-Meynell Wildlife Sanctuary, pers. comm. August 2007). The effects of stream barriers on habitat quality and connectivity are discussed below under *Threats: Habitat Loss / Impairment.*

(A)



(B)

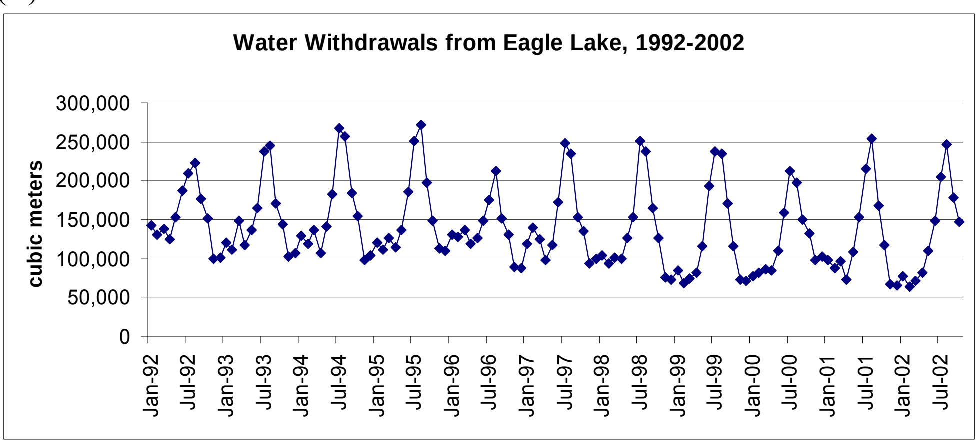


Figure 62. Lake levels and water withdrawals.

(A) Stage data from eight MDI lakes, and precipitation, April – December 2005. Precipitation bars represent cumulative rainfall for the periods since the previous date represented. Precipitation data are from the McFarland Hill NADP site.
(Figure from Seger *et al.* 2006)

(B) Water withdrawals from Eagle Lake, Bar Harbor (graph provided by C. Schmitt, University of Maine)

Wetland Hydrology

As a result of road-building, filling, ditching and dredging, humans have been altering the hydrologic regimes MDI wetlands for over 250 years (Neckles *et al.* 2007). Bridges, causeways, dikes and other structures that cross wetlands restrict or impede the natural hydrologic regime at a number of locations in the Park (Kahl *et al*. 2000). Of particular concern are the following areas:

- At Schoodic, just before Big Moose Island, the park loop road appears to be constricting the connection between the ocean and a small estuary. As a result of reduced tidal flows, upland vegetation has been encroaching into the former wetland (Kahl *et al*. 2000).
- Remnants of an old rock dam at the mouth of Northeast Creek restrict tidal flow into and out of the estuary, especially during neap tides when there is little or no seawater input (Caldwell and Culbertson 2007). Bridge abutments at the Route 3 road crossing also constrict the outlet of Northeast Creek.
- The outlet of Bass Harbor marsh is constricted by the Route 102 road crossings (Doering *et al*. 1995).
- In Great Meadow, historic roads, berms and ditches restrict sheet flow into this wetland, causing changes in the vegetation community (D. Manski, NPS, pers. comm.).

Jordaan (2006) noted that the presence of culverts affected all the estuarine sites surveyed for fish assemblages. Culvert location relative to mean tide is different for each site; this, combined with local topography, means that the structures have different influences on hydrologic dynamics.

Groundwater Levels

Increasing residential development in the Northeast Creek basin (northeastern part of MDI) has led to concerns about impacts on ground water quantity and quality. Nielsen (2002a) evaluated water use and groundwater recharge rates in the Northeast Creek basin and two adjacent watersheds. Approximately 20% of this area is within the ACAD boundary. Nielsen concluded that:

> (i) Groundwater use in the study area during 2001 was less than water recharge to the study area. For example, using a medium recharge rate, water use represented 2.5% of the estimated recharge volume. Water use was 18% of the recharge rate in one small sub-watershed (Liscomb Brook); in all others it was <7% (Figure 55A).
>
> (ii) Small changes in housing density would not substantially affect groundwater use relative to recharge.

Nevertheless, members of the public on MDI continue to be concerned that residential development in the Northeast Creek watershed may adversely affect water supply from drilled wells (J. Disney, MDI Water Quality Coalition, pers. comm. July 2007).
Ground water quality is discussed under *Threats: Nutrient Enrichment*.

Impacts of Hydrologic Changes on Rare Plant Species

According to Greene *et al*. (2002), changes in hydrology are a potential stressor for 6 rare plant species (out of 20 species considered) (Table 7). These changes, although not detailed by Greene et al. (2002), probably refer to water level alterations in wetlands and lakes. To our knowledge, there is no information that quantitatively documents the impact of hydrologic changes on individual plant species at ACAD.

Habitat Loss and Impairment

(Notes: Changes in hydrology – see above – are closely related to habitat loss and impairment. Visitor use impacts on habitat quality are discussed in the following section.)

Key Issues	*Extent of Problem*	*Information Base*
Stream barriers	EP	Fair
Beaver impacts on wetlands	OK	Good
Terrestrial habitat loss and fragmentation – impacts on biota	PP	Poor
Shellfish harvest and boat mooring impacts on eelgrass beds	PP	Poor / Inferential

Stream Barriers

Most larger lakes in the ACAD region have water control structures at their outlets (Figure 9). The height of these structures is between 6 and 14 feet, while the hydraulic height is generally 1-2 feet lower (data source: GIS database of Maine impoundments).

In addition to these lake outlet structures, there are also numerous culverts, bridges, weirs and dams across MDI streams. Many of these reduce or impair habitat connectivity. ACAD scientists have recently surveyed 131 stream crossings on 48 streams in the Park to characterize the extent to which these structures are barriers to the passage of fish (B. Connery, NPS, pers. comm. October 2007). Draft conclusions from this survey include the following breakdown of number of sites by quality of aquatic organism passage (AOP):

Bad (blocks AOP):	34%
Fair (partially blocks AOP):	56%
Good (does not block AOP):	9%

Reasons for obstructed passage include perched culverts and crossings blocked by debris. The survey also ranked streams for future restoration by considering, in addition to the extent of passage blockage, the amount of upstream habitat, land ownership and likely remediation costs.

These survey data are being used to prioritize sites for restoration. In addition to AOP quality, factors considered during the prioritization process include cost, amount of 'new' habitat that would be gained from restoration, length of stream in Park lands, existing and historical fisheries, number of abutting land owners, and other aspects of stream condition. Streams with high priority restoration sites include: Cromwell Brook, Heath Brook, Hunters Brook, Kebo Stream, Lurvey Brook, Marshall Brook and Stanley Brook.

An ongoing restoration project is designed to improve fish passage for alewives (*Alosa pseudoharengus*), American eel (*Anguilla rostrata*) and sea lamprey (*Petromyzon marinus*) between Somes Sound and Long Pond (D. Lamon, Somes-Meynell Wildlife Sanctuary, pers. comm. September 2007). Historically, >200,000 adult sea-run alewives followed streams leading from Somes Sound through a mill pond to Somes Pond, Ripple Pond and then on to Long Pond. In the 1970s, the estimated harvest of alewives was >80,000 fish. Because of deterioration of the fish ladder on the lower dam, only 360 fish were counted passing the dam in 2005 (note, however, that 2005 was a poor year for alewife runs elsewhere in Maine). Run sizes in 2006 and 2007 were >4,000 and >6,000 fish, respectively – still an order of magnitude lower than runs forty years ago. There are four water control structures and fishways between Somes Sound and Long Pond – two fishways were restored in 2006; work on other structures started in 2007. While none of these structures are on ACAD fee-owned lands, Long Pond is partially surrounded by ACAD (Figure 2). If the lake were made fully accessible to anadromous fish, it would provide almost 400 ha of freshwater habitat for these species. An additional key issue for fish passage in this system relates to dam management and ensuring minimum flows, particularly during fish immigration and emigration.

Water control structures at lake outlets may contribute to low-flow conditions in some streams. For example, a ca. 500 m section of Jordan Stream immediately downstream of the Jordan Pond dam was completely dry in the summer of 2007 when low lake water levels prevented flow to the stream (D. Manski, NPS, pers. comm.). There are no data on the natural flow regime of this and other streams prior to installation of water control structures.

Beaver Impacts on Wetlands

Following the re-introduction of beaver to MDI in 1921, a natural disturbance regime was restored to the island (Cunningham *et al*. 2006). Beaver create a "shifting mosaic" of wetlands resulting from patterns of colonization and abandonment. Beaver activity on MDI has been especially pronounced in areas burned by the 1947 fire, where subsequent early successional tree species produced a highly favorable environment for this species. The number of ponded wetland units on eastern MDI increased by 89% between 1944 and 1997 as a result of the increasing beaver population (Cunningham *et al*. 2006). This increase represented newly flooded wetlands as well as conversion of forested to open water and emergent wetlands. In recent years, forest succession in burned areas has reduced habitat quality for beaver. This has resulted in a corresponding reduction in actively maintained beaver dams, even though many of these wetlands persist (Figure 27, Cunningham *et al*. 2006).

Beaver-created wetlands provide valuable habitat for pond-breeding amphibians (Cunningham *et al*. 2006). Conversely, wetland creation may potentially reduce habitat quality for some fish species (e.g. brook trout) as a result of elevated water temperatures relative to free-flowing streams. While the positive impacts on amphibian populations have been documented at ACAD (Cunningham 2003), potential negative impacts on fish remain undocumented.

Terrestrial Habitat Loss and Fragmentation

A number of studies have examined faunal habitat characteristics, patch sizes and dispersal abilities on MDI. For example, Whitcomb (1993) found that spruce grouse (*Falcipennis canadensis*) occupied about one third of suitable habitat patches surveyed. However, marginal and unsuitable forest habitat between patches did not represent an inter-patch dispersal barrier for this species. Chilelli *et al*. (1994) used stochastic simulation modeling to study the effects of habitat quantity and quality (including connectivity) on population viability for three species: southern bog lemming (*Synaptomys cooperi*), fisher (*Martes pennanti*), and black bear (*Ursus americanus*). Interconnecting habitat fragments were found to be necessary for the maintenance of a viable metapopulation structure for southern bog lemmings. Demographic and environmental stochasticity were major influences on modeled population sizes of fisher on MDI. Simulated black bear populations on MDI were not large enough to maintain genetic vigor. Consequently, the island population of this species would have to be considered part of a viable mainland population.

Residential and other development is ongoing in many areas around ACAD and is presumably contributing to habitat fragmentation and habitat loss. Between 1976 and 2002, the amount of urban land in and, especially, around ACAD increased by 117%, from 11,601 acres (469 ha) to 25,160 acres (10,182 ha) (Table 3). Building and road densities in MDI watersheds are shown in Figure 5. The impacts of land cover change and habitat fragmentation on the flora and fauna of the region not been addressed quantitatively.

Habitat loss was identified as a stressor for a few rare plant species at ACAD by Greene *et al*. (2002) (Table 7). Potential stressors on other plant species have not been compiled in a similar way.

Habitat fragmentation and changes in land cover type (especially decline of early successional habitat) are potentially important stressors for many resident terrestrial bird species in and around ACAD (Appendices 8, 11). Supporting evidence comes from studies both in Maine and outside the state. However, this issue has been inadequately studied at ACAD. Consequently there is relatively little <u>direct</u> evidence of these factors operating in the Park.

Loss of open habitat as a result of vegetation succession and/or fire suppression is known to be a significant factor adversely impacting colonial water bird species (Folger 1986).

Impacts from Shellfish Harvesting and Boat Moorings on Eelgrass Beds

Commercial mussel harvesting can physically disrupt beds of eelgrass (*Zostera marina*) (e.g. Neckles *et al*. 2003). There has been concern that mussel dragging may be adversely affecting eelgrass beds in Frenchman Bay (J. Disney, MDI Water Quality Coalition, pers. comm. September 2007). However, there are no quantitative data to document any impacts around MDI.

Studies on eelgrass disturbance in southern Maine (Maquoit Bay; Neckles *et al*. 2003) indicated that grass beds severely damaged by mussel draggers would require an average of 11 years to recover. These results were based on data collected during a period of overall bed expansion in the study area; recovery trajectories were predicted to be as high as 22 years under less favorable conditions for re-growth.

Direct damage to seagrasses from dredge and fill operations (Thayer *et al*. 1984), boat propellers (Dawes *et al*. 1997), docks (Burdick and Short 1999), and anchors and mooring chains (Creed and Amado Filho 1999) have all been documented, but not for eelgrass in the MDI area, *per se*.

Visitor Use and Habitat Disturbance

Key Issues	Extent of Problem	Information Base
Impacts on terrestrial habitat	EP	Fair
Impacts on birds	EP	Fair
Impacts on freshwater systems	PP	Poor
Impacts on inter-tidal areas	PP	Fair

Visitor Impacts on Terrestrial Habitat

Visitors to ACAD participate in a range of recreational activities, many of which have impacts on natural resources, including vegetation, soils, water and wildlife[9]. High-use areas include: Cadillac Mountain summit, Jordan Pond House area, Sand Beach to Otter Point, parking areas associated with Eagle Lake, Acadia Mountain and Cadillac North Ridge, and the Ship Harbor – Bass Harbor lighthouse corridor (NPS 2003). Multiple challenges confront visitor use management at ACAD, including: uncontrolled access from state and town roads, many entry points, large visitor numbers, and uneven temporal and spatial distribution of use (NPS 2003).

In a 1998 survey, 72% of visitor groups indicated that they hiked on trails, while 40% and 30% walked or biked, respectively, on carriage roads (Littlejohn 1999). Intensity of use of ACAD's trail system is heterogeneous. Figure 8 summarizes August hiker census data for trails on MDI and Table 4 presents a compilation of selected visitor use statistics. This information has been discussed in the section on *Human Utilization of Park Resources*.

Trampling on trails and campsites results in direct and indirect natural resource impacts, including: loss of ground vegetation, altered vegetation composition including introduction of non-native species, altered microclimate, soil compaction, loss of organic litter, increased water runoff and reduced soil fauna (see Table 1 in Marion 2006). According to Greene *et al*. (2002), trampling by hikers is one of the primary stressors likely affecting rare (and other) plant species at ACAD (Table 7).

Hiking and camping effects on vegetation occur along both designated and social (visitor-created) trails. On Little Moose Island, soil erosion or compaction is common on 18% of undesignated trail length, with the trail surface being below ground level (Manning *et al*. 2006).

[9] Use impacts also include those on visitor perceptions and experiences which, in turn, are related to carrying capacity. These issues are being studied at ACAD under the Visitor Experience and Resource Protection (VERP) planning and decision making framework (Manning *et al*. 2006). Although this research is an essential component of broader Park management, it does not directly relate to condition of natural resources *per se*. Hence the present report does not cover research on visitor perceptions, carrying capacity, and associated issues.

A further 4% of trails exhibit signs of incipient erosion and compaction. On IAH, even relatively low trail use (compared to many locations on MDI) has produced trail incision of >4 inches in some areas (Figure 63). Between 0.2 and 4% of IAH trail lengths display excessive erosion or muddiness. Ongoing trail assessments are documenting impacts on the designated and social trails of MDI. Additional research on the Cadillac Mountain summit is focused on assessing visitor impacts to soils and vegetation and in developing protocols to allow the NPS to evaluate its visitor management actions (D. Manski, NPS, pers. comm. September 2008).

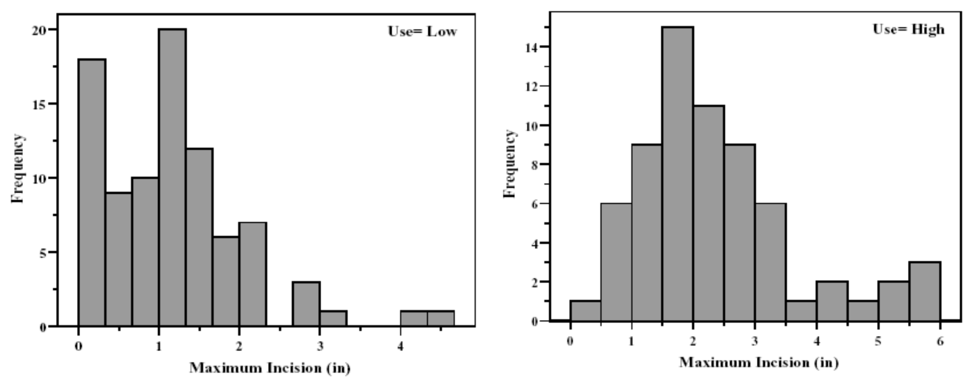


Figure 63. Frequency distribution of maximum incision in low- and high-use trail classes on IAH. (Figure from Marion 2006)

Visitor Impacts on Birds

Disturbance is a stressor potentially affecting a number of terrestrial, marsh and marine birds (Appendix 11). Because loons are especially sensitive to disturbance by visitors, a trail at Upper Hadlock Pond was recently closed to protect the nesting birds (D. Lamon, Somes-Meynell Wildlife Sanctuary, pers. comm. August 2007). Other trails are periodically closed to avoid disturbance of breeding peregrine falcons (*Falco peregrinus*) and nesting sea birds (Figure 64). Matz *et al*. (1997) documented the impact of disturbance on bald eagle (*Haliaeetus leucocephalus*) nests. They noted that there is risk of disturbance not only during the summer, when the birds are fledging, but also earlier in the season when nest abandonment may result.

Wilson *et al.* (undated) note that people in canoes and kayaks in Bass Harbor Marsh (and to a lesser extent Northeast Creek) represent a source of intrusion on bird populations, a factor that is likely to be particularly disruptive during the breeding season. In addition, there is evidence that persons with all-terrain vehicles intrude on the salt marshes of Bass Harbor Marsh at low tide, compacting both vegetion and substrate and potentially disrupting both breeding and non-breeding bird species. There are, however, no quantitative data on the extent of these impacts.

Visitor Impacts on Freshwater Systems

As in upland areas, visitor use can have direct and indirect effects on freshwater systems, including erosion / sedimentation, habitat modification and contamination. However, there is little quantitative documentation of the extent of visitor-associated effects via erosion and habitat modification. There is some evidence of nonpoint-source pollution associated with development (Kahl *et al*. 2000).

Contamination issues associated with swimming beaches are addressed under *Threats: Microbial Contamination*.

Visitor use can influence the aesthetic and visitor-experience characteristics of freshwater resources, including noise and crowding. Regulations passed by the Maine legislature in 1998 include prohibition of internal combustion engines or limitation of engine horsepower on seven Great Ponds on MDI. ACAD became the first park unit in the National Park System to ban personal watercraft within the park (Kahl *et al*. 2000).

Unauthorized introductions are modifying fish assemblages in many of Maine's lakes and streams (Vaux 2005). Several fish species currently found in ACAD freshwaters are non-native to the area (Table 12). The number of non-native species may increase in the future as a result of unintended and/or intentional introductions, particularly of bait species, by anglers.

Visitor Impacts on Intertidal Areas

On-going studies (Olson 2007; J. Long, Northeastern University, pers. comm.) are examining visitor impacts on the inter-tidal fauna and flora at SCH. This research is documenting effects of trampling and habitat disruption, as well as providing valuable base-line data on the biodiversity of coastal habitats in this Park unit.

Petraitis *et al*. (2001) evaluated visitor impacts at Anemone Cave, which has been a popular tourist attraction for many decades (although not currently publicized, it is still visited by many people). Visitor counts made in the late 1990s indicate that an average of 47 people entered the cave per 3-hour period around low tide between late May and late August (Jacobi 2000; Table 4). In August, about one third of people entering the cave disturbed pools; in other months this number was much lower. The authors concluded that visitors (i) trample and may be injuring anemones and other species in the cave, and (ii) do not appear to substantially disrupt the freshwater lenses in the pool. Longer-term impacts of visitors on species composition and abundance are unclear. While trail use by visitors appears to reduce barnacle densities in the Anemone Cave area, this is not a significant impact in view of the ubiquity of this faunal group.

Cammen and Larsen's (1992) study of the intertidal resources of ACAD characterized the small infauna of rocky shore and mudflat areas on MDI. The authors indicated that there is no need to protect intertidal mudflats from normal visitor activity such as worming and clamming. The reasons given include (i) the fauna are fecund and (ii) movement over the mudflats is difficult, making it unlikely that these areas will be exposed to intense visitor traffic.

MacArthur and Drury (1977) produced a semi-quantitative documentation of human impacts along coastal trails in the area from Sand Beach to Otter Cliffs. Some comparisons were made to trail status observations recorded a decade earlier by Barden (1970). The primary conclusion was that there had been a proliferation of trampled paths through vegetation.

Herbivory and Predation

Key Issues	***Extent of Problem***	***Information Base***
Browsing impacts on terrestrial vegetation	OK	Good
Predation impacts on mammals	PP	Fair

Herbivore Impacts on Vegetation

Several studies have investigated the damage caused to vegetation by white-tailed deer (*Odocoileus virginianus*) and other mammalian grazers, including snowshoe hare (*Leptus americanus*).

Although deer numbers increased dramatically following the 1947 fire (D. Manski, NPS, pers. comm.), the population on MDI is currently stable or declining and is below forage carrying capacity (Long *et al*. 1998). Forage is not thought to limit deer populations on MDI, rather fawn and adult doe mortality (Fuller and Harrison 2002). Deer densities are greater on the eastern portion of MDI than in the western region. Browsing at ACAD declined from 1980 to 1989, paralleling reductions in the deer population (Saeki 1991). Past browsing has suppressed stem densities in species such as rose, cherry (*Prunus* spp.), serviceberry (*Amelanchier canadensis*) and white pine (*Pinus strobus*). Habitat use by deer is influenced by understory composition, while use by hare is based on the extent of canopy closure, especially in dense coniferous forests.

Using exclosures, Saeki (1991 – see also Saeki and Harrison 1991) studied the effect of deer browsing at burned (from the 1947 fire) and unburned sites on MDI. Browsing influenced the height distribution of plants, particularly in the shrub height class (0.5 – 2.0 m) and this effect was dependent on fire history. Browsing also had a significant effect on plant species richness and densities. Overall, effects were greater in white cedar-dominated habitats than in hardwood habitats.

Gilbert and Harrison (1982) investigated the influence of white-tailed deer browsing on the vegetation of MDI prior to the arrival of coyotes in 1981 (*Canis latrans*). Predation by coyotes subsequently led to a reduction in the deer population (see below). The most heavily utilized species included: cherry (*Prunus* spp.), red maple (*Acer rubrum*), striped maple (*Acer pensylvanicum*), wild raisin (*Viburnum nudum* var. *cassinoides*), winterberry (*Ilex verticillata*), birch (*Betula* spp.), red oak (*Quercus rubra*), and sumac (*Rhus hirta*). The authors concluded that none of the browsed species were over-browsed as to restrict regeneration or to cause deformation, defoliation or mortality, with the exception of sumac. Further, the researchers suggested that no management efforts were needed and that the status of habitat/grazing should be monitored again in 10 years. Similarly, McLaughlin (1968) conducted a vegetation survey and identified some local areas of over-browsing, yet concluded that ACAD, as a whole, was not over-browsed. Allen (1970) also noted that over-browsing occurred in deer wintering areas. Baird (1966) developed a detailed habitat evaluation on IAH, including composition of overstory and understory vegetation. The total amount of preferred browse was < 7 pounds per acre for the entire island. At that time, deer subsisted to a large extent on food sources other than woody plants. The author noted that serious habitat deterioration can occur from a density of >1 deer per

25 acres. Frequent complaints about deer problems on IAH from local residents suggest that deer densities could be high on this island at present (D. Manski, NPS, pers. comm.).

Predation Effects on Mammal Populations

White-tailed deer populations on MDI lacked a top predator for approximately 80 years following extermination of wolves from Maine in the early 1900s and until the arrival of coyotes in 1981 (Fuller and Harrison 2003). By 1989, coyotes were reproducing and had established territories on MDI. Until the early 1980s, the lack of a predator, coupled with the no-hunting regulation on MDI, resulted in historic overpopulation of deer on the island.

Coyotes now are the major predator of deer and have contributed to recent declines in the deer population. Long (1995, see also Long *et al*. 1998) reported that the annual rate of fawn survival was 0.26. The leading cause of mortality was predation (at least 80% of predation was by coyote), followed by drowning and collisions with vehicles. Relative mortality rates for these three causes were, respectively, 0.52, 0.24 and 0.14. Recruitment to one year of age was lower than rates observed in other Maine deer populations. Low recruitment associated with multiple causes of fawn mortality may be limiting deer populations in some areas on MDI. Different rates of fawn survival across the island may explain an apparent patchy distribution of deer (Long *et al*. 1998).

Vinck (1993) compiled information on automobile accidents on MDI involving deer and noted that, while accidents occurred island-wide, they were concentrated in three focus areas.

Food use by coyote (the primary deer predator on MDI) was reported by O'Connell *et al*. (1992). The most common coyote foods were deer, raccoons (*Procyon lotor*), snowshoe hare and other small mammals (Cricetidae, Soricidae, Zapodidae), and fruits. Compared to the mainland populations, coyotes on MDI exhibited greater dietary diversity despite lower faunal diversity on the island. Predation on raccoons illustrates the ability of coyotes to expand their feeding niche in response to available resources on MDI.

Harvest / Hunting / Take

Key Issues	Extent of Problem	Information Base
Fisheries management: impacts on native populations	PP	Poor
Effects of worming on shorebirds	PP	Poor
Eel harvests: impacts on population status	PP	Poor
Deer hunt – effects of possible adoption of hunt	PP	Fair
Harvest of waterfowl	EP	Poor

In general, there is little information on the effects of harvesting activities on the biological resources of ACAD. Freshwater fisheries are managed by MDIFW but little is known about how stocking and fishery regulations influence populations of native species. There is a thriving fishery for elvers (young eels) in several streams on MDI. The impacts from this fishery on eel populations are essentially unknown; some researchers have suggested that there may be worldwide declines in eel population, but there are no long-term data to document such patterns (Gulf of Maine Council on the Marine Environment 2007).

Worm and shellfish harvests occur in mudflats around MDI. Possible harvesting impacts on shorebirds have not been investigated. However, research elsewhere has shown that shellfish take by humans can influence bird populations through both exploitative and interference competition (e.g. Stillman *et al*. 2003).

Some members of the public on MDI are lobbying for adoption of a deer hunt on the island – in part in response to perceived higher numbers of deer. However, while there may be higher concentrations of deer in peripheral areas of MDI, there is no evidence that the deer population is increasing; rather it appears to be stable or even declining (Fuller and Harrison 2002). Low fawn and adult doe survival are believed to be key factors influencing the current status of deer populations on MDI (Fuller and Harrison 2002). Park staff are concerned that by adding an additional mortality factor, a hunt could cause serious problems for the deer population on MDI (D. Manski, NPS, pers. comm.).

Over-harvest of some bird species is considered to be an existing or potential problem, particularly for marsh and marine taxa (Appendix 11).

Exotic Species

Key Issues	***Extent of Problem***	***Information Base***
Terrestrial exotic plants	EP	Fair
Freshwater invasive plants	PP	Good
Competition for nesting habitat by non-native birds	PP	Poor / Inferential
Exotic freshwater fish	PP / EP	Good
Exotic terrestrial invertebrates	PP	Poor
Invasive terrestrial invertebrates	EP	Fair
Invasive marine species	EP	Fair

The NPS defines exotic species as "those species that occupy or could occupy park lands directly or indirectly as the result of deliberate or accidental human activities" (NPS 2006). An invasive species is one which outcompetes native species for space and resources and, by some definitions, causes economic or environmental harm. Only some exotic species are considered to be invasive.

Terrestrial Exotic Plants

Twenty five percent of all plant taxa (~290 taxa) at ACAD are considered non-native to Maine (Greene *et al*. 2005). This compares to a figure of 30% statewide (Campbell *et al.* 1995). Nine percent of the 290 non-native species of ACAD are on the *Draft List of Invasive Plant Species of Maine* (Maine Natural Areas Program 2004). Out of the 40 taxa on this list, 24 occur at ACAD (Greene *et al.* 2004), primarily on MDI. Aggressively invasive plant species include Norway maple (*Acer platanoides*), Japanese and common barberry (*Berberis thunbergii* and *B. vulgaris*), oriental bittersweet (*Celastrus orbiculata*), honeysuckles (*Lonicera* x *bella*, *L. morrowii*, *L.*

xylosteum), and purple loosestrife (*Lythrum salicaria*) – all most likely intentionally introduced to MDI. Garlic mustard (*Alliaria petiolata*), a more recent invasive, was most likely unintentionally introduced. All currently recognized invasive species are much more abundant on the eastern side of MDI than on the unburned (and less-populated, less-visited) west side (Figure 65; also see below).

Aggressively invasive species such as shrubby St. Johnswort (*Hypericum prolificum*) and ninebark (*Physocarpus opulifolius*), while native further south, are in Maine only as garden escapees (Haines and Vining 1998). Forest woodrush (*Luzula luzuloides*) is another potentially invasive species. All three species are found adjacent to basin wetlands within the areas burned in the 1947 fire. These species could expand their distributions in response to further disturbance, or decline if pre-fire communities become more prevalent.

In an extensive survey of invasive species, Reiner and McLendon (2002) listed, described, and ranked exotic species that threaten ACAD and suggested options and management protocols for these species. The goals of their study were to (i) estimate potential effects of non-native species on native plant communities within ACAD, (ii) rank non-native species based on their potential impacts on native plant species and their communities, and (iii) develop management protocols to manage non-native species at levels that will protect native plant communities. Their ranking process involved literature reviews and field surveys. The initial screening list produced 45 taxa considered to be exotic at ACAD. An additional 25 taxa were identified that, while currently not present in the park, may occur there in the future. The authors note that 76% of ACAD exotic species originated in Eurasia, and 11% in North America. Their final assessment identified 16 species of concern and 8 species were recommended for highest management priorities at ACAD. The 8 species and their priority ranks are listed below.

Priority 1: *Lonicera japonica, Lonicera morrowii*, *Lonicera* x *bella* – all honeysuckles
Priority 2: *Celastrus orbiculata, Frangula alnus*, *Berberis thunbergii*, *Lythrum salicaria*, *Rosa multiflora*

Since 1988, purple loosestrife (*Lythrum salicaria*) has been actively managed on MDI (Chase *et al.* 2002; Figure 64). Active management appears to keep the plant from spreading too rapidly. To date, this species has not been recorded at SCH or IAH.

Greene *et al*. (2004) followed the Reiner and McLendon (2002) survey and further documented the distribution and abundance of invasive species at ACAD. They noted that of the 600 species that could be viewed as being potentially invasive, only 33 are considered to be invasive in Maine (Cameron 2000). From this list, Greene *et al*. focused on 24 invasive taxa; these included 11 species from the Reiner and McLendon (2002) study plus an additional 13 species. Alder buckthorn (*Rhamnus alnifolia*), non-native honeysuckles (*Lonicera* spp.) and Japanese barberry (*Berberis thunbergii*) occurred at more sites than any other invasive species. The majority of the documented species were on the eastern side of the island, within the extent of the 1947 fire (Figure 65). Invasive species were concentrated around Great Meadow and Sieur du Monts Spring. The density of plants was higher at these sites than in any other part of ACAD. Greene *et al*. (2004) suggested that the best strategy for management of invasive species at ACAD is by site rather than by species. Exotic species are considered a significant stressor for nine rare plant species (out of 20 considered) (Table 7).

Stubbs *et al*. (2005) investigated the influence of two invasive plant species (Japanese barberry and glossy buckthorn) on pollinator visitation patterns. The researchers concluded that the invasive species do not compete with native species for pollinators.

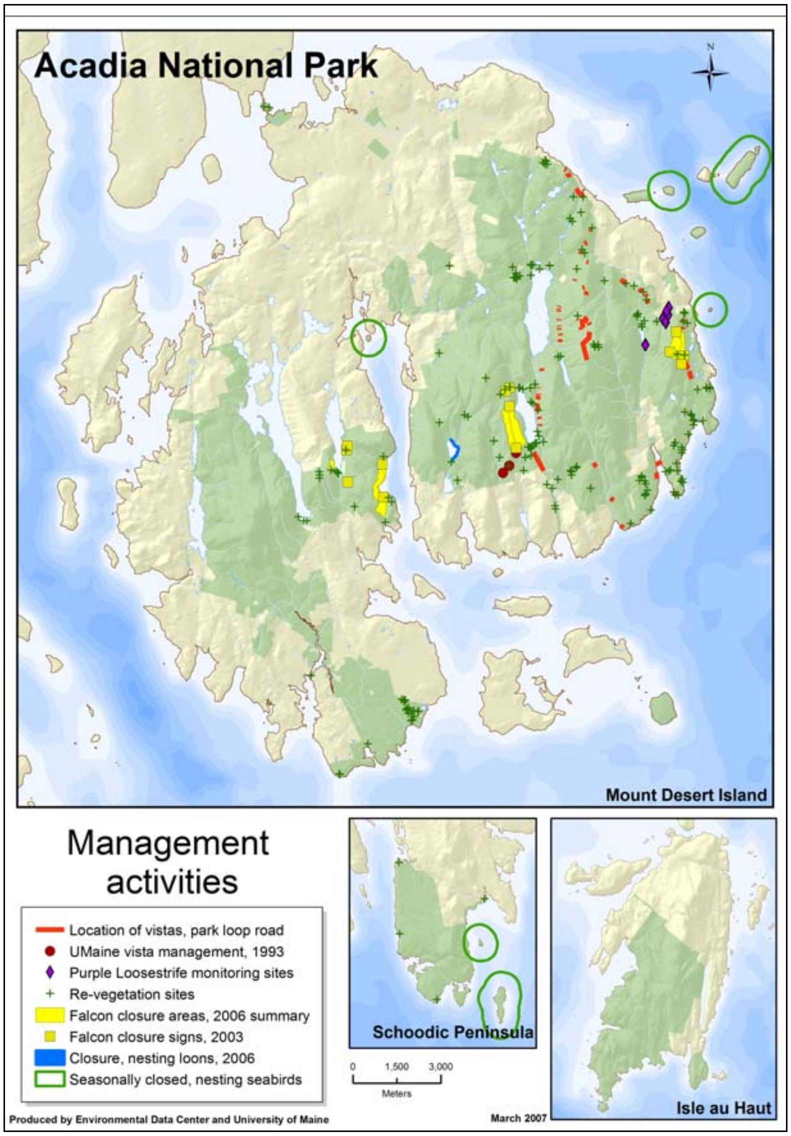


Figure 64. Selected management activities at ACAD.
(Data source: GIS coverages from ACAD Office of GIS)

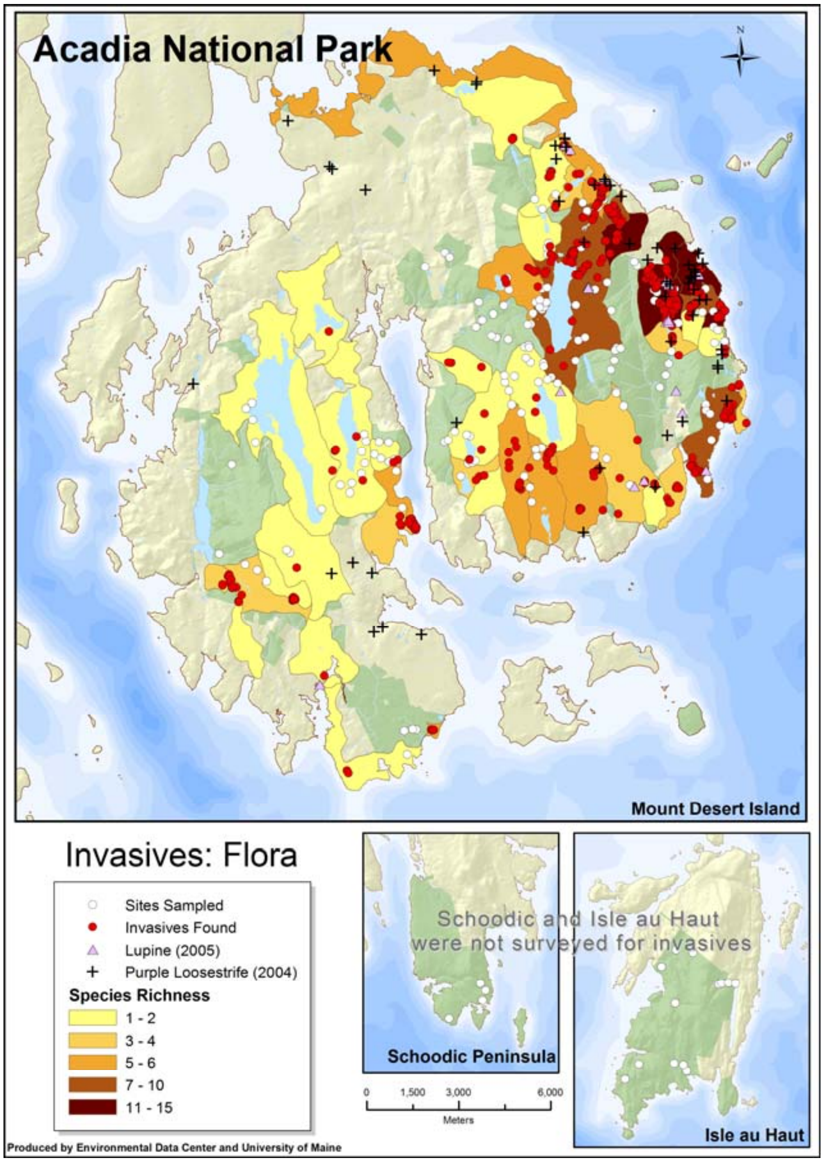


Figure 65. Distribution of invasive plants on MDI. The map shows the number of species in each watershed for which there were survey sites. Map is based on survey data in Greene et al. (2004). This survey was restricted to sites within ACAD. Additional data (courtesy of K. Anderson, ACAD Office of GIS) are shown for lupine and purple loosestrife records.

Recent data from sites monitored by the Northeast Temperate Network monitoring program suggest that there are fewer invasive plants at ACAD than at all seven other parks in the network (B. Mitchell, NPS, pers. comm.; see *Assessment of Condition*).

Freshwater Exotic Plants

Four invasive aquatic plant species (plus a milfoil hybrid) are currently known to exist in Maine: Eurasian milfoil (*Myriophyllum spicatum*), variable milfoil (*M. heterophyllum*), hydrilla

(*Hydrilla verticillata*) and curly-leaf pondweed (*Potamogeton crispus*). As of March, 2007, all occurrences of these plants are to the south and west of MDI (MDEP 2007). There are currently no invasive exotic freshwater plants in the ACAD region. Park staff conduct annual surveys to ensure early detection of any invasives that might arrive at ACAD. In their survey of plants on MDI, Greene *et al*. (1997) recorded only one non-native aquatic species – the water lily *Nymphaea tuberosa* which is naturalized at Little Long Pond in Seal Harbor. The authors noted that there was no evidence that the plant was spreading to other waterbodies on the island.

Exotic Birds

Non-native species such as starlings and house sparrows may be impacting some native bird populations via competition for nesting habitat (Appendix 11). However, data on these interactions in the ACAD region are largely absent.

Exotic Fish

Manipulations of freshwater fish communities in the ACAD region have occurred since before the creation of the Park (Stone *et al*. 2007). Manipulations include "stocking, bait introductions, and illegal, accidental, and intentional transfers of species by humans".

Most MDI lakes currently harbor species that are thought to be non-native to the waters of MDI (Figure 28). Just under 50% (12/29) of fish species in ACAD lakes and streams are not native to MDI (Table 12). Many of the species not native to MDI <u>are</u>, however, native to Maine. Fish species in the ACAD region that are not native to Maine include the black basses and brown trout.

Stone *et al*. (2007) note that non-indigenous fish species are now prominent members of the fish community in Eagle Lake (common shiner, *Luxilus cornutus*), Echo Lake (fallfish, *Semotilus corporalis*), Jordan Pond (common shiner), and Round Pond (smallmouth bass, *Micropterus dolomieu*). In each case, the "introduced species is now the most abundant or one of the most abundant species in the lake or pond (based on catch-per-unit data from surveys in 1998 and 1999)".

Transfer of baitfish into ACAD waters is a continuing threat in the Park. These introductions are leading to the increased homogenization of freshwater fish assemblages in ACAD lakes as well as in waters throughout much of Maine (Vaux 2005). The broader ecological ramifications of many of the non-predator introductions are not well understood. Three exotic predator species that are today causing concern because of their colonization of an increasing number of lakes and rivers in Maine are: smallmouth bass, largemouth bass (*Micropterus salmoides*) and Northern pike (*Esox lucius*). Smallmouth bass occurs in five ACAD lakes. Largemouth bass occurs in one MDI lake outside ACAD. The closest population of Northern pike to the ACAD region is in the lower Penobscot watershed.

Exotic Terrestrial Invertebrates

There are insufficient baseline survey data on ACAD invertebrates to permit estimation of the number of exotic species in the Park. Some new appearances of non-native taxa have been recorded in recent years, for example the European hammock spider, *Linyphia triangularis*, which occurs at SCH (Jennings *et al*. 2002). Recent research by Jakob *et al*. (2005) has addressed the impacts of this species on native spiders at ACAD. Final results from this work are not currently available.

The European fire ant (*Myrmica rubra*) is a pestiferous invasive species that is currently causing concern to residents on MDI. It was first recorded from the MDI area in the late 1960s. Since 1993, the number of complaints from the public about this stinging species has increased dramatically, with most complaints coming from MDI and the mid-coast area of the state (Groden *et al*. 2005). The fire ant has a patchy distribution on MDI (Figure 66). Nests are typically found in downed woody debris, leaf litter and soil under tree roots. This species is not only pestiferous to humans but also negatively impacts native ant fauna (Garnas 2004). Almost complete displacement of native ants by the colonizer reduces species richness and diversity. Fire ants appear to have few impacts on non-ant arthropods.

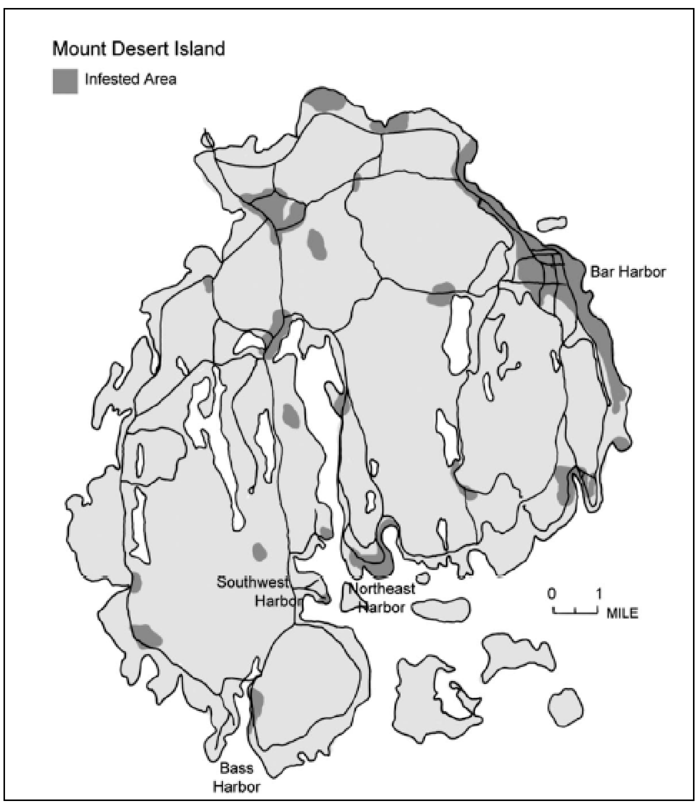


Figure 66. Distribution of European fire ant (*Mymica rubra*) on MDI.
(Figure from Groden *et al*. 2005, used with permission)

Invasive Marine Species

As of 2004, 33 marine introduced species had become established in Maine's coastal waters (Carlton 2004). Among them were seven species of algae, 25 invertebrate species, and one protista species. Ballast water is generally considered the most prevalent vector of marine introductions, but in Maine vectors such as fouling communities on vessel hulls, fishing and seafood trades practices, research activities, and other vectors may pose equal threats (Thayer and Stahlnecker 2006).

The following are among the most notable marine invasives in Maine (after Thayer and Stahlnecker 2006)[10].

Codium fragile, a spongy green alga also known as "oyster thief", is present in a number of locations along the Maine coast. It can smother beds of oysters and other shellfish.

The invasive bryozoan *Membranipora membranacea* has been present in the Gulf of Maine since 1987. It promotes kelp breakage by making the kelp blades more brittle and susceptible to wave damage.

Marine invasives include the Asian shore crab (*Hemigrapsus sanguineus*), a species that was first recorded in the U.S. in New Jersey in 1988. It reached Maine by 2001 and is now found as far north as the Schoodic Peninsula. The green crab, *Carcinus maenas*, is Maine's most destructive and costly invader. Despite extensive efforts to eradicate this invasive species, it has caused a substantial reduction in the population of soft-shelled clam (*Mya arenaria*) (Thayer and Stahlnecker 2006).

Invasive colonial tunicates have become problematic in many parts of the world because the rapid spread of colonies alters marine habitats and threatens to interfere with fishing, aquaculture, and other coastal and offshore activities. In Maine, *Didemnum* spp. have been present in the Damariscotta River area since the early 2000s, and recently (2007) appeared in Cobscook Bay.

Species that have not yet been reported in Maine but are considered to be possible future threats include the Chinese mitten crab (*Eriocheir sinensis*), the Pacific oyster (*Crassostrea gigas*), and the veined Rapa whelk (*Rapana venosa*).

Ongoing research at ACAD is focusing on approaches to forecasting the spread of marine invasive species and monitoring their status (Delaney 2006).

[10] A number of monitoring efforts have been developed over the past several years to help track the advance of invasives along the coast, and to help identify new invasives. Currently, five different data contributors within the Gulf of Maine list their data with the Massachusetts Institute of Technology Marine Invader Tracking Information System (http://chartis.mit.edu/mitis/), which in turn contributes to the International Nonindigenous Species Database Network (http://www.nisbase.org/nisbase).

Pests and Pathogens

Key Issues	*Extent of Problem*	*Information Base*
Pests/pathogens of terrestrial vegetation	PP	Poor / Inferential
Pests/pathogens of wetland fauna	EP	Fair
Pests/pathogens of bird fauna	PP	Poor / Inferential

Pests and Pathogens of Terrestrial Vegetation

Pathogens/pests could have detrimental short-term and long-term effects on plant species within ACAD. In addition to species-level effects, pests/pathogens can have impacts on ecosystem processes such as productivity, nutrient cycling, and support of consumer food webs. Pests and pathogens could be even more important than climate change in causing species transitions in eastern forests over the next few decades (Lovett *et al*. 2006).

Current or immediate threats to ACAD include gypsy moth (*Lymantria dispar*; target species: oak and aspen), beech bark disease (scale insect *Cryptococcus fagisuga* and pathogenic fungus *Neonectria*; target species: beech), hemlock wooly adelgid (*Adelges tsugae*; target species: hemlock).

The hemlock wooly adelgid, a small aphid-like insect introduced from Japan, has caused widespread hemlock mortality throughout the mid-Atlantic and southern New England region over the last 20 years (Orwig *et al.* 2002). Major trends associated with the decline in hemlock include shifts in canopy dominance to oak and mixed hardwoods, considerable understory development, including greater herb richness and abundance and increased density of clonal saplings, and expansion of several invasive shrub and woody vines (Small *et al.* 2005; Runkle 2005; Bailo *et al.* 2004). Although the pest has not been documented within ACAD, it was recently reported on private property outside the Park (J. Hazen Connery, NPS, pers. comm.). Although it is unclear if the pest managed to spread from infested nursery stock to trees outside the property, the findings suggest careful monitoring is essential to keep the situation under control. Orwig (2002) has noted the potential for movement of this pest northward along the east coast.

Additional pests and pathogens that could potentially affect ACAD resources include: Asian longhorned beetle (*Anoplophora glabripennis*), a wood-boring beetle that can affect red maple, a common species at ACAD. The emerald ash-borer (*Agrilus planipennis*; target species: *Fraxinus* spp.- ash) also can exert heavy mortality in white ash, a species common at ACAD. Like sugar maple, white ash is able to produce soil organic matter with a low C:N ratio and high nitrification rates (Venterea *et al*. 2003), so the loss of this species due to a pest such as the emerald ash-borer could also have significant effects on C and N cycles within the region. *Phytophthora ramorum*, the pathogen responsible for sudden oak death, has recently spread to eastern North America (Lovett *et al*. 2006). Red oak, a dominant species at ACAD, is known to be susceptible. Oaks also have unique foliar and litter properties that affect C and N cycling, producing litter with low decomposition rates, and, unlike white ash and sugar maple, soils with low rates of nitrification (Lovett *et al*. 2004). This leads to low nitrate leaching into surface waters and high retention of atmospherically deposited N. Widespread attack on oaks could have significant effects on ecosystem processes and subsequently on species composition of various vegetated communities.

Unpredictability of new introductions combined with the lack of knowledge about currently threatening pests and pathogens limit the ability to confidently forecast the nature and scope of change that could occur at ACAD in the presence of one or more of these pests/pathogens. Historically, there were efforts over many decades to control white pine blister rust and beech bark disease (as documented in numerous reports in the ACAD bibliographic database). Beech bark disease is currently widespread at ACAD where beeches occur. For example, of the 18 beech trees that are in NETN forest plots at ACAD (from 4 plots), all trees were clearly affected by the disease, except the two smallest (B. Mitchell, NPS, pers. comm.).

Pests and Pathogens of Wetland Fauna

Disease is one of several stressors known or thought to be impacting ACAD amphibian populations. Five major amphibian diseases have been documented at ACAD: ranavirus (Figure 67), chytridiomycosis (Bd), Ichthyophonus, Saprolegnia, and a Perkinsus-like organism (Gahl 2007). Disease screenings of ACAD amphibians indicated that three of these diseases (Ichthyophonus, Bd and Saprolegnia) were benign and thus may have natural controls on MDI. Some amphibian die-off events have been linked to ranavirus and the Perkinsus-like organism. However, in general, Gahl (2007) concluded that "disease events do not seem to exacerbate natural breeding population fluctuations" (see also Calhoun and Gahl 2006). Because no spatial autocorrelation of ranavirus disease events was detected, Gahl (2007) concluded that epizootics were not clustered and thus that landscape and within-pond stressors were likely to be more influential in ranavirus occurrence than movement of vectors. High catchment position was the primary landscape feature associated with ranavirus-caused larval mortality events. Aluminum and temperature were identified as potential environmental stressors associated disease events caused by ranavirus, Perkinsus-type organism and Ichthyophonus (Gahl 2007). Other water chemistry attributes appeared to be substantially unassociated with mortality events.

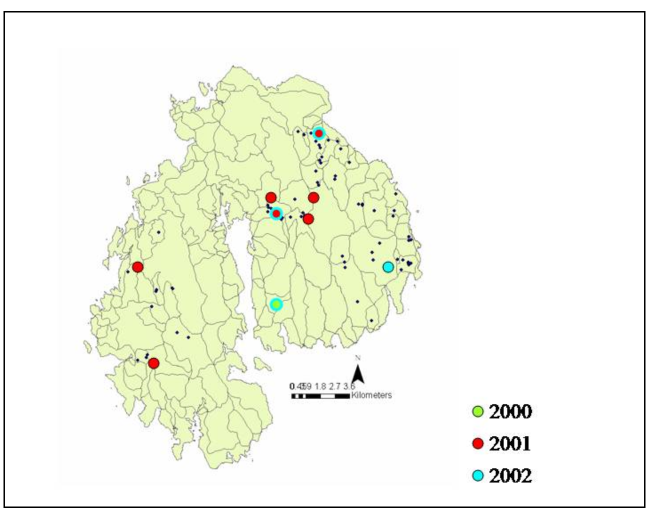


Figure 67. Ranavirus-associated amphibian die-off events on MDI.
(Figure courtesy of M. Gahl, University of Maine, Orono)

In their study of Hg concentrations in frog tadpoles, Bank *et al*. (2007b) noted that there had been amphibian disease outbreaks / dieoffs at three of their nine ACAD study sites. However, these authors noted that there is no known link between Hg and amphibian disease.

In 2001, water molds (*Saprolegniasis*) were detected in spotted salamander (*Ambystoma maculatum*) egg masses in ACAD, but it could not be determined if the eggs were alive or dead at the time the fungi invaded them (NEARMI 2007).

Most anuran amphibian populations in Maine are infected with the chytrid fungus *Batrachachytrium dendrobatidis*. However, to date there have been no die-offs attributable to this disease (NEARMI 2007).

Pests and Pathogens of Birds

There is some concern that avian cholera, avian botulism and other pathogens may impact bird populations in the ACAD region. However, there is currently little evidence to suggest current problems in the Park (Appendix 11).

Giardia and Beaver Populations

Giardiasis is a commonly diagnosed intestinal disease in humans (O'Connell 2003). Beaver are frequently thought of as a vector of Giardia. At least one of the water utilites on MDI has expressed concern that beaver presence in water supply lakes may jeopardize the utility's filtration waiver – this waiver is in effect because the supply lake is largely surrounded by ACAD. O'Connell (2003) reviewed the role of beaver in Giardia transmission and concluded that the connection between humans and beaver in relation to human cases of giardiasis is not clear. According to this author, removal of beaver from ACAD lakes to protect drinking water supplies is unwarranted. He notes that 20 mammal species inhabiting ACAD are known (from research elsewhere) to be capable of hosting Giardia.

Climate Change

Key Issues	***Extent of Problem***	***Information Base***
Sea level rise	EP	Good
Other impacts, modeled for ACAD	PP	Inferential

Although there is a growing literature on the potential impacts of climate change on ecosystems of the Northeastern U.S., there appear to be no published studies that use climate change models to explicity explore impacts on the biological resources of ACAD. Many species are at or near their range extents in the Acadia region. Consequently, climate change could have significant effects on the composition of plant and animal communities in the Park. Although some of the potential impacts of climate change on forest community structure have been mentioned in earlier sections of this report, an in-depth literature review of climate change research and possible implications for the Acadia region is outside the scope of this report.

Huntington *et al.* (2004) found that, for 11 sites across New England, there had been less snow over the period 1949-2000, including coastal sites.

Several studies have addressed the issue of sea-level rise in Maine (e.g. USEPA 1995). Mean sea level is expected to rise about 60 cm (2 feet) along most of the U.S. Gulf and Atlantic Coast in the next century (USEPA 1995). A recent map displaying areas in the ACAD region susceptible to two different sea level rise scenarios is shown in Figure 68.

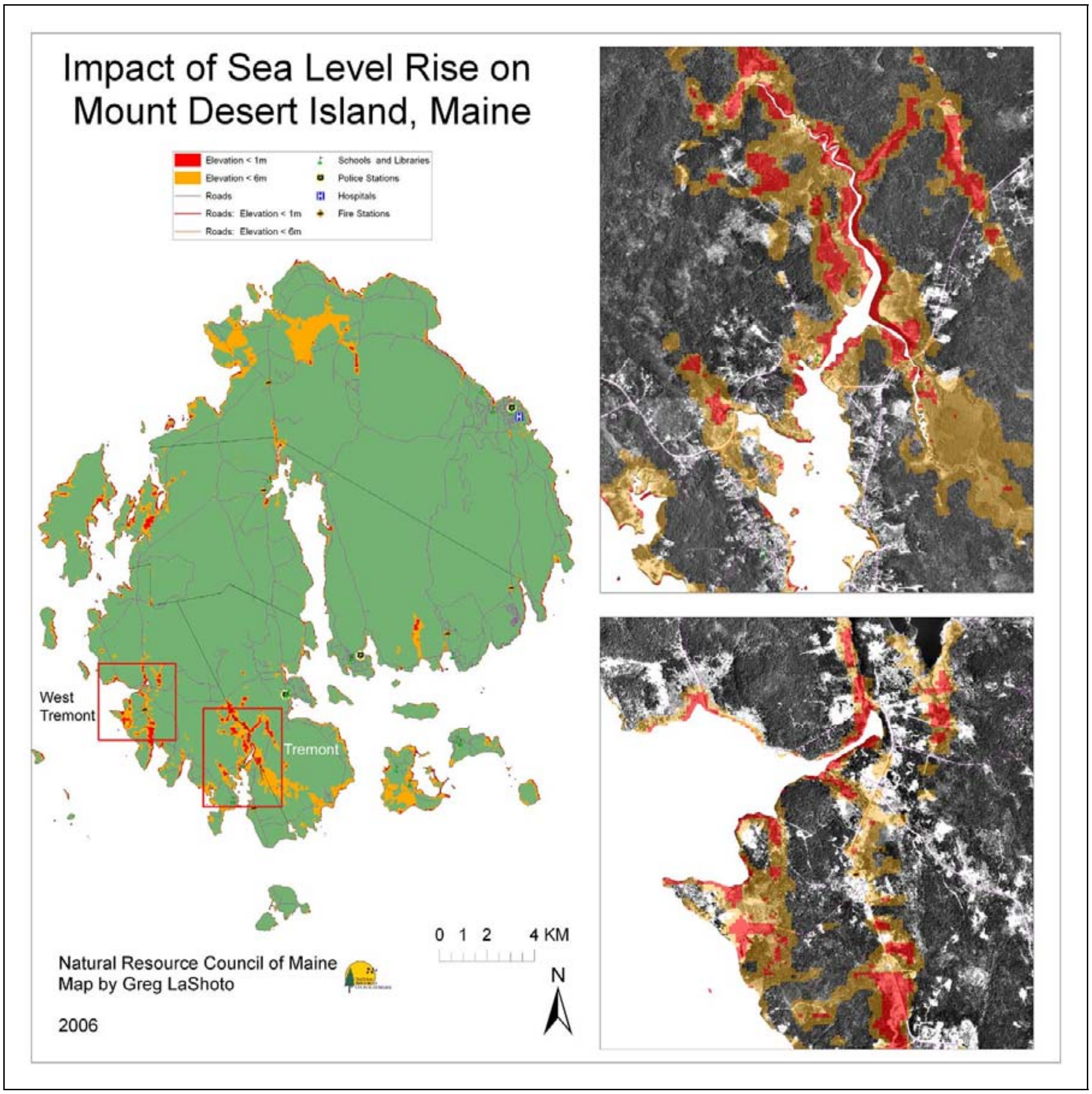


Figure 68. Impact of sea level rise on MDI. Areas shown in red and orange would be inundated by a sea level rise of 1 and 6 meters, respectively.
(Figure courtesy of Natural Resource Council of Maine and Colby College.)

Light Pollution

The impact of residential, municipal and commercial lighting on the night sky on MDI has recently become a topic of public interest. There are no known implications for non-human inhabitants of the ACAD region. Figure 69 shows a map of night sky illumination.

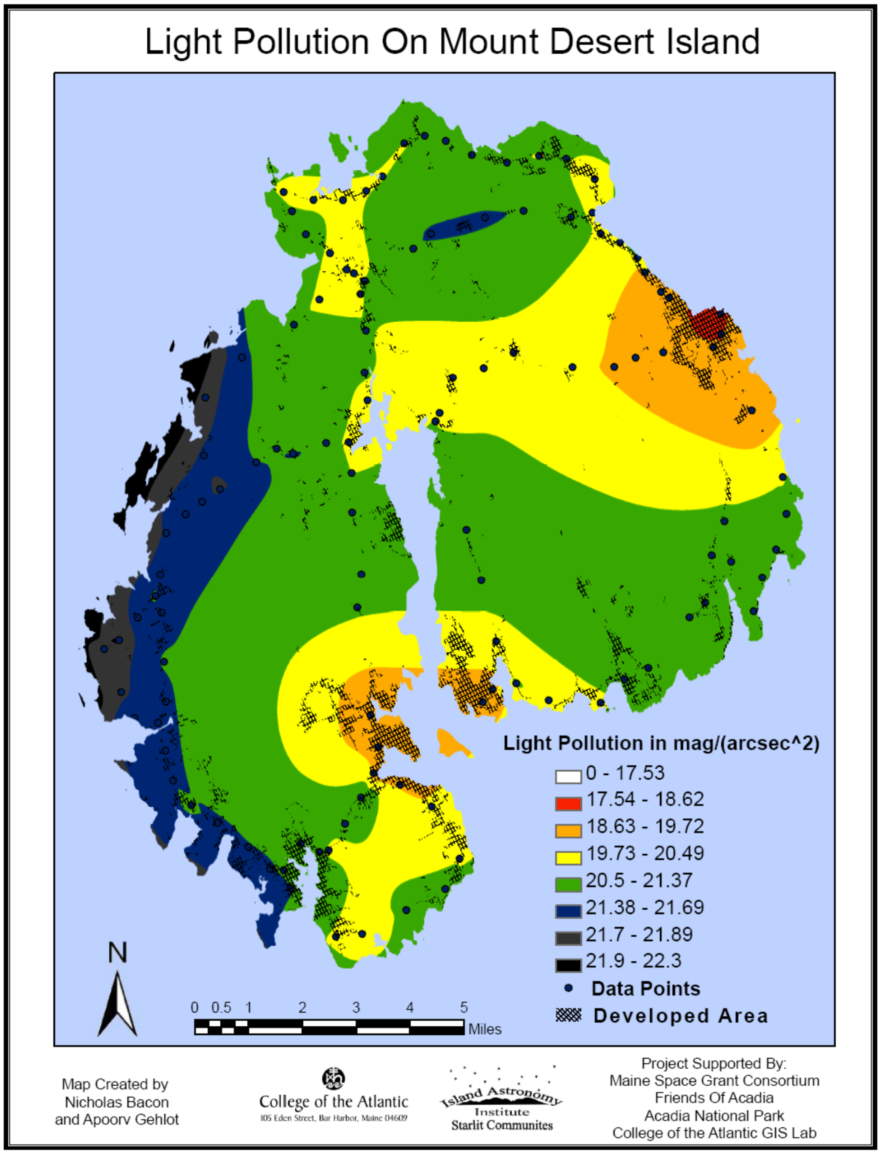


Figure 69. Map of MDI showing illumination in the night sky. Higher values indicate darker sky. (Map courtesy of N. Bacon and A. Gehlot, College of the Atlantic)

Multiple Stressors

Key Issues	*Extent of Problem*	*Information Base*
Synergistic effects of multiple stressors	PP	Poor

The effect of multiple stressors acting simultaneously or sequentially on organisms is a topic that is currently of considerable interest to many researchers and resource managers. A few studies at ACAD have referenced the potential roles of multiple stressors at ACAD. Examples include (i) the impacts of acid fog and ozone on conifers; and (ii) impacts of UV-B radiation, mercury, disease and landscape position on amphibians. However, there has been very little research specifically targeting possible synergistic effects of multiple stressors. Additional issues include the possible influence of nitrogen enrichment (from atmospheric sources) on susceptibility of terrestrial plant communities to invasion by exotic species, and the coupled impacts of N-rich and acidic deposition on terrestrial plant communities. Researchers have identified the issue of multiple stressors as an important area for future study at ACAD.

Threat Asssessments: A Summary

The resource – stressor matrix shown in Table 21 provides an overview of the stressors acting on the natural resources of ACAD. The matrix also shows the richness of the information resources associated with each stressor and resource category. This matrix comes with a note of caution. Since it attempts to summarize a lot of information within individual matrix cells, the table inevitably involves significant consolidation and 'averaging' of conclusions. Consequently, it is important that the reader consult the separate matrices presented above for each stressor. In these matrices, the various key issues associated with each stressor are identified and reviewed separately.

Two further summaries of the threats status and information richness are provided in Figures 70 and 71 – both are based on the resource / stressor matrix in Table 21.

Terrestrial systems, lakes, and streams – in particular their abiotic compontents – are the resources for which there is most information at ACAD, as shown by the number of threats for which the problem status is classed as "Existing Problem" or "OK". For the wetlands, estuaries and marine resource groups, a large proportion of the threats are classified as "Potential Problem" or "Unknown". These observations reflect the relative amounts of research effort invested in the ACAD region. Future research will likely provide information on the extent to which issues, currently considered to be potential problems, influence the natural resources of ACAD.

The following section of this report, *Assessment of Condition*, provides an additional synthesis of some of the material presented under our assessment of threats – information that relates specifically to metrics and other descriptors of resource condition.

Table 21. Resource stressor matrix showing extent of problem and knowledge base.

THREAT / STRESSOR	RESOURCE – COMPONENT								
	Terrestrial		Lakes & Streams		Wetlands & Estuaries		Grnd water	Marine	
	Abiotic	*Biotic*	*Abiotic*	*Biotic*	*Abiotic*	*Biotic*	*Abiotic*	*Abiotic*	*Biotic*
UV radiation	--		--	Inf	--	Inf	--	--	
Visibility	G	--	--	--	--	--	--	--	--
Ozone	G	G	--	--	--	--	--	--	--
Atm. deposition: acidity etc.	G	G	G	Inf		Inf	--		
Nutrient enrichment	G	Inf	G		G	F	G	P	Inf
Mercury	G	P	G	F	F	P		G	
Other contaminants	P	P	P		P		P	P	P
Microbial contam.	--	--	F	P				P	F
Fire	G	G	--	--	--	--	--	--	--
Altered hydrology	--	--	F		P	P	F	--	--
Habitat loss/impairment	--	Inf	--	F	--	F	--	--	Inf
Visitor use	F	F		P			--	F	F
Herbivory & predation	--	G	--		--		--	--	Inf
Exotic species	--	F	--	G	--	P	--	--	Inf
Harvest / hunt / take	--	F	--	P	--		--	--	P
Pests & pathogens	--	P	--		--	F	--	--	
Climate change	Inf	Inf	Inf	Inf	Inf	Inf	Inf	G	Inf
Synergistic effects from multiple stressors	--	Inf	--	Inf	--	Inf	--	--	Inf

KEY

Extent of problem	OK	EP: Existing problem	PP: Potential problem	Unk: Unknown
Knowledge base	G = Good	F = Fair	P = Poor	Inf = Inferential

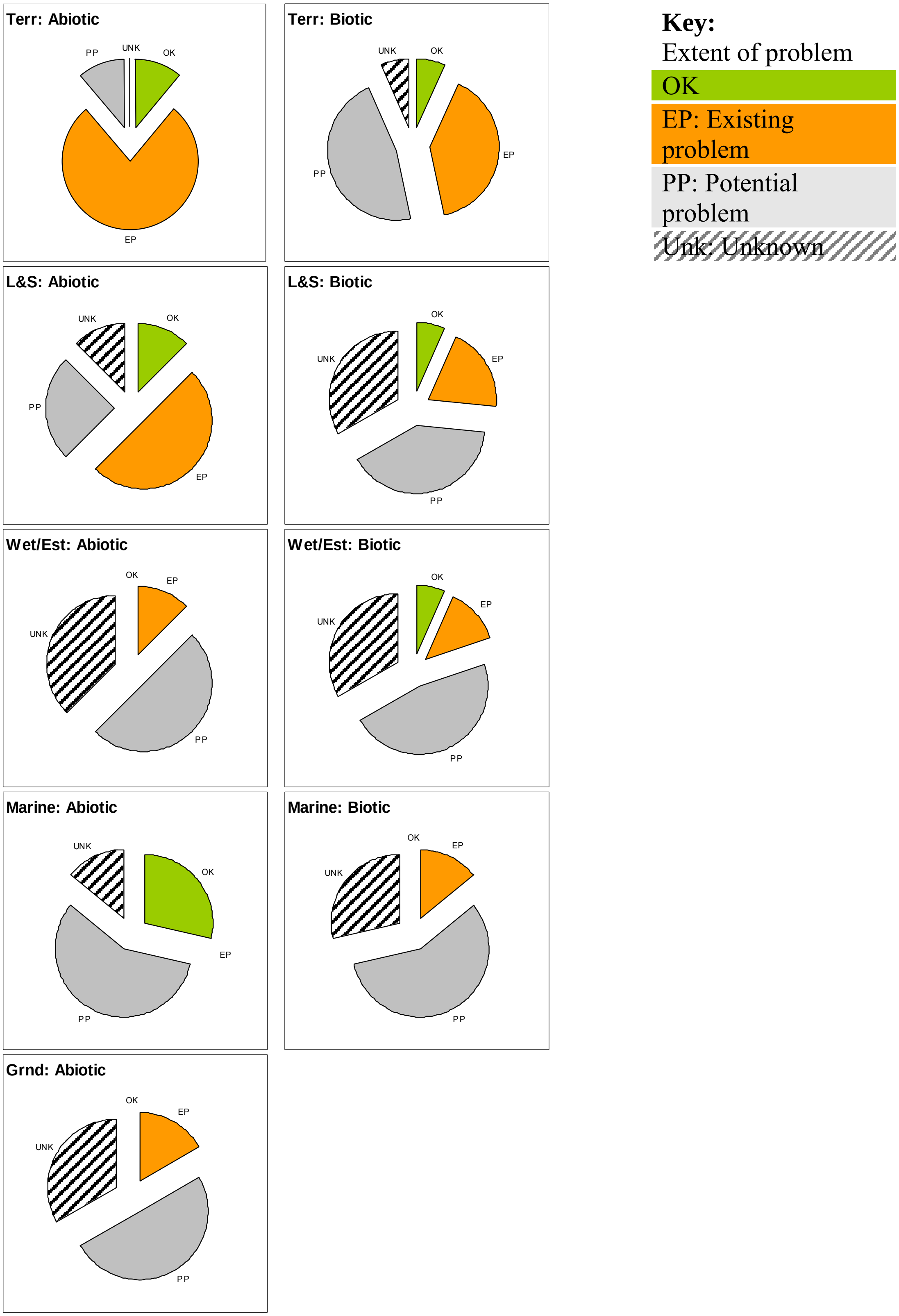


Figure 70. Summary of "extent of problem" for threats / stressors at ACAD, by resource. Data are derived from matrix in Table 21 and represent proportion of each threat category within each abiotic / biotic resource group.

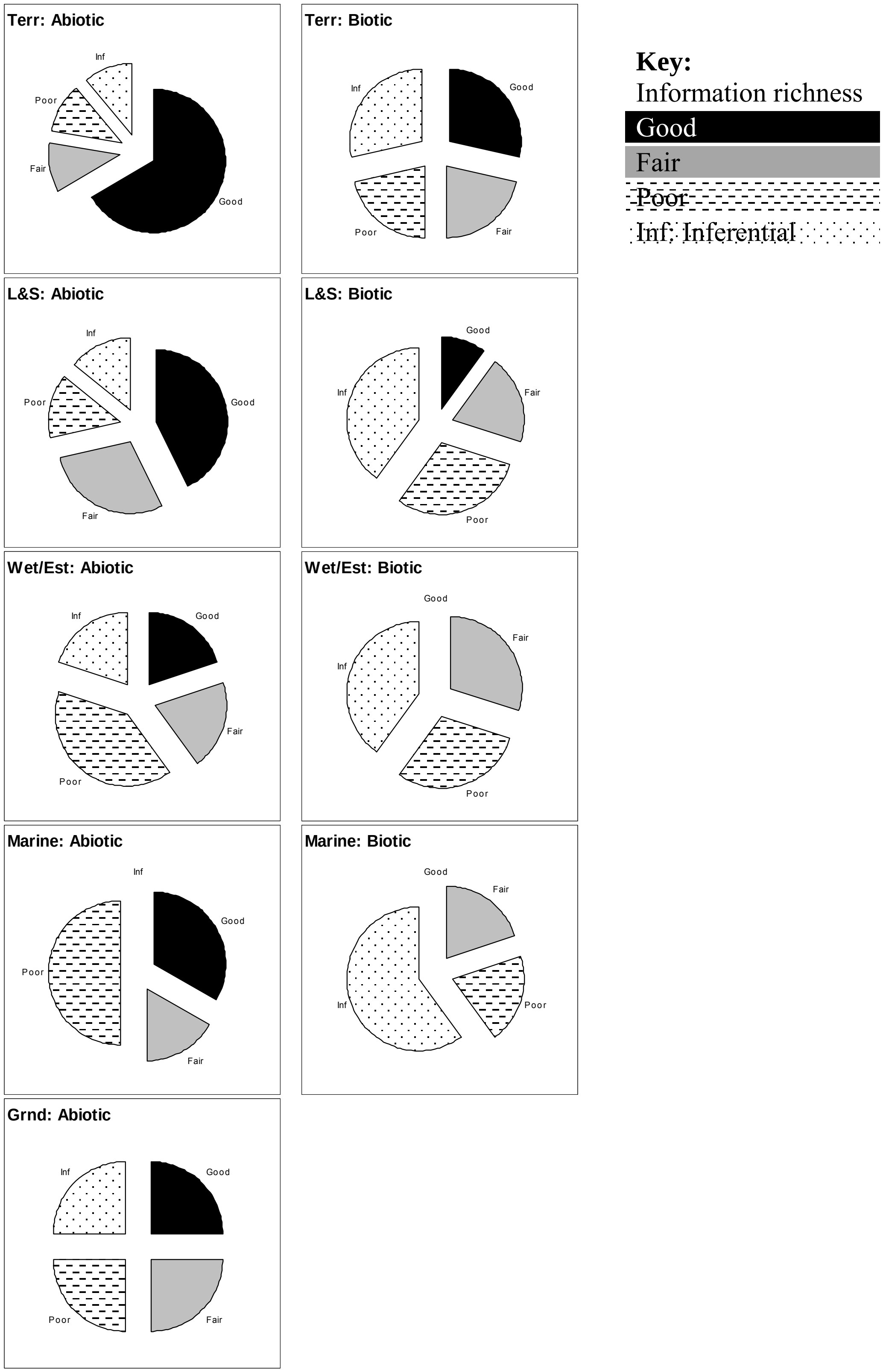


Figure 71. Summary of information richness for threats / stressors at ACAD, by resource. Data are derived from matrix in Table 21 and represent proportion of each information category within each abiotic / biotic resource group.

Assessment of Condition

Introduction

This section brings together information about metrics and other attributes that we have used to describe the condition of natural resources in the ACAD region. Most of this information has already been presented in some detail in the *Resource Characterization* and *Assessment of Threats* sections of this report.

As discussed previously, this Assessment used an information base that is very heterogeneous in terms of both quantity and quality. Consequently, a consistent and fully quantitative assessment of resource conditions was an unrealistic goal. Our selection of metrics and other condition attributes was based on (i) ecological theory, (ii) our threats assessment, (iii) the list of Vital Signs adopted by the Northeast Temperate Network (Mitchell *et al*. 2006), and (iv) information presented elsewhere, for example the ACAD water resource management plan (Kahl *et al*. 2000). Vital Signs metrics are generally included in our lists, regardless of whether or not there are currently data associated with the metrics. Absence of data serves to underscore information gaps. In some cases, we include more than a single metric to describe an aspect of condition.

For some attributes, it was only possible to make general, qualitative, statements about condition – these were generally based on discussions with Park resource management staff and other researchers. In some cases, we had to conclude that insufficient information was available to assess condition at any level of confidence at the present time.

However, for other attributes, we were able to use better defined benchmarks against which to compare ACAD data. Categories of benchmarks include:

- Park-desired conditions (explicit or inferred, regardless of attainability)
  - e.g. No exotic species.
- External criteria and reference conditions
  - e.g. State of Maine water quality classes and levels of attainment based on stream macroinvertebrates.
    Lake trophic state.
    Mercury body burdens (from Mercury Study Report to Congress 1997, Evers et al. 2005, others).
    Stream water quality reference conditions proposed by New England Wadeable Streams project (NEWS: Snook *et al.* 2007)
- Historical data (i.e. trends)
  - e.g. Lake water transparency and dissolved oxygen.
- Spatial frameworks (state, ecoregion / biophysical region, national
  - e.g. Lake water transparency and chemistry, mercury in biota, atmospheric deposition.

Condition summaries by resource group

In the following series of matrices, each metric or other descriptor is given a condition rank. We used three ranking statements: “Good”, “Caution”, and “Significant Concern”. For several of the air quality metrics, our rank of “Caution” equates to the “Moderate” rank used by the National Park Service (NPS 2006). For some NETN metrics with available data, ranks have been numerically defined (B. Mitchell, NPS, pers comm.) – we have used these metric classes. However, for many other metrics, rank was assigned using best professional judgment following review of the available data.

Supporting information is included alongside the ranking statement – often these data reference figures or tables in the *Resource Characterization* and *Assessment of Threats* sections of this report.

Where trend data are available, they are noted. Not all NETN-designated metrics have NETN data associated with them in these matrices – generally because the data were not available by the time of report preparation.

There are seven matrices summarizing condition data by resource group; a final table includes metrics associated with climate change:

- Air Quality
- Terrestrial
- Streams
- Lakes and Ponds
- Wetlands + Estuaries
- Groundwater
- Marine Intertidal and Coastal
- Climate Change Metrics

An asterisk (*) by a metric indicates that the metric is from the list of adopted Vital Signs (Mitchell *et al*. 2006). A cross (†) indicates the metric is a proposed Vital Signs metric.

One approach to summarizing overall condition within each resource group would be to simply state the number of metrics assigned to each condition rank. However, this is potentially misleading and inaccurate, since the study used a very heterogeneous information base – one that made it impossible to conduct a fully quantitative and consistent condition assessment. Furthermore, there is not a consistent number of metrics used for each thematic area – for example, within lakes, these areas might be water quality, structure and integrity of biological assemblages, contaminant levels in biota, and habitat issues. Finally, the selection of individual metrics to incorporate into an overall index of condition, and the weighting given to each metric, can greatly influence the final index value.

Nonetheless, with this caveat in place, we provide a summary of metric rankings as follows:

Air:
Good (0); Caution (4); Significant Concern (5); Insufficient data (0).

Terrestrial:
Good (9); Caution (10); Significant Concern (1); Insufficient data (5).

Streams:
Good (7); Caution (3); Significant Concern (3); Insufficient data (1).

Lakes and Ponds:
Good (12); Caution (4); Significant Concern (1); Insufficient data (0).

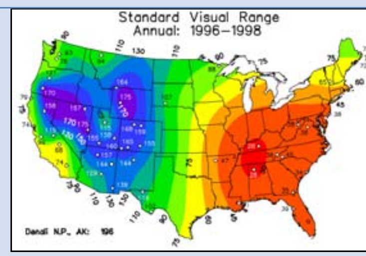
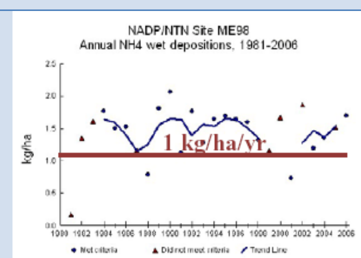
Wetlands/Estuaries:
Good (3); Caution (2); Significant Concern (2); Insufficient data (7).

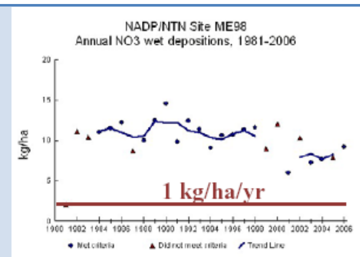
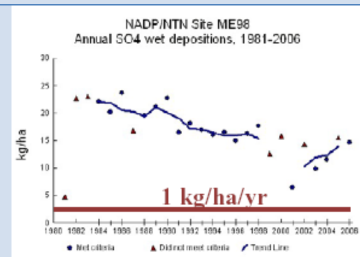
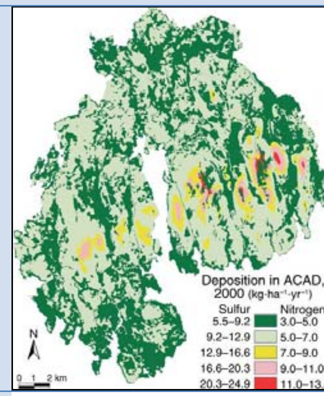
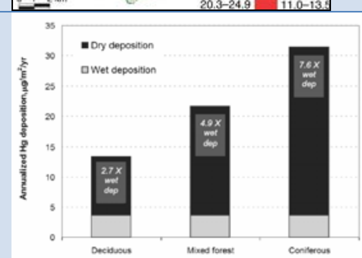
Groundwater:
Good (4); all other ranks (0).

Marine:
Good (2); Caution (2); Significant Concern (3); Insufficient data (3).

The reader is strongly urged to consult information for each metric before using the above summary.

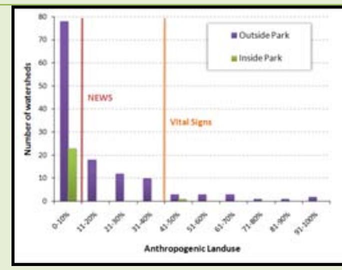
Air Quality

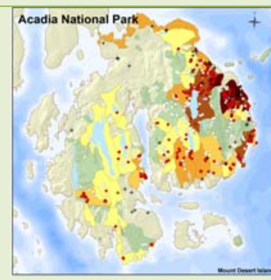
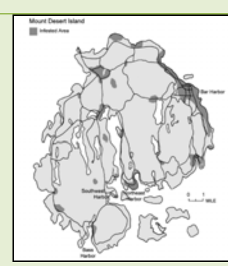
Metric	Condition	Data Summaries and/or Refs.
Ozone 3 year average of annual 4th-highest 8-hour ozone concentration*	**CAUTION** (concentration within range 68-84 ppb) • Although there is no trend or a decreasing trend, exceedences are heavily dependent on meteorology, which is unpredictable. • Higher elevation, coastal sites – specifically the Cadillac summit – have exceedences at greater frequencies than elsewhere in Maine.	NPS 2006
Ozone # 8-hr exceedences	**CAUTION** • 1983-2005: Mean = 5.2 / yr	Annual number of 8-hour ozone exceedances at six park units (Table 17)
Visibility Haze index*	**CAUTION** • Highly significant improving trend (clean days) • Significant improving trend (dirty days)	NPS 2006
Visibility Standard Visual Range	**CAUTION** • Benchmark: natural conditions on the 20% best days (ACAD/NPS/MANE-VU's goal through the Regional Haze Rule). • At ACAD, visibility conditions on the 20% best days are improving and are statistically significant. • On the 20% worst days, there is an improving trend at ACAD but it is not statistically significant. (H. Salazer, NPS, pers. comm.)	 (Fig 36)
Wet deposition of Ammonium*	**SIGNIFICANT CONCERN** • **No Trend** • NADP deposition data ranged 0.73 kg/ha/yr (2001, a drought year) to 1.87 (2002) during the most recent 10 years available (1997-2006); all values except for 2001 were greater than the NETN reference condition of < 1 kg/ha/yr.	 (Fig. 37)

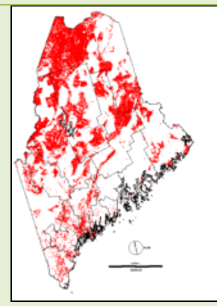
Wet deposition of Nitrate*	**SIGNIFICANT CONCERN** • **No Trend** • NADP deposition data ranged 5.98 kg/ha/yr (2001, a drought year) to 12.01 (2000) during the most recent 10 years available (1997-2006); all values were several times greater than the NETN reference condition of < 1 kg/ha/yr.	 (Fig. 37)
Wet deposition of Sulfate*	**SIGNIFICANT CONCERN** • **Improving Trend** • There has been a decline in deposition since the 1980s. NADP ranged 6.38 kg/ha/yr (2001, a drought year) to 17.6 kg/ha/yr (1998) during the most recent 10 years available (1997-2006); all values were several times the reference condition.	 (Fig. 37)
Sulfur and Nitrogen total deposition	**SIGNIFICANT CONCERN (S)** **CAUTION (N)** (rankings by NPS 2006) • S and N total deposition are dependent on vegetation type and site elevation. Hotspots of deposition were located at mountain summits and in areas of coniferous vegetation.	
Mercury wet + dry deposition	**SIGNIFICANT CONCERN** • Total deposition (throughfall) is typically 2-3 times wet-only deposition at Acadia. Wet-only deposition exceeded the likely 'pre-industrial' Hg deposition value of less than approximately 2 μg/m²/yr[11]; throughfall deposition approached or exceeded the estimate of pre-industrial total deposition.	 (Fig. 44)

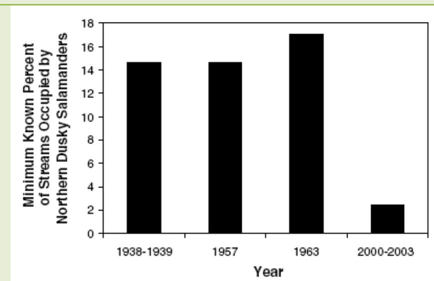
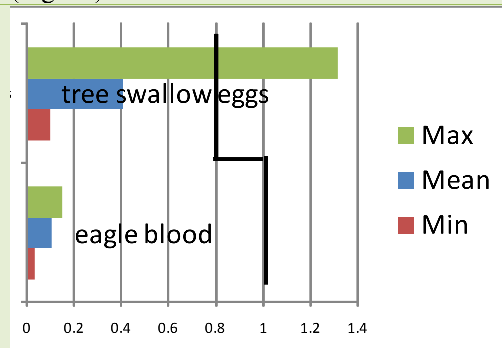
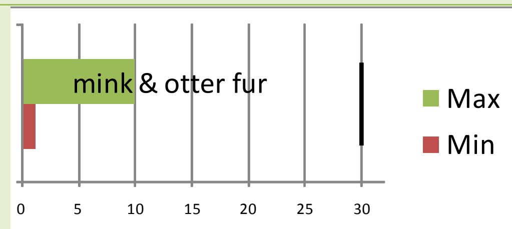
[11] (Roos-Barraclough et al. 2006)

Terrestrial Resources

Metric	Condition	Data Summaries and/or Refs.
Forest patch size	**GOOD** • Patch size at ACAD is > 50 ha and, based on research elsewhere, is considered adequate to support invertebrates, mammals, and most bird species.	Tierney *et al*. (in press)
Anthropogenic land-use	**GOOD** • 96% of watersheds inside the park (23 of 24) have <10% anthropogenic land use and the same 96% have <40% anthropogenic land use. • 60% of watersheds partly or entirely outside the park (78 of 131) have <10% anthropogenic land use; 90% of watersheds partly or entirely outside the park meet the NETN benchmark of <40% anthropogenic land use. • The value <10% is the benchmark used by Snook et al. (2007) to characterize reference watersheds. • The value <40% is the benchmark used by NETN Vital Signs to characterize park condition.	 + Tierney *et al*. (in press)
Landcover Change	**CAUTION** • 117% increase in urban lands within Park + 5-km buffer over period 1976-2002	Landcover change in the ACAD region, 1976-2002 (Table 3)
Forest Structure: Snag abundance* (NETN data)	**GOOD** • ≥ 10% all standing trees are snags and ≥ 10% all medium-large standing trees are snags (Plot-level data not available)	Tierney *et al*. (in press)
Forest Structure: CWD volume* (NETN data)	**CAUTION** • 19% plots GOOD • 24% plots CAUTION • 57% plots SIG. CONCERN	Forest plot-level data for four condition metrics (Table 18)
Forest Structure: Stand structural class*	**CAUTION / SIGNIFICANT CONCERN** • Measures proportion of late-successional stands; rank criteria depend on forest type. (Plot-level data not available)	Tierney *et al*. (in press)
Tree condition* (NETN data)	**GOOD** • 61% plots GOOD • 34% plots CAUTION	Forest plot-level data for four condition metrics (Table 18)

	• 5% plots SIGNIFICANT CONCERN	
Tree Health (Other data)	**CAUTION** • ≤22% of trees in Cadillac and Hadlock watersheds had signs of damage, measured using Forest Health Monitoring Protocol. • Hemlock woody adelgid – 2 recent outbreaks on MDI (trees removed). Other potential pest spp. (see p. 71). • Ozone causes leaf damage in several spp. and impacts radial growth in white pine. Ozone exposure causes reduced growth rate and/or tissue biomass in 3 out of 8 spp. tested. • Red spruce damaged by acid fog and rain.	See Threats sections: *Ozone; Atmospheric Deposition and Related Chemistry; Pests and Pathogens of Terrestrial Vegetation*
Terrestrial Invasive & Exotic Plants (Other data)	**CAUTION** • 25% ACAD plants are exotic (slightly less than value for entire state). Most of these exotic spp. are not aggressively invasive. • Invasive spp. more abundant on east side of MDI. • 24 spp. of potential concern as invasives (2004 study). • However, invasive plant density in monitored plots is lower at ACAD than at other parks in NETN (Tierney et al. in press)	 + Table 8; Fig. 64
Status of Rare Plant Populations	**CAUTION** • ACAD supports rare plant taxa, some of which occur nowhere else in Maine. • Although population trend data are not available for most rare species, the status of these plant populations is potentially threatened by a range of stressors. Trend data on rare plant populations is a critical need.	Table 7
Terrestrial Invasive Fauna	**CAUTION** • European fire ant established at multiple sites on MDI.	 (Fig. 66)
Forests: Deer Browse*	**GOOD / CAUTION** • Deer population currently below forage carrying capacity (but browsing impacts	See *Threats: Herbivory and Predation*

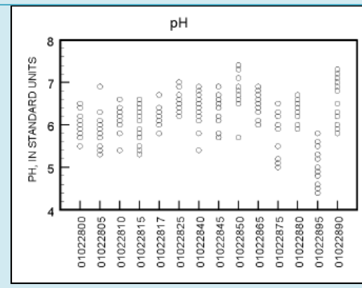
	plant height, species richness and densities in some areas). (NETN plot-level data not available)	
Forest Sensitivity to Nitrogen & Sulfur Deposition	**GOOD** • ACAD region generally not sensitive	 (Fig. 41)
Soil Chemistry: Acid Stress – Ca:Al ratio* (NETN data)	**CAUTION** • 32% plots: GOOD • 21% plots: CAUTION • 46% plots: SIGNIFICANT CONCERN	Forest plot-level data for four condition metrics (Table 18) + Tierney *et al*. (in press)
Soil Chemistry: Nitrogen Saturation – C:N ratio* (NETN data)	**GOOD** • 81% plots: GOOD • 16% plots: CAUTION • 3% plots: SIGNIFICANT CONCERN	Forest plot-level data for four condition metrics (Table 18) + Tierney *et al*. (in press)
Soil Chemistry: Hg	**CAUTION** • Most Hg is found in the organic horizon of soils; soils at burned sites had less Hg than soils at undisturbed sites which can have relatively large stocks of Hg. Soil Hg concentrations are within the range of other Northeastern sites (e.g., Grigal 2002, Demers et al. 2007); however, atmospheric deposition of Hg is elevated in the Northeast so these values could be considered high for rural sites.	Summary of Hg concentrations in environmental media (Fig. 47)
Birds: IBI Metrics *	*(Data not available)*	
Birds: Frequency of Occurrence *	*(Data not available)*	
Birds: Species Diversity *	*(Data not available)*	
Birds: Population Trends (resident spp.)	**UNKNOWN** • Increasing populations in 13% MDI spp. Decreasing populations in 2% spp. Insufficient data for 68% spp.	Resident birds: summary of population trends and information quality (Table 8)
Mammals: Deer Population Trends*	**CAUTION** • Deer population may be declining on MDI.	See *Threats: Herbivory and Predation*

Mammals: Other Population Trends	**UNKNOWN**	
Amphibian Population Trends	**SIGNIFICANT CONCERN** • Declining populations for 3 spp. (out of 12+ spp present in the Park). (1 salamander, 2 frogs).	 (Fig. 15)
Contaminants: Mercury and PCBs in Birds	**CAUTION** • The range of Hg in eagle blood (0.03 - 0.15 ppm, wet weight) was well below the threshold of 1 ppm. • The range of Hg in tree swallow eggs (0.097 - 1.313 ppm, wet weight) included some values that exceeded the threshold of 0.8 ppm. • High PCB levels in nesting bald eaglet blood and feathers (Matz et al. 1997)	 See Tables 19 and 20 for more information
Contaminants: Mercury in mammals	**GOOD** • The range of Hg in mink and otter fur (1.14 - 9.9 ppm, wet weight) was well below the proposed threshold of 30 ppm.	 See Tables 19 and 20 for more information

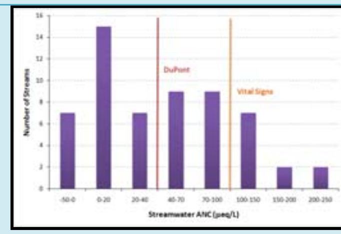
Streams

<table>
<tr><th>Metric</th><th>Condition</th><th>Data Summaries and/or Refs.</th></tr>
<tr><td>pH*</td><td>GOOD / CAUTION

• 1 out of 14 streams exhibits pH consistently < 6.0.

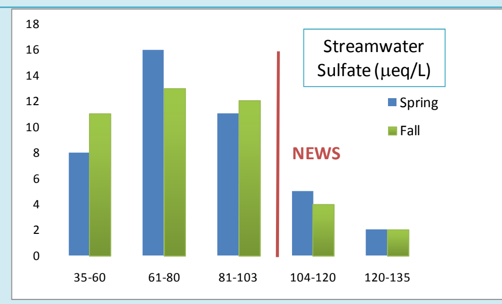
• Episodic acidification documented for several streams.</td><td>

(Fig 22)</td></tr>
<tr><td>ANC*</td><td>CAUTION

• Many streams have ANC < 40 ueq/L, the tolerance criterion of DuPont et al. (2005) for aquatic organisms (especially fish). However, NETN uses a more protective threshold of 100 ueq/L.</td><td>

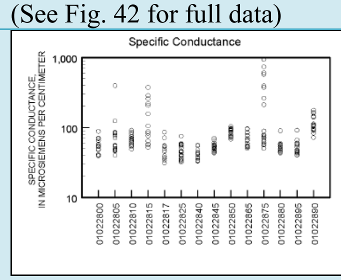
(Fig. 23)</td></tr>
<tr><td>Sulfate</td><td>GOOD

• Most sites exhibit lower SO_4 concentrations than NEWS reference condition of 104 ueq/L [12].

• Concentrations declining since 1980s (Kahl et al. 2004)</td><td>

(See Fig. 42 for full data)</td></tr>
<tr><td>Conductivity*</td><td>GOOD

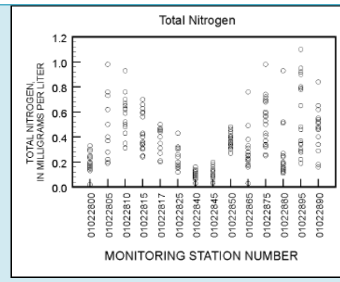
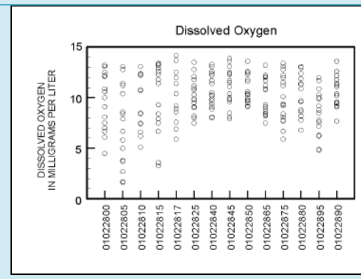
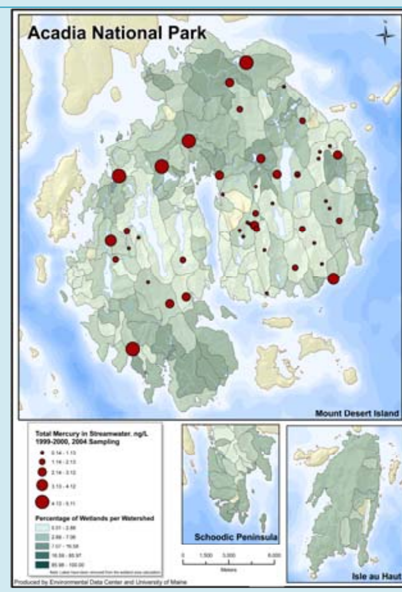
• 12 / 14 streams typically exhibit conductivities < 100 µS/cm [13]. Natural condition.

(NETN data not available)</td><td>

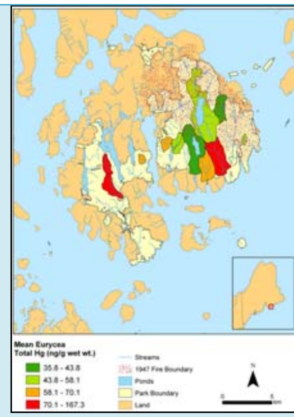
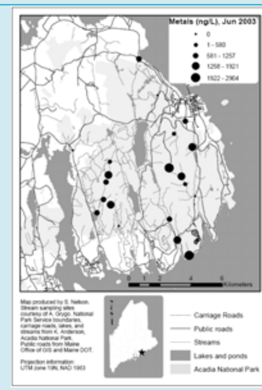
(Fig. 22)</td></tr>
</table>

[12] Threshold value (equivalent to 5 mg/L) that was judged to characterize “minimally stressed background sites” in New England Wadeable Streams Project, NEWS (Snook *et al.* 2007), based on human disturbance in a watershed, physical-chemical parameters, and biological responses.

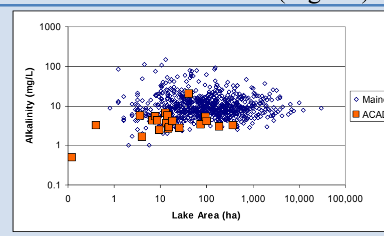
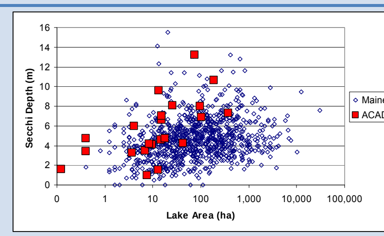
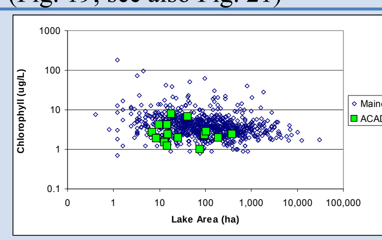
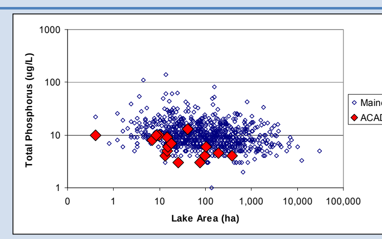
[13] Threshold value used by NEWS to characterize minimally disturbed sites. See footnote above for sulfate for more information.

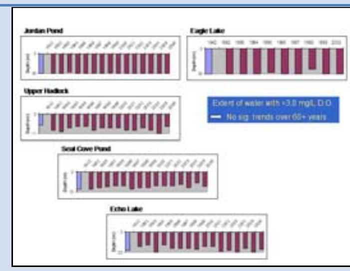
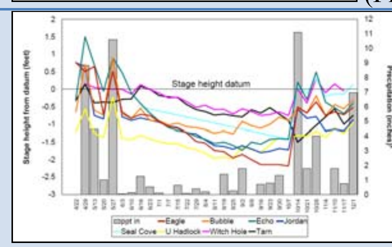
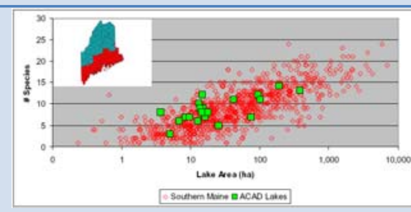
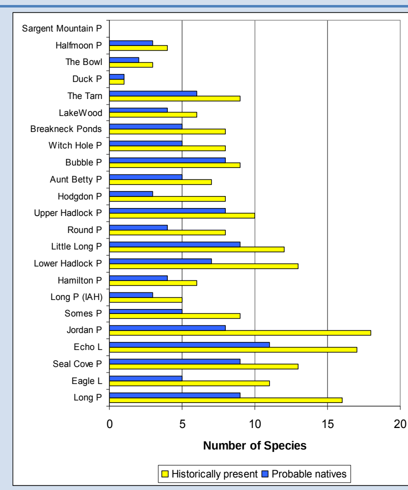
Total Nitrogen*	**CAUTION** • N concentrations in some streams are chronically elevated. • TN in 12/14 streams generally > 0.25 mg/L [14]. • TN in 3/14 streams consistently <0.38 mg/L. *(NETN data not available)* • Research at paired watersheds suggests some N saturation may occur at undisturbed, conifer-forested sites.	 (Fig. 22)
Minimum DO*	**GOOD** • Streams generally well oxygenated.	 (Fig. 22)
Water Temperature	**GOOD** • No evidence that temperature regimes differ from the natural condition.	
Trend in Flow*	**UNKNOWN**	
Mercury in Water	**SIGNIFICANT CONCERN** • 0/28 sampled streams exhibited Hg concentrations ≥ 7.5 ng/L; however, 10/28 had Hg concentrations greater than the average for Hadlock Brook, a site with elevated Hg in amphibians. • Hg is strongly related to DOC and episodic high flows and may exceed the NEWS reference condition; Hg at Hadlock Brook ranged up to 8 ng/L during high flow events. • Highest MDI concentrations are ~70% of maximum values observed in statewide survey. • Both Cadillac and Hadlock watersheds exceeded the MeHg level presumed to lead to biota body burdens >0.3 ppm during some periods (maxima: 0.28 ng/L (Cadillac) and 0.68 ng/L (Hadlock).	 (+ Fig. 47)

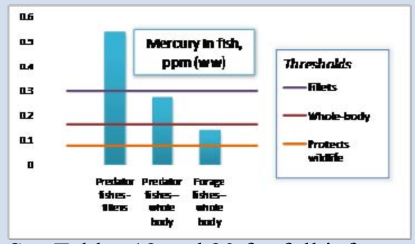
[14] NETN reference condition is <0.38 mg/L. NEWS reference condition is <0.25 mg/L as $NO_3 + NO_2$.

Mercury in Salamanders	**SIGNIFICANT CONCERN** • Average Hg in salamanders ranged 0.036-0.167 ppm (ww). In several watersheds, body burdens exceeded the 0.077 ppm criterion that most likely affords protection to predators of these species.	 (Fig. 48)
Other Contaminants	**GOOD** • VOCs and trace metal concentrations below detection and below acceptable ecological limits, respectively, in sampled streams. • Leachate from closed landfills is a threat to water quality in 2 streams.	 (Fig. 60)
Macro-invertebrates	**GOOD / CAUTION** • Bioassessments indicate that quality at many sites, although generally good, is slightly lower than the AA class designation for all ACAD streams. Two streams, Heath B. and Otter C., are degraded, based on the macroinvertebrate data.	Stream water quality attainment based on macroinvertebrate biomonitoring data (Table 14)
Fish Barriers	**SIGNIFICANT CONCERN** • 34% stream barriers block passage by aquatic organisms. 56% partially block passage.	See *Threats: Habitat Loss and Impairment*
Fish Assemblages	**CAUTION** • 1/3 stream fish species are non-native to MDI. • Diadromous species runs thought to be much smaller than historically.	Freshwater fishes in lakes and streams (Table 12)

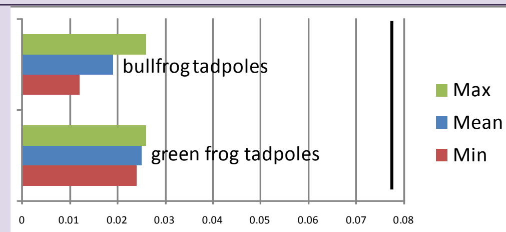
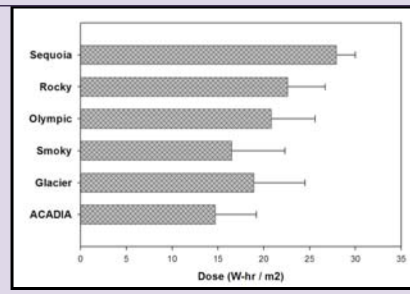
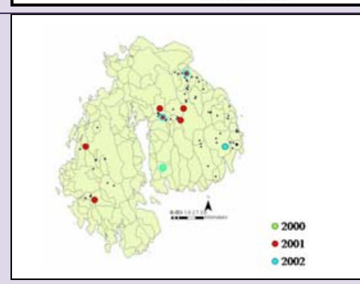
Lakes and Ponds

Metric	Condition	Data Summaries and/or Refs.
pH*	**GOOD / CAUTION** • Most lakes have pH > 6.0. Of the 2 ponds with pH < 5.0, one is naturally acidic. • No significant change in pH of ACAD lakes 1990-2000 despite sulfur emission reductions.	 (Fig. 16)
Alkalinity / ANC*	**CAUTION** • Alkalinity in most lakes is < 10 mg/L • Many lakes are naturally dilute; however, ANC has not increased in most lakes despite decreased acidic deposition. This is inconsistent with many lakes elsewhere in Maine and New England.	 (Fig. 19)
Transparency	**GOOD** • Most lakes are mesotrophic or oligotropic based on Secchi depths. • Larger ACAD lakes have higher transparencies than statewide population of surveyed lakes.	 (Fig. 19; see also Fig. 21)
Chlorophyll	**GOOD** • Lakes are mesotrophic or oligotropic based on chlorophyll concentrations.	 (Fig. 19)
Total Phosphorus*	**GOOD** • Epilimnetic TP concentrations generally < 10 ug/L. • No evidence of increasing phosphorus concentrations.	 (Fig 15)
Total Nitrogen*	**GOOD** • TN in 7/11 lakes < 0.24 mg/L. • TN in all lakes < 0.50 mg/L (except for marine-influenced Seawall Pond).	Seger *et al.* (2006)

Sulfate	**GOOD** • Significant decline in period 1900-2000, but less than in broader population of sensitive lakes in Maine.	Trends in selected lake water quality parameters (Table 12)
Surface Dissolved Oxygen*	**GOOD** • Surface waters are well oxygenated.	
Hypolimnetic Dissolved Oxygen*	**GOOD** • While some lakes exhibit low hypolimnetic DO in summer, there is no indication that levels of hypoxia have changed over the past 60 years.	 (Fig. 53)
Lake Water Levels*	**GOOD** (?) • No evidence for temporal trends in extent of drawdowns. • No evidence for adverse impacts on lake ecology from water level fluctuations, *but* there has been little research on this topic.	 (Fig. 62)
Loon Populations	**CAUTION** • Concern about reproductive rates on some lakes.	Loon populations on ACAD and Maine lakes (Fig. 26)
Fish: Species Richness	**CAUTION** • Some evidence that numbers of species in smaller ACAD lakes are higher than in similarly-sized lakes in southern Maine.	 (Fig. 29)
% Non-Native Fish	**CAUTION** • 15 / 28 ACAD species are thought to be non-native to MDI. • Illegal fish introductions are significant threat.	 (Fig. 25; see also Table 12)

Mercury in Fish	**SIGNIFICANT CONCERN** • Fish in ACAD lakes typically exhibit elevated tissue Hg concentrations, at levels higher or lower than statewide averages, depending on species. • All surveyed ACAD lakes had at least one fish sample for which fillet concentrations exceeded Maine advisory for human consumption.	 See Tables 19 and 20 for full information
Organic Contaminants in Fish	**GOOD (?)** • Low concentrations of PCBs and pesticides in 1993-94 survey. Entire park is at risk from organochlorines, but data are inadequate for full assessment.	
Invasive Plants*	**GOOD** • No aquatic invasive species currently in ACAD lakes. • Only one aquatic plant species appears to be non-native.	

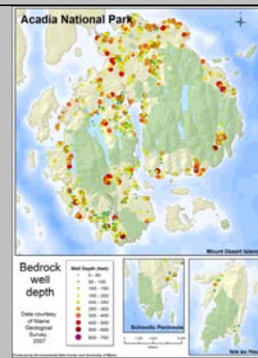
Wetlands (Freshwater and Saltwater)

Metric	Condition	Data Summaries and/or Refs.
Plant Spp. Richness*	**UNRANKED** • However, plant species richness higher in undisturbed wetlands.	Neckles *et al.* (2008) [15]
Water Quality*	**UNRANKED** • Conductivity and pH are both higher in disturbed wetlands – surface and ground water.	Neckles *et al.* (2008)
Mercury in Amphibians	**GOOD / CAUTION** • Hg in green frog (0.025±0.001 ppm, ww) and bullfrog (0.019±0.007 ppm ww) tadpoles was below the the 0.077 ppm criteria that most likely affords protection to predators of these species. However, population-level effects of these Hg burdens are unknown.	 See Tables 19 and 20 for full information
UV dosimetry	**GOOD / CAUTION** • UV dose to ACAD wetlands is lower than at wetlands in five other national parks. • However, there do not appear to be published data on impacts on UV in ACAD wetlands.	 (Fig. 35)
Amphibian Disease	**CAUTION** • Five major amphibian diseases recorded at ACAD. • Amphibian die-offs have been recorded and are apparently disease-related.	 (Fig. 67)
Multiple Stressors	**UNRANKED** • Neckles *et al.* (2008) used a multi-parametric index (SumRel) of anthropogenic stressors to classify all watersheds on MDI. Index includes following parameters: % agriculture, % urban, population density, road density, impervious surface. However, data are available only in draft report, so are not presented here. For selected observations of characteristics of reference vs. disturbed	Neckles *et al.* (2008)

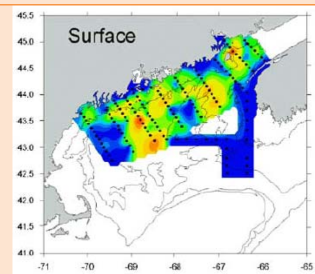
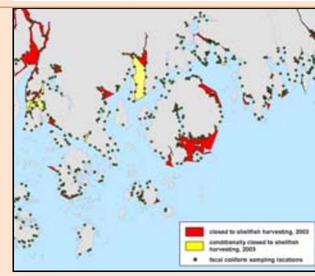
[15] The report by Neckles et al. (2008) is a draft; although referenced here, we do not include extensive data examples from this document.

	wetlands, see Plant Species Richness and Water Quality, above.	
Nutrient Loading to Wetlands and Estuaries	**SIGNIFICANT CONCERN / CAUTION / GOOD** • Eutrophication trend documented in Bass Harbor Marsh. • Potential for eutrophication, leading to degraded conditions, in Northeast Creek as a result of future development in watershed. • Anthropogenic nutrient loading and nutrient levels in Somes Sound do not represent a problem. Water quality in this estuary is good.	Nutrient loading and algal biomass in Bass Harbor Marsh (Fig. 54) Groundwater use and nitrate concentrations in selected sub-watersheds of the Northeast Creek system (Fig. 55)
Macoalgae Abundance in Estuaries	**SIGNIFICANT CONCERN** • Increasing abundance in Bass Harbor Marsh	
Other NETN metrics for freshwater wetlands: *Published data not available* Invasive plants. Landscape connectivity. Vegetation structure. Organic matter accumulation. Soil disturbance.		

Groundwater

Metric	Condition	Data Summaries and/or Refs.
Level*	**GOOD** • No evidence for trends of increasing depth to groundwater.	 (Fig. 24)
Specific Conductance*	**GOOD** • No evidence for increasing conductance in groundwater.	
Contaminants	**GOOD** • Most domestic and monitoring well samples from Bass Harbor Marsh and Northeast Creek watersheds contain few, if any, detectable contaminants (phenol is only contaminant detected). • Most well water samples contain arsenic at levels below the EPA maximum concentration. • Leachate from 2 landfills presumably present in surrounding groundwater (see item under Streams, above).	
Nutrients	**GOOD / CAUTION** • Groundwater in shallow, hyporheic zone, of Northeast Creek and Bass Harbor watersheds has elevated concentrations of dissolved nitrogen, perhaps indicating contamination from septic systems. • Nitrate concentrations in Northeast Creek watershed wells are below human health limit of 10 mg/L. except in one sub-watershed. • There is concern that increasing development may increase groundwater nitrogen levels in NEC and possibly other areas.	See *Threats: Nutrient Enrichment.*

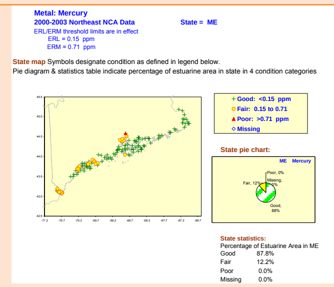
Marine Intertidal

Metric	Condition	Data Summaries and/or Refs.
Algal species†	**UNKNOWN** • Limited evidence of changes in vertical distribution limit for some taxa at one series of sites. • Insufficient data to document temporal trends in assemblage composition.	
Algal Blooms	**CAUTION** • Blooms occur and influence the shellfishing industry in the Gulf of Maine.	 (Fig. 57)
Shellfish Closures	**SIGNIFICANT CONCERN** • Areas are closed to shellfishing because of sewage-based contaminants and, at times, toxins from algal blooms.	 (Fig. 59)
Invertebrate Community Composition †	**UNKNOWN** • No information on temporal trends in marine invertebrate communities or populations. • Ongoing studies will provide important base data.	
Human trampling† (excl. caves)	**UNKNOWN** • Ongoing studies will provide important base data.	
Invertebrate Communities of Cave Tide Pools	**SIGNIFICANT CONCERN** • Trampling visitors likely impacts anemones and other species in Anenome Cave.	See *Threats: Visitor Impacts on Intertidal Areas*
Invasive species	**SIGNIFICANT CONCERN** • Several marine invasives currently exist in or near the ACAD area, including the Asian shore crab and green crab.	See *Threats: Invasive Marine Species*

<table>
<tr><td>Eelgrass</td><td>CAUTION

• Some evidence (anecdotal) from MDI area that eelgrass beds have been disrupted by mussel dragging and other activites.

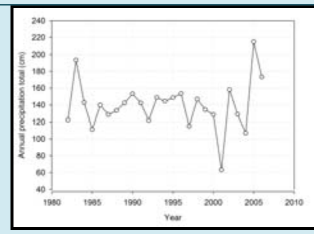
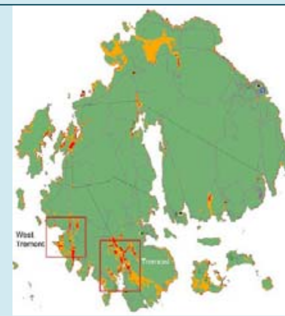
• Documentation of reduced eelgrass beds in the neighboring Penobscot Bay.</td><td> (Fig. 32)</td></tr>
<tr><td>Sediment Contaminants (off-shore)</td><td>GOOD

• Levels of measured contaminants generally low in the MDI area.</td><td>

(Fig. 51)</td></tr>
<tr><td>Fish Assemblages</td><td>GOOD (?)

• No evidence from available data that fish assemblages are in ‘degraded’ form.</td><td></td></tr>
</table>

Climate - Related

Metric	Condition	Data Summaries and/or Refs.
Precipitation patterns (changes in total amount and temporal distribution)	*Unranked*	 (Fig. 10)
Precipitation type (proportion of snow to rain)	*Unranked*	
Temperature	*Unranked*	
Sea level rise†	**SIGNIFICANT CONCERN**	 (Fig. 68)
Phenology (plant, bird, amphibian)†	*No data*	
Climate-induced species range shifts	*No data for ACAD*	

Conclusions and Information Needs

This section addresses information richness and information needs as they relate to the natural resources of the Acadia region. We first provide an overview of the 'status' of resource inventories. Secondly, we identify a series of key data gaps which, if filled, would improve understanding of the interrelationships between stressors and ecosystem responses at ACAD. This added information would also make possible a more rigorous and quantitative assessment of status and trends in resource condition based on a broad range of ecosystem attributes.

Biological resource inventories

Based on our review of available information, and discussions with ACAD staff and external researchers, we have attempted to characterize the level of completeness for biological resource inventories at ACAD, as well as information on trends in species composition and relative abundance.

Terrestrial Plants*:* Inventory of MDI vascular plants is relatively complete. Plant species lists for SCH and IAH are incomplete. Lichens have been well inventoried. Knowledge of mosses and ferns is sparse. Overall, there is little information on species-habitat relationships at ACAD. While rare plants have been well surveyed on MDI, there is little follow-up information on the status of rare plant populations.

Freshwater Plants: Vascular macrophytes were well surveyed over a decade ago; contemporary information is sparse. There are no contemporary macrophyte data from Long Pond on IAH. Populations of the several rare aquatic plant species have generally not been re-surveyed to document current status. There is little information on lake phytoplankton populations.

Wetland and Estuarine Plants: Species lists are probably relatively complete for the ACAD region as a whole. Until recently, quantitative data on community composition and relative abundance at individual wetlands or for wetland classes has been less available. As part of the NPS Vital Signs Monitoring Program, the Northeast Temperature Network has developed detailed freshwater wetland monitoring protocols that will now produce good information on status and trends of wetland vegetation and water chemistry (Neckles *et al*. 2007). For estuarine systems, plants in Bass Harbor Marsh were surveyed over a decade ago. More recent data are available for plants in Northeast Creek, and methods for assessing the condition of submerged aquatic vegetation in Bass Harbor Marsh and Northeast Creek estuaries are under development.

Marine Algae: Detailed surveys of rocky intertidal and mudflat algae have been completed at a few sites on MDI. The degree to which these sites are representative of the entire ACAD region is unknown. Ongoing surveys are developing information on coastal flora at SCH. Little is known about the marine flora at IAH and other islands.

Birds: The species list is relatively complete for the ACAD region. However, new surveys may find additional owl species – indeed, compared to other groups, we probably know the least about the owls of the ACAD region. For most bird species, there is little information on population sizes and trends, as well as responses to many environmental stressors.

Mammals: The species list is probably complete for the ACAD region. There is information on population size and trends for some species but not for many others.

Amphibians and Reptiles: The species list for the ACAD region is likely complete. Recent survey data, including information on relative abundance, are available.

Freshwater Fish: Presence/absence survey data are available from most lakes, ponds and streams on MDI. Population size and trend data are incomplete and the information is generally less readily accessible. Current monitoring of freshwater fish assemblages may not be sufficiently frequent or rigorous to detect species additions (for example, bait-bucket introductions).

Estuarine Fish: Three studies have investigated fish assemblages in Bass Harbor Marsh; two of these are over a decade old, while more recent data are those of Jordaan (2006). Information includes both species lists and relative abundance, as well as a number of other assemblage and population-level data. Fewer data are available from the Northeast Creek estuary, although some collections were made in the late 1990s.

Intertidal and Marine Fish: Intertidal and tidepool fish assemblages were surveyed in the early 2000s. There are detailed survey data on sub-tidal fish assemblages, including relative abundance (catch per unit effort) for many taxa.

Aquatic Invertebrates: Survey data on stream macroinvertebrates are available from a few sites on MDI. These data are collected with a standardized methodology, potentially permitting future inter-site and inter-year comparisons as the database expands. Data on lake benthic macroinvertebrates are very sparse – most of the information is from >50 years ago and these data are, for the most part, at the family or genus level. Damselflies and dragonflies (Odonata) have been reasonably well surveyed on MDI; many data have been collected in the past 10 years. Mayflies (Ephemeroptera) were well surveyed in the 1990s. (Note that most odonate and mayfly specimens have been collected as adults and therefore not in their aquatic life stage.) Some freshwater mussel collections have been made. Although many waterbodies have not been surveyed, it is likely that the mussel species list for the ACAD region is complete because of the relatively low species richness of this group. Data on the macroinvertebrates of wetlands and estuaries are sparse. Intertidal invertebrates have been quantitatively surveyed at a few sites on MDI. There are ongoing surveys of intertidal invertebrates at SCH. There is little information from IAH.

Current research is developing zooplankton data for some ACAD lakes. There are virtually no historical assemblage-level zooplankton data – data collected in the early 1940s are of limited use in terms of temporal comparisons since most identifications were, at the best, only to the genus level.

Data on groups of invertebrates that are associated with freshwaters have been integrated into a composite database (that has statewide coverage) (Vaux 2005). However, other invertebrate data from the Park do not currently reside in a centralized database, including the NPSpecies database.

Terrestrial Invertebrates: The Procter surveys from over 60 years ago are a rich information base on terrestrial invertebrates. Changes in taxonomy, however, complicate comparisons to more contemporary data sources (for example, for mayflies). Recent bioblitzes have generated useful species lists for ants, beetles, butterflies, flies, true bugs, and spiders. Except for ants (collections made on MDI), these bioblitzes have all occurred at SCH over a short time period. Their data, while valuable, may not represent a complete picture of species richness for these groups for ACAD as a whole. Relatively contemporary data on other invertebrate groups is patchy.

Trends in Species Composition and Relative Abundance: For virtually all floral and faunal groups, there is a dearth of information on trends in species composition and relative abundance for individual habitats. For example, over 20% of taxa in the catalogue of the vascular plants of the Acadia region are historic records and have not been documented in the area since 1980 (Greene *et al*. 2005). Trends in population sizes of birds and many other faunal groups are also largely undocumented. Understanding "natural" patterns of variance in the composition and relative abundance of species assemblages is critical to being able to evaluate status and trends. Currently, there is very little known about components of variance in plant and animal populations at ACAD.

Rare Species: Although there are relatively detailed survey data on rare plant taxa, there is little information on temporal trends in the presence and status of individual populations. Of particular importance is the impact of Park use by visitors on rare plants. For non-vascular plant groups, there is a need to better understand the distribution and status of rare species.

Threat and Condition Assessments: Information Needs

We developed a list of information needs through (i) discussions with ACAD and external researchers, (ii) a series of meetings organized by Acadia Partners and NPS to provide input to the development of a research opportunities catalogue for ACAD, and (iii) our review of the scientific literature. The latter includes several review documents that include statements of information needs, for example Haines and Webber (1999), Maniero and Breen (2003), Kahl *et al*. (2000) and Connery (1998). Note that the information needs reviewed here focus principally on issues related to the assessment of threats and resource condition.

For some threats and stressors, available information is largely limited to measures of their presence and, sometimes, spatial and/or temporal patterns; there is often little known about the effects of a stressor or the mechanisms whereby these effects are occurring. For example, loading of contaminants transported to the Acadia region via the atmosphere are, in general, fairly well known. The effects of these contaminants on the biota of ACAD are much less well understood. Mercury is one contaminant for which there is a reasonable amount of information on tissue concentrations. Nonetheless, there is little quantitative documentation of the impacts of mercury body burdens on faunal physiology, behavior, population dynamics and community-level interactions. Another example is exotic plants, for which there are relatively extensive survey data. However, the ways in which these species affect non-native taxa are, on the whole, poorly documented.

Whereas the MDI unit of the park is well-studied, very little information exists for other areas of the Park. The Schoodic peninsula, in particular, is under-studied. Streams, wetlands, and ponds on SCH have very little baseline monitoring, and represent interesting systems very closely coupled to the marine environment. In addition, there is currently some development pressure on park boundaries at SCH (as on MDI) and the effects of land-use change on in-Park resources for the Schoodic section have not been modeled to the same extent as those on MDI (if at all).

For some threats, research currently in progress (or recently completed but not yet published) will likely fill some key information gaps. Examples include the trampling effects of visitors on rocky intertidal flora and fauna, the landscape-level attributes of disease patterns in amphibians, and stream barriers that impede passage by fish and other aquatic organisms.

The following list of key information needs is largely structured around the series of threats addressed earlier in this report. However, it should be underscored that there are many inter-relationships among many of the topics.

Contaminants: Many of the contaminant-related information needs address issues associated with the inter-relationships between contaminants, watershed geochemistry, and landscape structure, including changes in land use and land cover.

Ozone: Data on the ozone impacts on terrestrial vegetation derive principally from sites on the eastern-facing sites of MDI. Data are needed from sites with other aspects since these may represent greater exposure to ozone (Haines and Weber 1999).

Mercury: Fog at Acadia has never been studied for Hg. Evidence from Nova Scotia indicates very high concentrations of Hg in fog on islands and the coast as compared to an inland site. This potentially large contribution of Hg to ACAD's ecosystems is unknown at this point.

There is a strong record of research regarding Hg in biota (body burdens) and in watershed components such as soil, litter, precipitation, and streams. However, the link between high levels of Hg in the environment and population-level effects of these high levels has not yet been made. Park Service officials have expressed interest in knowing whether the high Hg levels observed at the Park are having an observable effect. Further investigation into the mobility and transformations of Hg in Acadia's ecosystems could help us to understand whether there is cause for concern at sites that otherwise may be predicted to have low Hg deposition.

ACAD presents a unique template for Hg research, because of the marine influence. Some species of Hg in the environment include chloride, and could be affected by proximity to the ocean. It is unknown at this point whether proximity to the ocean affects Hg deposition, mobility, or processing in the terrestrial environment. In addition, some researchers have proposed that Hg may be re-emitted from oceans. To date, no research has identified the relative contribution of Hg from oceans as compared to Hg from inland sources.

Road salt: Recent research elsewhere has focused on the effects of road salting. Though studies on road salt have been conducted at ACAD, some research suggests that there could be temporal changes in road salt application methods and amounts that might be resulting in changes in salt loads. In addition, other research suggests that increases in salt loads may occur where there is increased housing/residential development. Developing a salt budget for Acadia will determine whether road salt might be an issue for the park, or if the proximity to the ocean makes this concern a non-issue.

Other contaminants: Some contaminants at ACAD have been little researched. Organochlorines are one example.

Hydrology and Water Quality: Several sites in the park have had stream gauges, lake level monitoring stations, or groundwater monitoring wells. However, in general, basic information regarding surface and groundwater hydrology is quite sparse.

The Park has an extensive water chemistry database for streams and lakes. However, long-term monitoring of streams is limited – streams have more typically been surveyed (temporal snapshot) or monitored for a few years, then programs are discontinued. Measuring the response to climate change, chemical interactions, and loading of pollutants requires ongoing monitoring without major changes in methodology.

Nutrient Enrichment: Atmospheric deposition is a major source of N for terrestrial and aquatic systems. Impacts of nitrogen enrichment on ACAD forests need to be better understood. The ecosystem-level ramifications of elevated N levels in ACAD streams are poorly understood. Primary production in many ACAD lakes would appear to be limited by P, rather than by N. Nutrient bioassays are needed to quantify nutrient limitation in freshwater ecosystems. Although there has been some work looking at the impacts of development on nutrient loading, much more needs to be known about how the spatial distribution and scale of various land-use classes influences nutrient loading to freshwater and estuarine systems. The potential impacts of finfish aquaculture in the ACAD region need to be better understood.

Wetlands Extent and Condition: Acadia's landcover includes a large proportion of wetlands and many vernal pools that are not always counted in wetland maps/analyses. Improved document and monitoring of the spatial distribution of vernal pools is of particular importance.

The chemistry of wetlands is largely unknown, particularly as compared to streams and lakes. Data collected during development of a wetlands monitoring protocol (Neckles *et al*. 2008) and to be collected by the Northeast Temperate Network's monitoring program will fill some of this gap.

Exotic Species: There is a need to know which exotic species represent threats to native fauna and flora, and what the competitive mechanisms are. This information is critical for developing and prioritizing management strategies. Rapid bioassessments for invasive species provide a potentially valuable tool for detecting problems at ACAD.

Management of Native Fauna: The impacts of current and future management activities on the status native animals in the Park need study. Examples include freshwater and diadromous fisheries and deer. Harvest (creel census) data are needed for MDI's lake fisheries.

Disease: Emerging patterns of disease transmission into and among ACAD fauna and flora need increased research. This includes monitoring of forest pests – about which there is currently very little information – and a better understanding of the susceptibility to disease of forest stands of differing age and composition.

Habitat Fragmentation: The impacts of habitat fragmentation and circum-Park development on the biological resources of the Park are likely multi-dimensional and do not appear to have been substantively addressed. One exception is the impacts of land-use change on water quality and habitat integrity of the Northeast Creek system. Fish passage is an example of an issue where data already exist on the extent of fragmentation (by dams and poorly constructed and/or maintained culverts). Initial stream crossing evaluations have not only evaluated crossing structures, but have also characterized the extent of upstream habitat, as well as various economic and ownership attributes. This information provides an excellent foundation for further investigating and prioritizing stream restoration in the Acadia area.

Ecosystem-Level Linkages between Park and Non-Park Lands: Since many watersheds on MDI cross park boundaries, there is a need to better understand and quantify how land management activities on non-park lands influence park resources. Nutrient loading from development has been mentioned above. Another example is the role of private lands in providing connectivity between habitat patches on park lands.

Synergistic Effects from Multiple Stressors: This is significant area of research which has been scarcely tapped at ACAD.

Effects of Climate Change: Recent research in Maine has suggested that there has been less snow and a warming trend, based on 50 years of climate and hydrologic data (Huntington *et al*. 2004, Huntington 2003, Hodgkins *et al*. 2003). We are not aware of any studies that explore what the effects of these climate changes might be on Acadia's ecosystems. Because the Park is located at an ecotone, with many species being either at their southernmost boundary or their northernmost boundary, species shifts could potentially occur. It is important to identify unique habitats in and around ACAD that are likely to be especially vulnerable to climate change.

Restoration Opportunities, Approaches and Evaluations: Effective approaches for restoring degraded plant and animal populations merit investigation and evaluation; candidate approaches need to be implemented and compared. The example of fish passage in streams, noted above, is an excellent example of restoration opportunities, backed by a methodology that provides a quantitative basis for prioritization.

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Appendices

Appendix 1.
Land use / land cover statistics by watershed cluster.

Watershed clusters are groups of small watersheds – cluster level C in Figure 4. Except for some coastal watersheds, clusters are defined by hydrology.

Small watersheds include named and unnamed watersheds (Perrin 1996). For MDI watersheds, the following list identifies named watersheds by their cluster number in the table, below. (For each cluster, individual watersheds appear in order of size.)

Land use/cover data are derived from the USGS / NPS Vegetation Mapping Project (Lubinski *et al*. 2003).

MD1:1	Jones Marsh, North Coast
MDI:2	Customhouse, Schooner Head, Great Head, Meadow Brook, Bar Harbor, Compass Harbor, Eddie Brook.
MDI:3	Little Hunters Brook, Seal Harbor, Blackwoods, Otter Point, Northeast Harbor.
MDI:4	Brown Mountain, Sargent Cove, Browns Brook, Monument Cove Drainage, Norumbega, Squantum Point.
MDI:5	Somesville, Man o'War Brook, Valley Cove, Acadia Mountain.
MDI:6	Seawall Pond, Fernald & Norwood Cove, Hutchins Brook, Southwest Harbor.
MDI:7	Halfway Brook, Cousins Creek, Webster Brook, Richtown, Tinker Brook, Moosehorn Brook, Duck Cove Brook, Seal Cove, Bernard, Bass Harbor Head, Goose Cove.
MDI:8	Stewart Cove South, Pretty Marsh, Goose Marsh, Bartlett Narrows.
MDI:9	Smiths Brook, Meadow Brook, Prays Brook, Western Bay.
MDI:10	Faun Pond, Lake Wood, French Hill Pond & Brook, Aunt Betsey's Brook, Hamilton Pond & Stony Brook, Old Mill Brook, Fresh Meadow Marsh.
MDI:11	Breakneck Ponds, Breakneck Brook.
MDI:12	Halfmoon Pond, Duck & Witch Hole Brooks, Witch Hole Pond, Bubble Pond, New Mill Meadow, Eagle Lake.
MDI:13	Cromwell Brook, The Tarn, Great Meadow, Kebo Brook.
MDI:14	Bear Brook Pond, Bear Brook.
MDI:15	The Bowl, Otter Creek & Canon Brook.
MDI:16	Hunters Brook.
MDI:17	Stanley Brook.
MDI:18	Sargent Mountain Pond, Little Long Pond, Jordan Pond.
MDI:19	Little Harbor Brook.
MDI:20	Hadlock Brook, Lower Hadlock Pond, Upper Hadlock Pond.
MDI:21	Sargent Brook.
MDI:22	Chasm Brook, Gilmore Meadow, Heath Brook & Sunken Brook, Richardson Brook, Aunt Betty Pond.

MDI:23	Tavern Brook, Babson Creek, Kitteredge Brook.
MDI:24	Mill Pond, Ripple Pond, Duck Pond & Brook, Round Pond, Little Round Pond, Great Brook, Somes Pond, Long Pond.
MDI:25	Little Echo Pond, Echo Lake.
MDI:26	Lurvey Brook, Heath Brook, Buttermilk Brook, Bass Harbor Marsh, Adams Brook, Marshall Brook.
MDI:27	Flyes Brook, Steward Brook, Hodgdon Brook & Pond, Seal Cove Pond.

Watershed Cluster	**Area**		**Residential, Commercial, Transportation, Built-up (11+12+14+16+17)**		**Agricultural, Rangeland (shrub, brush) (24+31+32)**		**Rock, Quarries, etc. (74+75)**		**Deciduous Forest (41)**		**Evergreen Forest (42)**	
	Whole Cluster (ha)	*% Park*	% Whole	*% Park*	% Whole	*% Park*	% Whole	*% Park*	% Whole	*% Park*	% Whole	*% Park*
MDI:1	1221	9.9	23.1	*10.0*	4.8	*0.3*	1.4	*0.0*	4.3	*9.1*	17.3	*22.2*
MDI:2	950.5	56.6	31.8	*2.4*	1.2	*2.1*	1.7	*2.3*	33.1	*53.2*	5.2	*8.2*
MDI:3	1148.8	38.3	33.0	*7.0*	1.2	*1.6*	1.7	*3.0*	3.6	*8.4*	31.2	*44.7*
MDI:4	814	55.5	10.5	*1.9*	3.2	*1.0*	0.1	*0.0*	0.6	*0.6*	48.8	*62.8*
MDI:5	717.9	33.1	12.6	*0.1*	4.0	*2.2*	2.1	*0.4*	1.2	*2.7*	26.8	*40.0*
MDI:6	1432.5	22.0	32.2	*7.9*	4.2	*3.0*	0.8	*0.5*	0.1	*0.0*	27.2	*36.7*
MDI:7	1813.2	12.3	20.6	*1.5*	9.1	*2.8*	1.4	*2.3*	0.0	*0.0*	50.8	*81.5*
MDI:8	989.5	4.0	6.8	*0.8*	5.3	*0.0*	0.7	*0.0*	0.3	*0.0*	51.1	*59.0*
MDI:9	1238.2	0.0	7.8	*0.0*	2.5	*0.0*	0.6	*0.0*	1.9	*0.0*	41.5	*0.0*
MDI:10	2584	27.5	4.7	*0.1*	8.0	*1.3*	1.6	*0.0*	9.7	*18.2*	11.8	*5.2*
MDI:11	382.3	97.9	0.7	*0.1*	1.2	*1.3*	0.0	*0.0*	34.0	*34.1*	5.7	*5.8*
MDI:12	1480.8	85.7	1.4	*1.6*	3.1	*3.6*	0.2	*0.2*	18.0	*20.9*	21.9	*25.5*
MDI:13	757.5	79.6	11.1	*2.1*	2.8	*2.2*	0.2	*0.2*	44.3	*51.1*	17.8	*21.6*
MDI:14	142.7	64.4	11.8	*2.1*	0.1	*0.1*	0.0	*0.0*	39.6	*47.4*	18.4	*26.1*
MDI:15	901.5	83.7	8.2	*1.0*	7.6	*8.6*	0.1	*0.1*	37.0	*39.6*	18.1	*20.6*
MDI:16	587	94.7	0.6	*0.5*	2.6	*2.8*	0.5	*0.5*	6.8	*7.1*	38.0	*38.8*
MDI:17	378.6	63.4	11.3	*3.2*	1.2	*1.3*	0.4	*0.3*	3.1	*4.8*	44.4	*40.4*
MDI:18	834.2	62.9	1.3	*0.8*	9.9	*13.9*	0.4	*0.7*	11.8	*18.8*	33.1	*35.4*
MDI:19	356.1	61.0	0.2	*0.0*	7.5	*12.3*	0.0	*0.0*	2.2	*3.6*	24.5	*23.8*
MDI:20	548.2	79.7	5.9	*1.3*	7.5	*9.4*	0.0	*0.0*	0.9	*1.1*	46.0	*49.8*
MDI:21	379.2	70.4	2.3	*0.0*	2.7	*3.5*	0.7	*0.0*	6.5	*6.6*	18.0	*22.1*
MDI:22	976.4	83.5	2.5	*0.7*	3.4	*2.4*	0.1	*0.1*	21.1	*23.4*	14.7	*16.8*
MDI:23	759.3	7.8	4.5	*0.1*	4.2	*0.0*	1.2	*0.0*	2.8	*22.1*	22.9	*5.0*
MDI:24	2338.3	33.9	3.9	*0.1*	1.7	*0.5*	0.2	*0.1*	3.7	*2.1*	25.3	*46.7*
MDI:25	833.9	38.7	6.9	*2.3*	2.9	*0.5*	0.9	*0.0*	3.3	*3.1*	23.7	*49.3*
MDI:26	2173.9	63.9	4.3	*0.3*	1.9	*0.8*	2.4	*0.0*	0.0	*0.0*	45.9	*45.3*
MDI:27	1249	60.1	4.2	*0.3*	4.7	*2.1*	0.2	*0.0*	0.4	*0.1*	44.0	*50.7*
MDI:Total	**27988.5 ****	**44.8**	**10.4**	**1.4**	**4.2**	**3.1**	**0.9**	**0.4**	**8.4**	**15.4**	**29.4**	**33.2**
SCH:50 ***	1961.9	41.2	3.9	*2.9*	4.2	*7.1*	2.2	*4.0*	0.7	*0.2*	70.0	*75.7*
IAH:60	2297.1	46.1	3.3	*0.1*	1.6	*0.6*	2.0	*2.0*	0.1	*0.0*	70.6	*77.0*
Islands:70	264		2.1		8.1		7.2		3.5		49.6	

Watershed Cluster	Mixed Forest (43)		Forested Wetland (61)		Nonforested Wetland, Bays and Estuaries (62, 54)		Lakes (52) *	Great Ponds (>10 acres) *
	% Whole	*% Park*	% Whole	*% Park*	% Whole	*% Park*	% Whole	% Whole
MDI:1	39.8	*50.5*	3.8	*0.4*	5.5	*7.5*	0.0	1.0
MDI:2	21.6	*22.8*	3.0	*5.3*	2.5	*3.7*	0.0	0.0
MDI:3	26.7	*33.2*	1.0	*1.1*	1.6	*1.0*	0.0	0.0
MDI:4	30.9	*29.7*	3.5	*3.3*	2.4	*0.7*	0.0	0.0
MDI:5	49.3	*51.2*	3.0	*2.3*	1.1	*1.1*	0.0	0.0
MDI:6	26.3	*32.2*	8.1	*18.3*	1.2	*1.5*	0.0	0.0
MDI:7	12.5	*6.5*	3.1	*3.7*	2.6	*1.8*	0.0	0.0
MDI:8	28.1	*36.9*	3.5	*2.1*	4.1	*1.2*	0.4	0.0
MDI:9	40.3	*0.0*	2.9	*0.0*	2.4	*0.0*	0.0	0.0
MDI:10	48.4	*46.6*	11.7	*21.0*	4.1	*7.7*	0.0	0.9
MDI:11	49.9	*50.1*	3.6	*3.7*	4.8	*4.9*	0.0	2.2
MDI:12	36.1	*42.0*	4.0	*4.6*	3.6	*1.6*	11.9	13.4
MDI:13	16.5	*14.7*	4.2	*5.2*	3.2	*2.8*	0.0	1.0
MDI:14	23.4	*15.3*	1.4	*1.3*	5.2	*7.7*	0.0	0.0
MDI:15	25.1	*26.3*	2.4	*1.9*	1.6	*1.8*	0.0	0.5
MDI:16	51.1	*49.9*	0.4	*0.3*	0.2	*0.2*	0.0	0.0
MDI:17	37.6	*46.8*	1.5	*2.4*	0.5	*0.7*	0.0	0.0
MDI:18	29.2	*28.2*	2.2	*1.1*	3.0	*0.7*	9.0	10.7
MDI:19	64.7	*60.0*	0.8	*0.2*	0.0	*0.0*	0.0	0.0
MDI:20	31.7	*35.4*	1.8	*2.0*	6.3	*1.0*	0.0	5.5
MDI:21	67.3	*65.9*	1.9	*1.0*	0.7	*0.8*	0.0	0.0
MDI:22	44.3	*41.7*	11.3	*12.1*	2.6	*2.9*	0.0	1.3
MDI:23	52.0	*67.1*	12.2	*5.8*	0.1	*0.0*	0.0	0.0
MDI:24	41.7	*46.8*	4.4	*3.1*	0.7	*0.0*	18.7	18.9
MDI:25	48.2	*42.4*	2.0	*2.1*	0.7	*0.0*	11.4	12.0
MDI:26	30.8	*35.4*	10.7	*14.6*	3.9	*3.5*	0.0	0.0
MDI:27	32.0	*42.2*	4.1	*4.1*	0.7	*0.3*	9.7	9.7
MDI:Total	**35.6**	**38.0**	**5.2**	**6.2**	**2.5**	**2.2**	**3.2**	**3.7**
SCH:50 ***	9.6	*1.8*	2.0	*3.6*	3.8	*4.7*	0.0	0.4
IAH:60	15.8	*13.4*	4.3	*5.0*	2.1	*1.7*	1.2	1.2
Islands:70	22.4		0.4		6.6		0.0	

* The NPS vegetation map classifies lakes and ponds as mix of nonforested wetlands (smaller waterbodies) and lakes (larger waterbodies). The column "Great Ponds" provides data on all lakes >10 acres (0.4 ha) - these data were derived from a separate GIS coverage of hydrography and should not be summed with vegetation map landcover classes.
** Total area for MDI excludes small 'sliver' polygons in GIS coverage that are not incorporated into the cluster framework.

*** Vegetation map landcover data do not include entire watersheds; thus landcover percentages do not sum to 100%.

Appendix 2

Legislative background and management objectives

Acadia National Park was established in 1916 as the Sieur de Monts National Monument. In 1919, the park was renamed Lafayette National Park, and again in 1929 when it was given its current name. The 1929 legislation also authorized expansion of the park, and in 1986 the permanent boundary was established. Legislation in 2001 authorized 'the re-incorporation into ACAD of lands that were formerly part of the Park but which were subsequently used for military purposes' on the Schoodic Peninsula (National Park Service 2004). The National Park Service acquired land on IAH in 1943 (Marion 2006).

The following discussion is taken from Kahl *et al*. (2000) with updates.

Federal Legislation

• *National Park Service Organic Act (1916)* - The Organic Act specifies that the National Park Service is responsible for the preservation and conservation of natural resources in all park lands under its jurisdiction. This act was reinforced by Congress in 1970 with legislation stating that all park lands are united by a common purpose, regardless of title or designation. Hence, all water resources in the National Park System are protected by federal law, and it is the fundamental duty of the National Park Service to protect those resources unless otherwise indicated by Congress.

• *Federal Water Pollution Control Act (Clean Water Act) 1972 and Amendments (1977, 1987)* - This law is designed to restore and maintain the chemical, physical and biological integrity of the nation's waters. As part of the act, Congress recognizes the primary role of the states in managing and regulating the nation's water quality within the general framework developed by Congress. All federal agencies must comply with the requirements of state law for water quality management, regardless of jurisdictional status or land ownership. States are directed to implement the protection of water quality through best management practices and water quality and technology-based standards.

• The *1990 Clean Air Act Amendments* were designed to reduce acid rain and improve public health by reducing emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) from industrial sources. Phase 1 reductions were implemented in 1995 and Phase II was implented in 2000. U.S. EPA reports that as of 2005, power plant emission reductions were >7 million tons, representing 41% reductions from 1980 levels (www.epa.gov). ACAD region lakes and streams are generally poorly buffered and sensitive to acidic deposition. Therefore, they have been monitored to characterize 'recovery' from acidic deposition, both by academic researchers and the NPS resource management division.

• *Safe Drinking Water Act (1974) and Amendments (1986)* - This act sets national minimum water quality standards and requires regular testing for developed public drinking water supplies. Most significantly for MDI, the act requires filtration for all uncovered public surface drinking water supplies. Waivers from filtration require evidence of adequate watershed control and protection. This requirement affects one municipal and three private water companies on MDI who draw their waters from lakes and watersheds within or adjacent to the park boundary.

• *Coastal Zone Management Act (1972) and Amendments (1990)* - This federal act provides assistance and encouragement to coastal states in the effective protection and careful development of the coastal zone. Maine's coastal program was approved in 1978 and is administered by the Maine State Planning Office (SPO), with other regulatory functions carried out by the Department of Environmental Protection, Department of Marine Resources, and Department of Economic and Community Development. In Maine, all federal properties are excluded from the state's designated coastal zone. However, any park activity with an off-site impact on the coastal zone must be consistent with Maine's coastal zone management plans.

• *Water Quality Improvement Act (1970)* - This act requires federally regulated activities to have state certification that they will not violate water quality standards.

• *Endangered Species Act (1973)* - This act provides for the conservation, protection, restoration, and propagation of selected native species that are threatened with extinction. All entities using federal funding must consult with the Secretary of the Interior (through the U.S. Fish and Wildlife Service) on activities that potentially affect federally listed flora and fauna.

• *National Environmental Policy Act (1969)* - This law requires systematic analysis of major federal actions, including a consideration of reasonable alternatives and an analysis of short- and long-term irretrievable, irreversible, and unavoidable impacts. Specifically, NEPA requires that an environmental impact statement (EIS) be prepared as part of the review and approval process by federal agencies of major actions which significantly affect the quality of the human environment.

• *Executive Orders on Wetlands and Floodplain Management (1977) - Executive Order 11990, the "Protection of Wetlands*," requires all federal agencies to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands.

State Legislation

• *Great Ponds* - Great Ponds are defined in Maine Statutes as any inland body of water which in its natural state has a surface area in excess of 10 acres (4 ha) or impoundments more than 30 acres (12 ha) in size (Title 38, Chapter 3, 1973, c. 608 Article 1-A, subsection 381). Maine law currently recognizes the 1641-1647 Colonial Ordinance of the Massachusetts Bay Colony in common law. Under this ordinance, rights to fishing, fowling, and navigation of Great Ponds (codified in Maine statute) as well as of the intertidal zone of the coastline (under the so-called Public Trust doctrine), are held by the public in perpetuity.

• *Classification of Maine Waters* - The federal Clean Water Act requires Maine to establish water quality standards for all water bodies in the state. Maine's anti-degradation policy gives the Maine Department of Environmental Protection the authority to classify waters in national and state parks as "an outstanding national resource (where) water quality must be maintained and protected". Streams within the boundaries of ACAD are currently classified as AA "outstanding natural resources", a designation which requires aquatic life to be "as naturally occurs", meaning they must have essentially the same physical, chemical and biological characteristics as found in situations with similar habitats free of measurable effects of human activity. All Great Ponds and natural lakes and ponds less than 10 acres in size in the State of Maine are classified GPA, a designation which bans new discharge of pollutants or the erosion of materials placed on lakeshores into the water.

• Management jurisdiction for *coastal areas* is complicated by the fact that the Park's deeded authority extends to low tide in some areas and only to high tide in others areas (Table A2.1). The deeded boundary in other coastal sections is unclear.

While marine waters beyond low tide are outside National Park Service jurisdiction, they are an integral part of the park's setting. The State of Maine classifies marine waters directly adjacent to park owned shoreline as "SA" which requires estuarine and marine life, dissolved oxygen and bacteria levels to be as naturally occurs. No direct discharges of pollutants are allowed in "SA" waters. Marine waters within 500 feet of privately owned shoreline on Mount Desert Island, Isle au Haut and the Cranberry Isles are classified "SB", a classification which allows existing discharges as long as they do not impair naturally occurring habitats or exceed bacterial standards.

• *Land Use Regulations* - Although Maine towns have home rule authority, water management policies outside the park generally stem from both local zoning and state laws. The Maine Department of Environmental Protection oversees the adoption of mandatory shoreland zoning regulations, and the Department of Economic and Community Development oversees comprehensive planning which recognizes water quality objectives.

• *Maine's Nonpoint Source Management Plan* identifies projects for future consistency review purposes. The plan calls for projects at the park to be reviewed by the Maine State Planning Office for their effects on water quality and their consistency with the state plan.

• *The Maine Natural Resources Protection Act* recognizes "resources of state significance". These include Great Ponds, outstanding river segments, coastal wetlands, fragile mountain areas and significant wildlife habitat. The National Park Service at Acadia makes every effort to comply with the Natural Resources Protection Act to protect soil and water resources and respect the state's desire to protect resources of state significance.

Management Objectives

As stated by ACAD's Resource Management Plan (Manski 1998):

> "Resource management at ACAD is focused on protecting the integrity of natural resources, preserving cultural heritage, and maintaining quality visitor experiences. Consistent with current Park strategic planning documents, resource management program activities emphasize: a) development of knowledge about and the identification of threats to Park ecosystems, cultural resources, and visitor experiences; b) application of scientific study in formulating solutions to Park issues; c) participation with other entities in the implementation of appropriate management actions to meet Park stewardship responsibilities; d) compliance with applicable federal, State, and local laws, and; e) communication of the results of our work with others to achieve the Park's mission".

Kahl *et al*. (2000) provide a detailed review of water resources management objectives at ACAD, including the following:

> "National Park Service policy (National Park Service, 1988) calls for water resources to be maintained in their natural condition free from pollutants generated by human activity. The General Management Plan for Acadia (National Park Service, 1992) includes water resources in the overall management zoning scheme. Offshore islands and all wetlands are placed in the "Protected Natural Area Subzone" which seeks to perpetuate "*geological or ecological values without any or with minimal human intrusion*". However, the plan creates special use zones which include, among other areas, municipal water supply pump stations, dams and the 14 Great Ponds within or adjacent to park boundaries. Acadia shares management responsibilities in these zones with other organizations."

Table A2.1. Park ownership of intertidal areas (from Kahl *et al*. 2000)

Park boundaries clearly deeded to the low tide line
Bar Island (western half), Bar Harbor
Otter Cove to Hunter's Brook
Somes Sound (shoreline adjacent to Norumbega, Flying, and Acadia Mountains)
Seawall picnic area to Bass Head Harbor
Park boundaries clearly deeded to end at high tide
Oak Hill Cliff near Schooner Head Overlook, Bar Harbor
Seawall Pond
Pretty March picnic area
Park boundaries requiring deed inspection and/or clarification of intertidal ownership
All remaining shoreline areas in Acadia National Park

Appendix 3.
Migrant birds in the Acadia National Park region.

Scientific Name	Abundance	MDI	IAH	SCH
Ammodramus caudacutus Saltmarsh Sharp-tailed Sparrow	Rare	Unconfirmed in Park		
Anas acuta Northern Pintail	Rare	Present in Park		Unconfirmed in Park
Anas americana American Wigeon	Uncommon	Present in Park		
Anas clypeata Northern Shoveler	Rare	Unconfirmed in Park		
Anas strepera Gadwall	Rare	Present in Park		
Anthus rubescens American Pipit	Common	Present in Park		Present in Park
Ardea alba Great Egret	Occasional	Present in Park		
Arenaria interpres Ruddy Turnstone	Common	Present in Park	Unconfirmed in Park	Present in Park
Aythya affinis Lesser Scaup	Rare	Unconfirmed in Park		
Bartramia longicauda Upland Sandpiper	Rare	Present in Park		
Branta bernicla Brant	Occasional	Historic	Unconfirmed in Park	Unconfirmed in Park
Calidris alba Sanderling	Occasional	Unconfirmed in Park	Unconfirmed in Park	
Calidris alpina Dunlin	Rare	Unconfirmed in Park		
Calidris canutus Red Knot	Common	Unconfirmed in Park		
Calidris fuscicollis White-rumped Sandpiper	Uncommon	Present in Park	Unconfirmed in Park	Historic
Calidris melanotos Pectoral Sandpiper	Rare	Present in Park		
Calidris minutilla Least Sandpiper	Common	Present in Park	Historic	Present in Park
Calidris pusilla Semipalmated Sandpiper	Abundant	Present in Park	Historic	Historic
Calonectris diomedea Cory's Shearwater	Rare			
Catharus bicknelli Bicknell's Thrush	Rare	Present in Park		Present in Park
Catharus minimus Gray-cheeked Thrush	Rare	Present in Park		
Charadrius melodus Piping Plover	Rare	Unconfirmed in Park		
Charadrius semipalmatus Semipalmated Plover	Common	Unconfirmed in Park	Unconfirmed in Park	Historic
Egretta thula Snowy Egret	Occasional	Present in Park		Present in Park
Fulica americana American Coot	Rare	Present in Park		Present in Park
Limnodromus griseus Short-billed Dowitcher	Abundant	Present in Park		Present in Park
Morus bassanus Northern Gannet	Common	Unconfirmed in Park	Unconfirmed in Park	Unconfirmed in Park
Numenius borealis Eskimo Curlew	Extinct	Unconfirmed in Park Historic		Historic
Numenius phaeopus Whimbrel	Rare	Present in Park		Historic
Oxyura jamaicensis Ruddy Duck	Rare	Unconfirmed in Park		Unconfirmed in Park
Passerella iliaca Fox Sparrow	Common	Historic	Unconfirmed in Park	Unconfirmed in Park

Phalaropus lobatus Red-necked Phalarope	Rare	Unconfirmed in Park	Unconfirmed in Park	Unconfirmed in Park
Pluvialis dominica American Golden-plover	Rare	Unconfirmed in Park		
Pluvialis squatarola Black-bellied Plover	Common	Present in Park	Unconfirmed in Park	Historic
Puffinus gravis Greater Shearwater	Rare	Unconfirmed in Park	Unconfirmed in Park	Unconfirmed in Park
Puffinus griseus Sooty Shearwater	Rare	Unconfirmed in Park	Unconfirmed in Park	Unconfirmed in Park
Puffinus puffinus Manx Shearwater	Rare	Unconfirmed in Park	Unconfirmed in Park	Unconfirmed in Park
Tringa flavipes Lesser Yellowlegs	Uncommon	Present in Park	Unconfirmed in Park	Present in Park
Tringa melanoleuca Greater Yellowlegs	Common	Present in Park		Historic
Tringa solitaria Solitary Sandpiper	Common	Present in Park	Unconfirmed in Park	Historic
Vireo philadelphicus Philadelphia Vireo	Uncommon	Present in Park		Present in Park
Zonotrichia leucophrys White-crowned Sparrow	Common	Historic		Present in Park

(Appendix 3, continued)

Appendix 4.
Methods used to assess condition, population trends and threats for the resident bird species of ACAD[1].

CONDITION ASSESSMENT
For each species, we summarized residency, abundance, and distribution information within ANP. We relied on existing information to summarize the abundance and distribution of birds in ANP. In addition, for each species we recorded the accuracy and reliability of the reported population status and distribution information using the following data quality codes: 1) Poorly known: little or no effort to discern population status or distribution throughout ANP; 2) Scattered reports: existing information may or may not correctly estimate status or distribution; 3) Generally well known: scattered anecdotal reports likely reflects status and distribution, but only poor or incomplete data available; 4) Reliable data: park-wide survey with good status and distribution information.

POPULATION TRENDS
Population trends of each resident species within ANP were determined by three methods (if available): Christmas Bird Count (CBC), Breeding Bird Surveys (BBS), and anecdotal population trends reported in a publication. Data for the CBC have been collected every December/January (with few exceptions) on Mount Desert Island since 1934 and on Schoodic Peninsula since 1957; we used these data to assess long-term changes in bird populations in the ANP region. These data are available online at National Audubon Society (2006). Only species recorded during 5 or more surveys were included in the analyses. Because these count data are strongly influenced by yearly count effort (Root 1988), we used the number of individuals reported per hour of search effort to assess population trends. To determine species that are declining on these counts, we used Spearman Correlation of count year vs. individuals reported per hour of effort. Exact p values for Spearman correlations were estimated by Monte Carlo simulations. Breeding bird Surveys were conducted by the same observer along a set route (3 separate legs) on Mount Desert Island for three consecutive years (1995-1997). Because of the limited number of surveys conducted, trend analysis was not possible on these data. Instead, we documented species where the relative abundance (RA) declined or increased in a linear manner during the three years of surveys. Anecdotal information was accessed through the park's NPSpecies database, the park's annotated bibliography of research, and through study of published and unpublished reports.

SPECIES OF CONSERVATION CONCERN IN ACADIA NATIONAL PARK
To determine the species of potential conservation concern in the ANP region, we relied on multiple regional assessments because the list of species of conservation concern in the ACAD region are not universally accepted among various agencies and organizations (US Fish and Wildlife Service 1995, 2006; Rosenberg and Wells 1999; Rosenberg and Hodgman 2000; Hodgman and Rosenberg 2000; Panjabi et al. 2005; Maine Department of Inland Fisheries and Wildlife 2005). Our goal was to err on the side of including all

[1] Prepared by G. Mittelhauser

species of potential conservation concern in the ACAD region. Four criteria (listed below) were used to assess the population status of each species and place it onto the list of species of conservation concern in ACAD. The review excluded species that are not native to Maine and those that occur as migrants or irregularly as vagrants. Overall, this approach ensured that all species that cannot be described as secure over the long term in the region are considered of Conservation Concern in ACAD, and not only those with a relatively high extinction risk.

- MAINE CONSERVATION STATUS: Birds assessed as endangered, threatened, of special concern, or listed as priority code 1 (high potential for state extirpation without management intervention or protection) or priority code 2 (moderate to high potential for state extirpation without management intervention or protection) by Maine Department of Inland Fisheries and Wildlife (2005); also birds listed as Endangered, Threatened, or of Special Concern in Maine.
- DECLINING SPECIES: Birds whose breeding or non-breeding population declined, or whose range contracted in the ACAD region. Species that historically declined but have recovered substantially were not included.
- ATLANTIC NORTHERN FOREST REGION STATUS: Birds of conservation priority in the Atlantic Northern Forest Bird Conservation region (Dettmers 2007).
- WATERBIRDS OF CONSERVATION CONCERN: Species of North American waterbirds whose populations are of conservation concern in the mid-Atlantic, New England, and Maritimes region (Parsons et al. 2007).

STRESSOR ASSESSMENT

Rather than list potential stressors for all resident birds in the ACAD region, we detailed information on species of conservation concern in the region as outlined above. We relied on the 'Birds of North America' series to document potential stressors in a species, regardless of whether the stressors have been documented within ACAD. To document known stressors within ACAD, we relied on park reports and publications as well as other reports and publications from the local region.

Appendix 5.

Condition assessment for breeding and resident land bird populations in Acadia National Park.

Species in bold letters are considered of potential conservation concern in Acadia National Park. Locations referred to in table refer to Mount Desert Island (MDI), Isle au Haut (IAH), Schoodic Peninsula (SCH), and small offshore islands (ISL).

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	PROPOSED ANP PRIORITY[6]
Accipiter cooperii **Cooper's Hawk**	Breeding	MDI: Occasional; Breeding recently reported at Compass Harbor (Witt 1997) SCH: Unconfirmed breeder	1		0	3-SC		2
Accipiter gentilis **Northern Goshawk**	Breeding Winter	MDI: Rare, breeding recently reported at Aunt Betty's Pond SCH: Probable breeder	1	MDI CBC – Increasing (P = 0.006) (mean = 1.0, n = 16) SCH CBC – Increasing (P = 0.01) (mean = 1.0, n = 6)	5	3-SC	MODERATE	2
Accipiter striatus **Sharp-shinned Hawk**	Breeding Winter	MDI - Uncommon in summer, occasional in winter, breeding recently reported at Ship Harbor and Seawall Campground (Witt 1997) SCH: Uncommon breeder, uncommon in winter IAH: Uncommon during summer and winter; Breeding suspected (Jones 1987) but not confirmed ISL: Observed on Schoodic Island during summer (Mittelhauser et al. 1992), but breeding not confirmed	1	MDI CBC – No Change (+) (P = 0.13) (mean = 1.2, n = 26) MDI – Decreased sharply as a breeding bird in the last 30 years (Russell 1984) SCH CBC – Increasing (P = 0.05) (mean = 1.0, n = 11)	3			2
Aegolius acadicus Northern Saw-whet Owl	Breeding Winter	MDI: Rare to uncommon summer and winter, breeding reported for MDI although no records of nesting within park SCH: Rare in winter; no summer records; Breeding not confirmed IAH: Uncommon, Breeding suspected but not confirmed	1		0			4
Archilochus colubris Ruby-throated Hummingbird	Breeding	MDI: Common breeder on MDI; BBS average RA = 0.04% SCH: Occasional in summer; Breeding not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed ISL: Uncommon; Breeding suspected (Mittelhauser et al. 1992) but not confirmed	1	MDI BBS – No change	2			4
Asio otus **Long-eared Owl**	Breeding (historic) Winter	MDI: Rare summer and winter, has bred on MDI (Russell 1984)	2		0	2	HIGH	3

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	PROPOSED ANP PRIORITY[6]
Bombycilla cedrorum Cedar Waxwing	Breeding Winter	MDI – Abundant in summer, rare in winter, breeding on MDI, breeding suspected but not confirmed within park boundaries; BBS average RA = 3.3% SCH: Common; breeding suspected but not confirmed IAH: Common during summer, no winter records; Breeding suspected (Jones 1987) but not confirmed ISL: Occasional in summer, nesting confirmed on Schoodic Island (Mittelhauser et al. 1992), no winter records	1	MDI CBC – Increasing (P = 0.01) (mean = 30.3, n = 12) MDI BBS – RA increasing 0.8%/year	5			4
Bombycilla garrulus Bohemian Waxwing	Winter	MDI: Occasional SCH: Uncommon	1	MDI CBC – Increasing (P < 0.001) (mean = 27.2, n = 12)	5			4
Bonasa umbellus **Ruffed Grouse**	Breeding Winter	MDI: Common, breeding at many areas on MDI; BBS average RA = 0.1% SCH: Uncommon summer and winter; breeding not confirmed but likely IAH: Rare in winter on IAH; no summer records	2	MDI CBC – No Change (-) (P = 0.30) (mean = 5.8, n = 60) MDI BBS – No Change SCH CBC – No Change (-) (P = 0.52) (mean = 2.6, n = 32)	2	3	MODERATE	2
Bubo virginianus Great Horned Owl	Breeding Winter	MDI: Rare to uncommon breeder and winter resident, breeding reported for MDI (Long 1987) SCH: Uncommon in summer and winter; Breeding not confirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI CBC – No Change (+) (P = 0.44) (mean = 1.1, n = 11)	2			4
Buteo jamaicensis Red-tailed Hawk	Breeding	MDI: Occasional, no recent records of breeding in recent years, last record of breeding confirmed in 1961 (Bond 1971) SCH: Unconfirmed in summer	1		0			4
Buteo lagopus Rough-legged Hawk	Winter	MDI: Occasional SCH: Rare in winter	1	MDI CBC – No Change (+) (P = 0.24) (mean = 1.1, n = 15) SCH CBC – Declining (P = 0.04) (mean = 1.0, n = 6)	3			4
Buteo lineatus **Red-shouldered Hawk**	Summer	MDI: Rare; Breeding not confirmed although Tyson and Bond (1941) report that this species may nest occasionally on MDI and Sullivan (1937) and Pellew (1927) report this species as common during the summer SCH: Unconfirmed IAH: One historic summer record (Manville 1964), no other summer records	1	MDI – formerly common on MDI (Pellew 1927)	1	3		3

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	PROPOSED ANP PRIORITY[6]
Buteo platypterus Broad-winged Hawk	Breeding	MDI: Common, Breeding confirmed at Seal Cove, Northeast Creek, and Seawall (Witt 1997); BBS average RA = 0.04% SCH: Unconfirmed breeder IAH: At least some summer records (Manville 1964, Pierson 1983, Jones 1987); breeding suspected (Jones 1987) but not confirmed within park boundaries	1	MDI BBS – No Change MDI – Reported as formerly a common breeder on MDI (Eliot 1931)	2	3		2
Calcarius lapponicus Lapland Longspur	Winter	MDI: Very rare SCH: Unconfirmed	1		0			4
Caprimulgus vociferus **Whip-poor-will**	Breeding	MDI – Common, nesting near Echo Lake (Tyson and Bond 1941); BBS average RA = 0.04% IAH: Uncommon, Breeding reported on island (Jones 1987)	1	MDI BBS – No Change REGION – Significant declines noted in region (Rosenberg and Wells 1999)	1	2	MODERATE	2
Cardinalis cardinalis Northern Cardinal	Breeding Winter	MDI – Common winter and summer, nesting reported for MDI; BBS average RA = 0.07% SCH: Uncommon to rare in winter; no confirmed summer records IAH: Record of species from early June 1983 on island (Pierson 1983) is only record for island	1	MDI CBC – Increasing ($P < 0.001$) (mean = 4.5, n =31) MDI BBS = RA Increasing 0.1%/year SCH CBC – Increasing ($P = 0.02$) (mean = 1.1, n = 15)	5			4
Carduelis flammea Common Redpoll	Winter	MDI: Irregular in winter SCH: Variable populations from year to year	1	MDI CBC – No Change (+) ($P = 0.36$) (mean = 52.6, n = 30) SCH CBC – No Change (+) ($P = 0.29$) (mean = 76.2, n = 15)	2			4
Carduelis pinus Pine Siskin	Breeding Winter	MDI Common breeder, uncommon in winter, breeding reported at Ship Harbor (Witt 1997); BBS average RA = 1.7% SCH: Uncommon in winter; breeding not confirmed IAH: Common in summer, uncommon in winter; Breeding suspected (Jones 1987) but not confirmed ISL: Unconfirmed; breeding suspected (Witt 1997) but not confirmed	1	MDI CBC – No Change (+) ($P = 0.07$) (mean = 32.2, n = 45) MDI BBS – No Change SCH CBC – No Change (+) ($P = 0.79$) (mean = 18.0, n = 18)	2			4
Carduelis tristis American Goldfinch	Breeding Winter	MDI – Common in summer, irregular in winter, considered a common breeder on MDI; BBS average RA = 2.1% SCH: Common in winter; breeding not confirmed IAH: Common in summer, uncommon in winter, Breeding suspected (Jones 1987) but not confirmed	1	MDI CBC – Increasing ($P < 0.001$) (mean = 59.2, n = 52) MDI BBS – No Change SCH CBC – No Change (+) ($P = 0.19$) (mean = 43.5, n = 32) SCH – Decline reported (1995-96) (Glanz and Connery 1999)	3			4

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	PROPOSED ANP PRIORITY[6]
Carpodacus mexicanus House Finch	Breeding Winter	MDI: Common in summer, irregular in winter, considered a common breeder around towns and villages (Witt 1997); BBS average RA = 0.2% SCH: Uncommon in winter; breeding not confirmed IAH: Uncommon in summer, rare in winter, Breeding suspected (Jones 1987) but not confirmed	1	MDI CBC – Increasing (P < 0.001) (mean = 13.0, n = 16) MDI BBS – RA Decreasing 0.06%/year SCH CBC – Increasing (P = 0.008) (mean = 8.3, n = 9)	3			4
***Carpodacus purpureus* Purple Finch**	Breeding Winter	MDI: Common in summer, irregular in winter, breeding reported from summit of Cadillac Mountain (Long 1987); BBS average RA = 1.8% SCH: Uncommon in winter; breeding not confirmed IAH: Uncommon during summer and winter, Breeding suspected (Jones 1987) but not confirmed	1	MDI CBC – Increasing (P < 0.001) (mean = 5.8, n = 38) MDI BBS – RA Increasing 0.2%/year SCH CBC – No Change (+) (P = 0.11) (mean = 3.9, n = 16) SCH – Increase reported (1995-96) (Glanz and Connery 1999)	3	2	HIGH	1
Cathartes aura Turkey Vulture	Summer	MDI: Common, breeding status is uncertain (Witt 1997)	1	MDI – Numbers have steadily increased since the 1970's (Witt 1997)	1			4
***Catharus fuscescens* Veery**	Breeding	MDI: Common breeder, breeding at Sieur de Monts Spring and Great Meadow (Witt 1997); BBS average RA = 0.6% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBs – No change REGION – Declining in the eastern spruce-hardwood forest region of the northeast (Rosenberg and Hodgman 2000)	3	2	HIGH	1
Catharus guttatus Hermit Thrush	Breeding	MDI: Common breeder throughout MDI; BBS average RA = 3.3% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change MDI – Steadily diminishing in numbers, 'perhaps discouraged by too many Rockefeller roads'	2			4
Catharus ustulatus Swainson's Thrush	Breeding	MDI: Common breeder throughout MDI; BBS average RA = 1.1% SCH: Common breeder (Glanz and Connery 1999) IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed ISL: Unconfirmed	1	MDI BBS – No Change SCH – Decline noted 1995-96 (Glanz and Connery 1999)	3			4
***Certhia americana* Brown Creeper**	Breeding Winter	MDI: Common summer and winter, breeding on MDI; BBS average RA = 0.2% SCH: Occasional; breeding not confirmed but probable IAH: Uncommon during summer, rare during winter, Breeding suspected (Pierson 1983) but not confirmed	1	MDI CBC – No Change (+) (P = 0.06) (mean = 5.3, n = 59) MDI BBS – RA Increasing 0.2%/year SCH CBC – No Change (+) (P = 0.53) (mean = 2.2, n = 31)	3		MODERATE	2

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Chaetura pelagica **Chimney Swift**	Breeding	MDI: Common, Breeding confirmed on MDI (all nests reported in chimneys), no breeding records specific to ANP; BBS average RA = 0.05% SCH: Unconfirmed breeder IAH: Reported on island in summer, Breeding suspected but not confirmed	1	MDI BBS – No Change MDI – Diminishing species, long ago most cottage chimneys harbored a nest or two (Eliot 1931) REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3	2	HIGH	2
Charadrius vociferus **Killdeer**	Breeding	MDI: Common, breeding occurs on many areas on MDI; BBS average RA = 0.03% SCH: Unconfirmed breeder IAH: No summer records	1	MDI BBS – No Change	2	3	MODERATE	2
Chordeiles minor **Common Nighthawk**	Breeding	MDI: Common breeder, nesting on south ridge of Cadillac Mountain (Tyson and Bond 1941); BBS average RA = 0.06% SCH: Occasional; Breeding not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – No Change REGION – Significant declines noted in region (Rosenberg and Wells 1999)	2	2	HIGH	1
Circus cyaneus **Northern Harrier**	Breeding	MDI: Occasional, Breeding reported at New Mill Meadow and Northeast Creek (Witt 1997) SCH: Unconfirmed breeder IAH: No confirmed summer records	1		0	3	MODERATE	2
Cistothorus platensis **Sedge Wren**	Breeding	MDI: Rare, Breeding reported on MDI (Witt 1997, Russell 1984, Long 1987), but no nesting records within park boundaries; species reaches northeastern most edge of breeding range in Maine	2		0	1-E		3
Coccothraustes vespertinus Evening Grosbeak	Breeding Winter	MDI: Occasional in summer, common in winter, breeding reported on MDI (Witt 1997); BBS average RA = 0.08% SCH: Occasional in winter; breeding not confirmed IAH: Uncommon during summer and winter, Breeding not confirmed	1	MDI CBC – No Change (-) (P = 0.88) (mean = 133.9, n = 42) MDI BBS – No Change MDI – Has become common only in the last 25 years (Russell 1984) SCH CBC – No Change (-) (P = 0.45) (mean = 59.4, n = 29) MAINE – increasing its eastern range over last 90 years (Palmer 1949)	2	3		4
Coccyzus erythropthalmus **Black-billed Cuckoo**	Breeding	MDI: Uncommon, breeding reported on Cadillac Mountain (Bond 1969); BBS average RA = 0.02% SCH: Rare in summer; breeding not confirmed IAH: No summer records	1	MDI BBS – RA Decreasing 0.01%/year REGION – Significant declines noted in region (Rosenberg and Wells 1999)	4	2	MODERATE	2

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Colaptes auratus **Northern Flicker**	Breeding	MDI: Common Breeder throughout MDI; BBS average RA = 0.2% SCH: Common; Breeding suspected but not confirmed IAH: Common, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3	2	MODERATE	2
Colinus virginianus Northern Bobwhite	Summer Winter	MDI: Locally common, no evidence of breeding reported; BBS average RA = 0.04%	1	MDI BBS – No Change	2			4
Columba livia Rock Dove	Breeding Winter	MDI: Common, breeding recorded for MDI; BBS average RA = 0.07% SCH: Common; breeding not confirmed ISL: Common, breeding not confirmed	1	MDI CBC – Increasing ($P < 0.001$) (mean = 80.4, n = 39) MDI BBS – RA Increasing 0.06%/year SCH CBC – Increasing ($P < 0.001$) (mean = 38.2, n = 30)	5			4
Contopus cooperi **Olive-sided Flycatcher**	Breeding	MDI: Occasional, nesting at Sieur de Monts Spring (Long 1987); BBS average RA = 0.03% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – No Change MDI – Formerly more common (Witt 1997) REGION – Significant declines noted in region (Rosenberg and Wells 1999)	2	2-SC	HIGH	1
Contopus virens **Eastern Wood-Pewee**	Breeding	MDI: Common breeder throughout MDI; BBS average RA = 0.4% SCH: Occasional; Breeding not confirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed ISL: Uncommon; Breeding suspected (Mittelhauser et al. 1992) but not confirmed	1	MDI BBS – No Change REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3	3	HIGH	1
Corvus brachyrhynchos American Crow	Breeding Winter	MDI: Common, breeding suspected but not confirmed within park boundaries; BBS average RA = 4.0% SCH: Common; breeding not confirmed IAH: Common summer and winter, breeding confirmed on island (Pierson 1983) ISL: Common summer and winter, breeding suspected but not confirmed	1	MDI CBC – Increasing ($P < 0.001$) (mean = 218.5, n = 62) MDI BBS – RA Increasing 0.6%/year SCH CBC – No Change (-) ($P = 0.65$) (mean = 84.6, n = 46)	3			4
Corvus corax Common Raven	Breeding Winter	MDI: Common breeding suspected but not confirmed within park boundaries; BBS average RA = 0.5% SCH: Historic record of nesting (Sullivan 1937); no recent breeding confirmed IAH: Uncommon summer and winter, breeding confirmed on island (Manville 1964, Pierson 1983) ISL: Occasional summer and winter, breeding not confirmed	1	MDI CBC – Increasing ($P = 0.002$) (mean = 27.5, n = 61) MDI BBS – No Change SCH CBC – No Change (-) ($P = 0.28$) (mean = 15.0, n = 46)	3			4

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Cyanocitta cristata Blue Jay	Breeding Winter	MDI: Very common summer and winter; Breeding throughout island; BBS average RA = 2.0% SCH: Uncommon; Breeding not confirmed IAH: Common in summer, uncommon in winter; Breeding suspected (Jones 1987) but not confirmed	1	MDI CBC – Increasing (P = 0.01) (mean = 121.4, n = 55) MDI BBS – No Change SCH CBC – No Change (+) (P = 0.91) (mean = 43.0, n = 45)	3			4
***Dendroica caerulescens* Black-throated Blue Warbler**	Breeding	MDI: Common, breeding reported within park (Witt 1997); BBS average RA = 0.1% SCH: Uncommon; Breeding not confirmed IAH: Uncommon during summer, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – No Change	2	2	HIGH	1
***Dendroica castanea* Bay-breasted Warbler**	Breeding	MDI: Common, considered an erratic breeder on MDI (Witt 1997), breeding records exist from within park; BBS average RA = 0.3% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change	2	2	HIGHEST	1
Dendroica coronata Yellow-rumped Warbler	Breeding	MDI: Common breeder throughout island, nesting in the Ship Harbor area (Bond 1955); BBS average RA = 2.4% SCH: Common breeder (Witt 1997, Glanz and Connery 1999) IAH: Common during summer, Breeding confirmed on island (Pierson 1983) ISL: Occasional in summer, breeding suspected (Witt 1997) but not confirmed	1	MDI BBS – No Change	2			4
***Dendroica fusca* Blackburnian Warbler**	Breeding	MDI: Common, breeding reported at Bass Harbor Head and Otter Point (Witt 1997); BBS average RA = 1.5% SCH: Common breeder (Glanz and Connery 1999) IAH: Uncommon, Breeding confirmed on island (Pierson 1983)	1	MDI BBS – No Change REGION – Declining in the northern New England region (Hodgman and Rosenberg 2000)	3	2	MODERATE	2
Dendroica magnolia Magnolia Warbler	Breeding	MDI: Common breeder on MDI, breeding reported at Ship Harbor (Bond 1955); BBS average RA = 2.2% SCH: Common breeder (Glanz and Connery 1999) IAH: Uncommon, Breeding confirmed on island (Pierson 1983)	1	MDI BBS – No Change	2			4

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Dendroica palmarum **Palm Warbler**	Breeding	MDI: Common breeder on MDI, breeding reported at Seawall and Wonderland (Witt 1997) and Ship Harbor (Bond 1955); BBS average RA = 0.04% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding not confirmed	1	MDI BBS – No Change	2	3	MODERATE	2
Dendroica pensylvanica **Chestnut-sided Warbler**	Breeding	MDI: Common breeder, nesting in the Ship Harbor area (Bond 1955); BBS average RA = 1.4% SCH: Uncommon; breeding not confirmed but suspected IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – No Change MDI – Species has increased on MDI since the fire of 1947 (Bond 1969) REGION – Declining in the northern New England region (Hodgman and Rosenberg 2000)	3	2	HIGH	1
Dendroica petechia Yellow Warbler	Breeding	MDI: Common breeder on MDI, nesting in the heath near Seawall (Bond 1955); BBS average RA = 0.8% SCH: Uncommon; breeding suspected but not confirmed IAH: Common, Breeding suspected (Pierson 1983) but not confirmed ISL: Occasional; breeding confirmed	1	MDI BBS – RA Increasing 0.06%/year	2	3		4
Dendroica pinus Pine Warbler	Breeding	MDI: Locally common breeder, breeding reported for MDI but no confirmed records of nesting within park boundaries SCH: Uncommon; breeding not confirmed IAH: Unconfirmed (Manville 1964)	1		0			4
Dendroica striata **Blackpoll Warbler**	Breeding	MDI: Rare breeder, nesting along the shoreline at Wonderland (Witt 1997); BBS average RA = 0.03% SCH: Uncommon breeder (Glanz and Connery 1999) IAH: Few summer records, Breeding suspected (Manville 1964) but not confirmed ISL: Unconfirmed; breeding suspected (Pellew 1927, Witt 1997) but not confirmed	1	MDI BBS – No Change	2	3	MODERATE	2
Dendroica tigrina **Cape May Warbler**	Breeding	MDI: Common to occasional breeder, breeding confirmed in the Ship Harbor area (Bond 1955); BBS average RA = 0.1% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding not confirmed	1	MDI BBS – No Change MDI – Commonly bred in the 1930s and 1940s during the large spruce budworm outbreaks, and for many years after have not been known to breed (Russell 1984); species is again common and breeding on MDI (Witt 1997)	2	2	HIGH	1

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Dendroica virens **Black-throated Green Warbler**	Breeding	MDI: Very Common breeder throughout MDI; BBS average RA = 18.9% SCH: Common Breeder (Glanz and Connery 1999) IAH: Abundant, Breeding confirmed on island (Pierson 1983) ISL: Unconfirmed; breeding suspected but not confirmed	1	MDI BBS – No Change	2	2	MODERATE	2
Dolichonyx oryzivorus **Bobolink**	Breeding	MDI: Common but local breeder on MDI, breeding on MDI but no confirmed nests within park; BBS average RA = 0.5% SCH: Unconfirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – RA Increasing 0.07%/year	2	2	HIGH	2
Dryocopus pileatus Pileated Woodpecker	Breeding Winter	MDI: Common summer and winter, breeding reported on MDI; BBS average RA = 0.2% SCH: Unconfirmed IAH: Unconfirmed (Manville 1964)	1	MDI CBC – Increasing ($P < 0.001$) (mean = 2.0, n = 31) MDI BBS – No Change SCH CBC – Increasing ($P = 0.01$) (mean = 2.1, n = 23)	5			4
Dumetella carolinensis Gray Catbird	Breeding	MDI: Common, breeding at Western Point (Allen 1969); BBS average RA = 0.5% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change MDI – Increased as a summer resident on MDI since the fire of 1947 (Bond 1969)	2			4
Empidonax minimus Least Flycatcher	Breeding	MDI: Common breeder, breeding at Sieur de Monts Spring (Long 1987); BBS average RA = 0.04% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – No Change	2	3		4
Eremophila alpestris **Horned Lark**	Summer Winter	MDI: Uncommon in winter, no summer records, no records of breeding SCH: Uncommon migrant, no summer or winter records ISL: Unconfirmed, but reportedly most frequently found on the outer islands	1	REGION – Significant declines noted in region (Rosenberg and Wells 1999)	1	2	MODERATE	3
Euphagus carolinus **Rusty Blackbird**	Summer	MDI: Rare in summer, no breeding records on MDI to date (Witt 1997) SCH: Unconfirmed ISL: Rare, no evidence suggesting breeding	1		0	2-SC	HIGH	3
Falcipennis canadensis **Spruce Grouse**	Breeding Winter	MDI: Rare summer and winter, breeding within park (Whitcomb et al. 1994) SCH: Uncommon breeder and in winter; population of 34 estimated during 1992 (Whitcomb et al. 1994).	4	MDI – Relatively common on MDI until 1910 when numbers gradually declined until the early 1930s (Barden 1970); MDI population in 1993 estimated at 56 birds (Whitcomb et al. 1994)	1	3		2

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Falco columbarius Merlin	Summer	MDI: Occasional in summer, sightings of birds have occurred regularly during the summer, but no other direct evidence of breeding SCH: Unconfirmed breeder IAH: No summer records	1		0	3		4
Falco peregrinus **Peregrine Falcon**	Breeding	MDI: Locally common, Breeding at 3 locations within the park; BBS average RA = 0.06% SCH: Uncommon during summer; no records of breeding IAH: No summer records	4	MDI BBS – No Change MDI – extirpated as a breeding population during the past decade (Bond 1969), recent reintroduction efforts have been successful	3	1-E		1
Falco sparverius American Kestrel	Breeding	MDI: Uncommon, Breeding reported on MDI (Witt 1997) but no details of nesting within park boundaries; BBS average RA = 0.03% SCH: Unconfirmed breeder IAH: No summer records	1	MDI BBS – No Change	2			4
Geothlypis trichas Common Yellowthroat	Breeding	MDI: Very Common breeder throughout MDI; BBS average RA = 3.7% SCH: Common; breeding suspected but not confirmed IAH: Common, Breeding confirmed on island (Pierson 1983) ISL: Occasional on islands, breeding confirmed (Mittelhauser et al. 1992)	1	MDI BBS – No Change	2	3		4
Haliaeetus leucocephalus **Bald Eagle**	Breeding Winter	MDI: Common breeder and winter resident, breeding confirmed; BBS average RA = 0.01% SCH: Common in summer and winter IAH: Nesting on island; commonly observed both summer and winter ISL: Common in summer and winter; nesting on many park islands	4	MDI CBC – Increasing ($P = 0.02$) (mean = 5.2, n = 62) MDI BBS – No Change SCH CBC – Increasing ($P = 0.009$) (mean = 4.0, n = 41)	5	2-T	MODERATE	1
Hirundo rustica **Barn Swallow**	Breeding	MDI: Common Breeder on MDI, breeding at Anemone Cave (Long 1987); BBS average RA = 0.4% SCH: Uncommon; Breeding not confirmed IAH: Common, Breeding confirmed on island (Pierson 1983) ISL: Uncommon, nesting on Baker Island (Russell 1984)	2	MDI BBS – No Change	2	2	MODERATE	2
Hylocichla mustelina **Wood Thrush**	Breeding	MDI: Common Breeder, breeding reported at Sieur de Monts Spring (Witt 1997); BBS average RA = 0.09% IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3	2	HIGHEST	1

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Icterus galbula **Baltimore Oriole**	Breeding	MDI: Uncommon breeder, breeding at Sieur de Monts Spring area (Witt 1997); BBS average RA = 0.02% SCH: Unconfirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – No Change REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3	2		2
Junco hyemalis Dark-eyed Junco	Breeding Winter	MDI: Very Common breeder throughout MDI; BBS average RA = 1.9% SCH: Uncommon in summer and winter; breeding suspected but not confirmed IAH: Uncommon in summer and winter, Breeding confirmed on island (Pierson 1983)	1	MDI CBC – No Change (+) (P = 0.11) (mean = 41.8, n = 67) MDI BBS – No Change SCH CBC – No Change (+) (P = 0.97) (mean = 22.4, n = 37)	2			4
Lanius excubitor Northern Shrike	Winter	MDI: Uncommon in winter SCH: Uncommon IAH: Rare in winter	1	MDI CBC – No Change (+) (P = 0.31) (mean = 1.5, n = 38) SCH CBC – No Change (+) (P = 0.29) (mean = 1.7, n = 25)	2			4
Loxia curvirostra **Red Crossbill**	Breeding Winter	MDI: Irregular abundance, breeding reported at Otter Point and Ship Harbor (Long 1987); BBS average RA = 0.4% SCH: Variable; breeding not confirmed IAH: Uncommon summer and winter, Breeding suspected (Jones 1987) but not confirmed	1	MDI CBC – No Change (-) (P = 0.45) (mean = 16.4, n = 18) MDI BBS – RA Increasing 0.4%/year MDI – extremely rare in summer from 1920 to 1940, since then it has become occasionally abundant (Bond 1969) SCH CBC – No Change (+) (P = 0.84) (mean = 24.1, n = 10)	3	2		2
Loxia leucoptera White-winged Crossbill	Breeding Winter	MDI; Irregularabundance, breeding reported from Otter Point and Ship Harbor (Witt 1997, Long 1987); BBS average RA = 0.1% SCH: Variable; breeding not confirmed IAH: Occasional during summer and winter, Breeding suspected (Jones 1987) but not confirmed	1	MDI CBC – No Change (+) (P = 0.43) (mean = 49.9, n = 41) MDI BBS – RA Decreasing 0.1%/year SCH CBC – No Change (+) (P = 0.84) (mean = 37.2, n = 17)	3	3		4
Meleagris gallopavo Wild Turkey	Breeding Winter	MDI: Rare, no evidence of breeding SCH: Rare year round IAH: Occasional to common based on recent introduction of wild stock to island, Breeding suspected but not confirmed	1		0			3
Melospiza lincolnii Lincoln's Sparrow	Breeding	MDI: Uncommon breeder, nesting reported at Big Heath (Long 1987) SCH: Uncommon; Breeding not confirmed IAH: Present on island during early June 1983 (Pierson 1983), no other records	1		0			4

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Melospiza melodia Song Sparrow	Breeding	MDI: Abundant breeder throughout MDI; BBS average RA = 1.7% SCH: Uncommon; Breeding not confirmed IAH: Common, Breeding suspected (Pierson 1983) but not confirmed ISL: Common, Breeding confirmed on Schoodic Island (Mittelhauser et al. 1992)	1	MDI BBS – No Change	2			4
Mimus polyglottos Northern Mockingbird	Breeding Winter	MDI: Occasional in summer and winter, breeding reported on MDI although no breeding records exist for within the park	1	MDI – Recorded with increasing frequency in the last 10 years (Russell 1984)	1			4
***Mniotilta varia* Black-and-white Warbler**	Breeding	MDI: Common breeder, breeding at Sieur de Monts Spring (Witt 1997); BBS average RA = 1.8% SCH: Uncommon; Breeding suspected but not confirmed IAH: Common, Breeding confirmed on island (Pierson 1983)	1	MDI BBS – RA Increasing 0.5%/year REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3	2		2
Molothrus ater Brown-headed Cowbird	Breeding	MDI: Very Common breeder throughout MDI; BBS average RA = 0.5% SCH: Occasional; Breeding suspected but not confirmed IAH: Common, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – No Change MDI – Increasing in numbers (Pellew 1927)	3			4
***Myiarchus crinitus* Great Crested Flycatcher**	Breeding	MDI: Common but local breeder, breeding at Sieur de Monts Spring (Long 1987); BBS average RA = 0.4% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed ISL: Rare, Breeding not confirmed	1	MDI BBS – RA Increasing 0.04%/year MDI – Species has extended its range on MDI in recent years, likely a result of the fire of 1947 (Bond 1969)	2	2		2
Nyctea scandiaca Snowy Owl	Winter	MDI: Rare in winter SCH: Rare ISL: Rare in winter	2		0			4
Oporornis philadelphia Mourning Warbler	Breeding (Historic)	MDI: Rare in summer, has bred in the park in past years but no recent breeding records (Witt 1997); BBS average RA = 0.03% SCH: Uncommon; Breeding not confirmed	1	MDI BBS – No Change	2			4
***Parula americana* Northern Parula**	Breeding	MDI: Common breeder throughout MDI; BBS average RA = 2.3% SCH: Occasional; breeding suspected but not confirmed IAH: Abundant, Breeding confirmed on island (Pierson 1983)	1	MDI BBS – No Change	2	2	MODERATE	2

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND [2]	TREND CONF [3]	MAINE PRIORITY STATUS [4]	REGIONAL CONCERN [5]	PROPOSED ANP PRIORITY [6]
Passer domesticus House Sparrow	Breeding Winter	MDI: Locally common summer and winter, breeding reported for MDI but no breeding records for the park SCH: Unconfirmed	1	MDI CBC – No Change (-) (P = 0.78) (mean = 49.4, n = 57) SCH CBC – No Change (-) (P = 0.52) (mean = 12.1, n = 24)	2			4
Passerculus sandwichensis Savannah Sparrow	Breeding	MDI: Common Breeder, breeding at Bass Harbor Marsh (Witt 1997); BBS average RA = 0.2% SCH: Uncommon; breeding not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed ISL: Common, Breeding on Baker (Witt 1997) and Schoodic (Mittelhauser et al. 1992) Islands	1	MDI BBS – No Change	2			4
Passerina cyanea Indigo Bunting	Summer	MDI: Occasional, no nests discovered on MDI, but breeding is suspected; BBS average RA = 0.01%	1	MDI BBS – No Change	2			4
Perisoreus canadensis **Gray Jay**	Breeding Winter	MDI: Very rare summer and winter, breeding reported near Bass Harbor Marsh (Bond 1969), Great Heath (Witt 1997), and Town Hill (Long 1987) SCH: Uncommon; Breeding on Big Moose Island (Glanz and Connery 1999)	1	MDI CBC – No Change (+) (P = 0.30) (mean = 1.7, n = 20) MDI – Decreased greatly in numbers during the past 100 years (Bond 1949) SCH CBC – No Change (-) (P = 0.41) (mean = 4.1, n = 16)	2		MODERATE	3
Petrochelidon pyrrhonota **Cliff Swallow**	Breeding	MDI: Common breeder on MDI, breeding at Anemone Cave (Witt 1997); BBS average RA = 0.3% SCH: Historically nested (Goodridge 1962), no recent breeding records IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – RA Declining 0.3%/year	2			2
Phasianus colchicus Ring-necked Pheasant	Breeding Winter	MDI: Rare, no evidence of breeding SCH: Historic record; no indication if population is established IAH: Uncommon based on previous introductions to island (Manville 1964); breeding suspected but not confirmed within park boundaries.	1	MDI CBC – No Change (-) (P = 0.14)	2			4
Pheucticus ludovicianus **Rose-breasted Grosbeak**	Breeding	MDI: Uncommon breeder, breeding at Sieur de Monts Spring (Long 1987); BBS average RA = 0.1% SCH: Uncommon; breeding not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – RA Increasing 0.04%/year	2	2	MODERATE	2

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	PROPOSED ANP PRIORITY[6]
Picoides arcticus **Black-backed Woodpecker**	Breeding Winter	MDI: Rare breeder and rare in winter, breeding in the upper part of Bass Harbor Head (Long 1987) SCH: Uncommon in summer and winter IAH: Uncommon in winter, no summer records	1	MDI CBC – No Change (+) (P = 0.23) (mean = 1.3, n = 9)	2	3	MODERATE	2
Picoides pubescens Downy Woodpecker	Breeding Winter	MDI: Very common breeder throughout MDI, common in winter; BBS average RA = 0.4% SCH: Common in summer and winter; Breeding suspected but not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI CBC – No Change (+) (P = 0.39) (mean = 26.7, n = 64) MDI BBS – No Change SCH CBC – No Change (-) (P = 0.25) (mean = 8.0, n = 45)	2			4
Picoides villosus Hairy Woodpecker	Breeding Winter	MDI: Common breeder throughout MDI, common in winter; BBS average RA = 0.3% SCH: Uncommon summer and winter; Breeding suspected but not confirmed IAH: Common in summer, uncommon in winter, Breeding confirmed on island (Pierson 1983)	1	MDI CBC – No Change (+) (P = 0.43) (mean = 17.8, n = 60) MDI BBS – No Change SCH CBC – No Change (+) (P = 0.68) (mean = 5.3, n = 40)	2			4
Pinicola enucleator **Pine Grosbeak**	Winter	MDI: Irregular abundance SCH: Uncommon ISL: Rare, Breeding not confirmed	1	MDI CBC – Declining (P = 0.004) (mean = 36.7, n = 34) SCH CBC – No Change (-) (P = 0.78) (mean = 19.5, n = 17)	3	3	MODERATE	3
Pipilo erythrophthalmus **Eastern Towhee**	Breeding	MDI: Common breeder, breeding reported on the slopes of Cadillac Mountain (Witt 1997); BBS average RA = 0.1% SCH: Uncommon; breeding not confirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3	2		2
Piranga olivacea **Scarlet Tanager**	Breeding	MDI: Uncommon breeder, breeding at Sieur de Monts Spring (Witt 1997); BBS average RA = 0.08% SCH: Uncommon; breeding not confirmed	1	MDI BBS – No Change	2	2		2
Plectrophenax nivalis Snow Bunting	Winter	MDI: Uncommon to rare SCH: Uncommon to rare IAH: Rare in winter	1	MDI CBC – No Change (+) (P = 0.58) (mean = 11.3, n = 19) SCH CBC – No Change (-) (P = 0.25) (mean = 14.9, n = 7)	2			4
Poecile atricapilla Black-capped Chickadee	Breeding Winter	MDI: Common breeder throughout MDI; BBS average RA = 3.7% SCH: Common in summer and winter; Breeding suspected but not confirmed IAH: Common summer and winter, Breeding suspected (Jones 1987) but not confirmed ISL: Unconfirmed	1	MDI CBC – Increasing (P = 0.006) (mean = 313.6, n = 68) MDI BBS – No Change SCH CBC – No Change (+) (P = 0.64) (mean = 110.0, n = 46)	3			4

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	PROPOSED ANP PRIORITY[6]
Poecile hudsonica **Boreal Chickadee**	Breeding Winter	MDI: Uncommon breeder and uncommon in winter, breeding at Bass Harbor Light (Witt 1997) SCH: Common but local breeder (Glanz and Connery 1999), uncommon to occasional in winter IAH: Uncommon and local, summer and winter, Breeding confirmed on island (Palmer 1949, Pierson 1983) ISL: Unconfirmed but likely present (Long 1987)	1	MDI CBC – Declining ($P = 0.04$) (mean = 6.4, $n = 26$) SCH CBC – Declining ($P = 0.03$) (mean = 6.6, $n = 23$)	5		HIGH	1
Pooecetes gramineus **Vesper Sparrow**	Summer	MDI: Rare in summer, no evidence of nesting on MDI (Witt 1997) SCH: Rare in summer IAH: Unconfirmed (Manville 1964)	1	REGION – Significant declines noted in region (Rosenberg and Wells 1999)	1	2-SC	MODERATE	3
Progne subis **Purple Martin**	Breeding (Historic)	MDI: Unconfirmed during summer, historically nested on MDI (Long 1987) SCH: Rare; no historic breeding records IAH: Rare; formerly nested on island (Manville 1964)	2	MDI – Formerly abundant on MDI (Pellew 1927)	1	2		3
Quiscalus quiscula Common Grackle	Breeding	MDI: Common in summer, breeding throughout MDI; BBS average RA = 1.0% SCH: Uncommon; breeding not confirmed IAH: Common, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change	2			4
Regulus calendula Ruby-crowned Kinglet	Breeding	MDI: Common breeder on MDI breeding at Otter Point (Davis 1961); BBS average RA = 0.6% SCH: Occasional in summer; Breeding suspected but not confirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change MDI – Formerly very rare on MDI, now common and widespread (Tyson and Bond 1941) REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3			4
Regulus satrapa Golden-crowned Kinglet	Breeding Winter	MDI: Common breeder throughout MDI, common in winter; BBS average RA = 1.6% SCH: Common breeder (Glanz and Connery 1999), common in winter IAH: Common summer and winter, Breeding confirmed on island (Pierson 1983)	1	MDI CBC – Increasing ($P < 0.001$) (mean = 20.1, $n = 62$) MDI BBS – No Change SCH CBC – No Change (+) ($P = 0.22$) (mean = 11.7, $n = 40$) SCH – Decline noted 1995-96 (Glanz and Connery 1999)	3			4
Riparia riparia **Bank Swallow**	Breeding	MDI: Common breeder on MDI (Witt 1997), no confirmed breeding within park boundaries SCH: Rare in summer; Breeding not confirmed ISL: Uncommon, Breeding on Schoodic Island (Mittelhauser et al. 1992)	1		0	3	MODERATE	2

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND [2]	TREND CONF [3]	MAINE PRIORITY STATUS [4]	REGIONAL CONCERN [5]	PROPOSED ANP PRIORITY [6]
Sayornis phoebe Eastern Phoebe	Breeding	MDI: Common breeder, nesting at Sieur de Monts Spring (Witt 1997); BBS average RA = 0.3% SCH: Unconfirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – RA Decreasing 0.1%/year	2			4
Scolopax minor **American Woodcock**	Breeding	MDI: Common, Breeding in many areas on MDI; BBS average RA = 0.01% SCH: Occasional; breeding unconfirmed IAH: Uncommon during summer; Breeding historically reported (Hebard 1959)	1	MDI BBS – No Change REGION – Declining in the eastern spruce-hardwood forest region of the northeast (Rosenberg and Hodgman 2000)and the northern New England region (Hodgman and Rosenberg 2000)	3	2	HIGHEST	1
Seiurus aurocapillus **Ovenbird**	Breeding	MDI: Common breeder throughout MDI; BBS average RA = 4.8% SCH: Occasional; Breeding suspected but not confirmed IAH: Common, Breeding confirmed on island (Pierson 1983)	1	MDI BBS – No Change	2	3	MODERATE	2
Seiurus noveboracensis Northern Waterthrush	Breeding	MDI: Uncommon breeder on MDI, breeding suspected within the park; BBS average RA = 0.1% SCH: Uncommon; Breeding suspected (Witt 1997) but not confirmed IAH: Uncommon to rare, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change	2			4
Setophaga ruticilla **American Redstart**	Breeding	MDI: Common breeder throughout MDI; BBS average RA = 1.7% SCH: Common; Breeding suspected but not confirmed IAH: Common, Breeding confirmed on island (Pierson 1983)	1	MDI BBS – No Change SCH – Increase noted during 1995-96 (Glanz and Connery 1999)	3	3	HIGH	2
Sialia sialis Eastern Bluebird	Breeding	MDI: Rare breeder on MDI, breeding confirmed on MDI, but no breeding records confirmed within park; BBS average RA = 0.01%	1	MDI BBS – No Change MDI – formerly more common on MDI, a slight increase during the late 1960s (Bond 1969)	3			4
Sitta canadensis Red-breasted Nuthatch	Breeding Winter	MDI: Very common breeder throughout MDI and common during winter; BBS average RA = 1.8% SCH: Uncommon in summer and winter; Breeding not confirmed IAH: Common, Breeding suspected (Pierson 1983) but not confirmed ISL: Uncommon, breeding suspected (Mittelhauser et al. 1992) but not confirmed	1	MDI CBC – Increasing ($P < 0.001$) (mean = 40.1, n = 62) MDI BBS – No Change SCH CBC – No Change (+) ($P = 0.11$) (mean = 15.5, n = 41)	3			4

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	PROPOSED ANP PRIORITY[6]
Sitta carolinensis White-breasted Nuthatch	Breeding Winter	MDI: Locally common summer and winter, breeding reported for MDI although no breeding records exist for within the park SCH: Uncommon in winter, no summer records; Breeding not confirmed IAH: Uncommon, Breeding not confirmed	1	MDI CBC – No Change (+) (P = 0.18) (mean = 8.3, n = 45) SCH CBC – No Change (+) (P = 0.26) (mean = 1.5, n = 21)	2			4
Sphyrapicus varius **Yellow-bellied Sapsucker**	Breeding?	MDI: Common, breeding on MDI although no records of breeding from within park; BBS average RA = 0.01% SCH: Unconfirmed IAH: Uncommon in summer; no evidence of breeding	1	MDI BBS – No Change	2	2	HIGH	1
Spizella arborea American Tree Sparrow	Winter	MDI: Common in winter SCH: Unconfirmed IAH: Unconfirmed	1	MDI CBC – No Change (-) (P = 0.68) (mean = 52.7, n = 61) SCH CBC – No Change (-) (P = 0.08) (mean = 21.0, n = 41)	2			4
Spizella passerina Chipping Sparrow	Breeding	MDI: Common breeder on MDI; BBS average RA = 0.4% SCH: Uncommon; Breeding not confirmed IAH: Uncommon in summer, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change	2			4
Spizella pusilla **Field Sparrow**	Breeding	MDI: Rare breeder on MDI, breeding suspected within park boundaries SCH: Unconfirmed in summer	1	MDI – Southern species that has become established as a summer resident since the fire of 1947 (Bond 1969) REGION – Significant declines noted in region (Rosenberg and Wells 1999)	1	2		3
Stelgidopteryx serripennis Northern Rough-winged Swallow	Breeding (Historic)	MDI: Rare, Historically bred on MDI, but no recent records (Witt 1997); BBS average RA = 0.06%	1	MDI BBS – No Change MDI – This southern species has been steadily spreading northward and now appears regularly on MDI (Bond 1969)	3	3		3
Strix varia **Barred Owl**	Breeding Winter	MDI: Uncommon breeder and winter resident, breeding on MDI (Witt 1997) SCH: Rare during summer and winter; Breeding not confirmed IAH: Uncommon, Breeding not confirmed	1	MDI CBC – No Change (+) (P = 0.44) (mean = 1.0, n = 9)	2	2		2
Sturnella magna **Eastern Meadowlark**	Breeding (Historic)	MDI: Rare breeder on MDI, no recent breeding records within park (Witt 1997) SCH: Unconfirmed in summer	1	REGION – Significant declines noted in region (Rosenberg and Wells 1999)	0	2-SC		3

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	PROPOSED ANP PRIORITY[6]
Sturnus vulgaris European Starling	Breeding Winter	MDI: Common summer and winter, breeding throughout MDI; BBS average RA = 1.1% SCH: Common in summer and winter; Breeding not confirmed IAH: Common summer, uncommon in winter, Breeding confirmed on island (Pierson 1983) ISL: Occasional; Breeding on Schoodic Island (Mittelhauser et al. 1992)	1	MDI CBC – No Change (+) (P = 0.17) (mean = 148.6, n = 63) MDI BBS – No Change MDI – Recently become a regular and common summer resident on MDI (Tyson and Bond 1941) SCH CBC – No Change (+) (P = 0.85) (mean = 87.0, n = 46)	3			4
***Tachycineta bicolor* Tree Swallow**	Breeding	MDI: Common breeder throughout MDI; BBS average RA = 1.3% SCH: Uncommon in summer; Breeding not confirmed IAH: Common, Breeding confirmed on island	1	MDI BBS – RA Declining 0.6%/year	2	3		2
***Toxostoma rufum* Brown Thrasher**	Breeding	MDI: Common breeder on MDI; BBS average RA = 0.1% SCH: Uncommon; breeding not confirmed IAH: Uncommon, Breeding not confirmed	1	MDI BBS – RA Declining 0.04%/year MDI – Rarely seen on MDI before the fire of 1947, now they occur on the burnt lands (Bond 1969) REGION – Significant declines noted in region (Rosenberg and Wells 1999)	2	2		2
Troglodytes aedon House Wren	Breeding?	MDI: Uncommon to rare, breeding confirmed on MDI (Bond 1969) but no records within park boundaries; BBS average RA = 0.01% SCH: Unconfirmed IAH: Unverified historic record of nesting on island (Manville 1964)	1	MDI BBS – No Change	2	3		4
Troglodytes troglodytes Winter Wren	Breeding	MDI: Common, Breeding at many areas on MDI; BBS average RA = 1.4% SCH: Occasional; breeding not confirmed but likely IAH: Uncommon during summer, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change	2			4
Turdus migratorius American Robin	Breeding Winter	MDI: Very Common breeder throughout; BBS average RA = 4.9% SCH: Occasional; Breeding suspected but not confirmed IAH: Common in summer, Rare in winter, Breeding suspected (Pierson 1983) but not confirmed	1	MDI CBC – Increasing (P = 0.05) (mean = 12.7, n = 56) MDI BBS – No Change SCH CBC – No Change (+) (P = 0.61) (mean = 8.9, n = 32) SCH – Decline noted from 1995-96 (Glanz and Connery 1999)	3			4

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	PROPOSED ANP PRIORITY[6]
Tyrannus tyrannus **Eastern Kingbird**	Breeding	MDI: Occasional; breeding at Breakneck and Beaverdam Ponds (Russell 1984); BBS average RA = 0.1% SCH: Unconfirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3	2		2
Vermivora peregrina Tennessee Warbler	Breeding	MDI: Uncommon breeder, breeding in the Lurvey Spring and Marshall Brook area (Bond 1969, 1971); BBS average RA = 0.04% SCH: Uncommon; breeding not confirmed	1	MDI BBS – No Change	2	3		4
Vermivora ruficapilla Nashville Warbler	Breeding	MDI: Common breeder on MDI, Breeding near Wonderland (Bond 1955); BBS average RA = 2.6% SCH: Common breeder (Glanz and Connery 1999) IAH: Uncommon, Breeding confirmed on island (Pierson 1983)	1	MDI BBS – No Change	2			4
Vireo gilvus Warbling Vireo	Breeding	MDI: Rare, nesting at Sieur de Monts Spring (Long 1987); BBS average RA = 0.01%	1	MDI BBS – No Change	2			4
Vireo olivaceus Red-eyed Vireo	Breeding	MDI: Common breeder, breeding at many locations on MDI; BBS average RA = 3.8% SCH: Uncommon; Breeding not confirmed IAH: Common, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change	2			4
Vireo solitarius Blue-headed Vireo	Breeding	MDI: Common breeder throughout MDI; BBS average RA = 1.0% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Jones 1987) but not confirmed	1	MDI BBS – No Change SCH – Decline noted 1995-96 (Glanz and Connery 1999)	3			4
Wilsonia canadensis **Canada Warbler**	Breeding	MDI: Common breeder on MDI, breeding near The Bowl (Tyson and Bond 1941); BBS average RA = 0.4% SCH: Uncommon; breeding not confirmed IAH: Uncommon, Breeding confirmed on island (Manville 1964)	1	MDI BBS – RA Increasing 0.01%/year REGION – Significant declines noted in region (Rosenberg and Wells 1999)	3	2	HIGHEST	1
Wilsonia pusilla Wilson's Warbler	Breeding	MDI: Occasional breeder, no breeding reported in the last couple of years (Witt 1997); BBS average RA = 0.02% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change MDI – No breeding reported in the last couple of years (Witt 1997)	3			4

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND [2]	TREND CONF [3]	MAINE PRIORITY STATUS [4]	REGIONAL CONCERN [5]	PROPOSED ANP PRIORITY [6]
Zenaida macroura Mourning Dove	Breeding Winter	MDI: Common in summer and winter, breeds sparingly near developed areas (Witt 1997); BBS average RA = 2.8% SCH: Common summer and winter; breeding not confirmed IAH: Uncommon during summer, rare during winter; Breeding suspected (Pierson 1983) but not confirmed	1	MDI CBC – Increasing ($P < 0.001$) (mean = 226.1, n = 43) MDI BBS – No Change SCH CBC – Increasing ($P < 0.001$) (mean = 66.5, n = 35) SCH – Declines reported from 1995-1996 (Glanz and Connery 1999)	3			4
Zonotrichia albicollis White-throated Sparrow	Breeding	*Zenaida macroura* Mourning Dove	1	MDI BBS – No Change	2	3		4

1 DATA QUALITY: 1) Poorly known: little or no effort to discern population status or distribution throughout ANP; 2) Scattered reports: existing information may or may not correctly estimate status or distribution; 3) Generally well known: scattered anecdotal reports likely reflects status and distribution, but only poor or incomplete data available; 4) Reliable data: park-wide survey with good status and distribution information.

2. POPULATION TREND: To calculate the mean number of birds observed during CBCs, only counts where the species was observed were included. If a species was not reported during a count in a year, that years data was not included in calculating the mean. Sample size reported (n) is the number of years a species was reported.

3 TREND CONFIDENCE: 0: no data available for assessment of trends; 1: anecdotal evidence or no easily discernable trends; 2: slight or no trends evident based on surveys; 3: trends possible or vary over time, mixed evidence; 4: trends significant, based on <10 years data; 5: trends significant, based on > 10 years data.

4 MAINE PRIORITY STATUS: Maine Fish and Wildlife priority codes(Maine Department of Inland Fisheries and Wildlife 2005): **1**: high potential for state extirpation without management intervention and/or protection; **2**: moderate to high potential for state extirpation without management intervention and/or protection; **3** low to moderate potential for state extirpation, yet, there are some remaining concerns regarding restricted distribution, status, and/or extreme habitat specialization. **T**: Threatened in Maine; **E**: Endangered in Maine; **SC**: ‘Special Concern’ in Maine (Maine Department of Inland Fisheries and Wildlife 1996).

5. REGIONAL CONCERN: Conservation priority categories for birds in BCR 14 (Dettmers 2007).

6. Proposed ANP Priority birds for research: 1. Highest; 2. High; 3. Moderate or peripheral; 4. Low.

Appendix 6.

Condition assessment for breeding and resident marsh bird populations in Acadia National Park.

Species in bold letters are considered of potential conservation concern in Acadia National Park. Locations referred to in table refer to Mount Desert Island (MDI), Isle au Haut (IAH), Schoodic Peninsula (SCH), and small offshore islands (ISL).

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND [2]	TREND CONF [3]	MAINE PRIORITY STATUS [4]	REGIONAL CONCERN [5]	WATERBIRD CONSERVATION CONCERN [6]	PROPOSED ANP PRIORITY [7]
Agelaius phoeniceus Red-winged Blackbird	Breeding	MDI: Common, breeding at many areas on MDI; BBS average RA = 1.6% SCH: Uncommon; no confirmed breeding IAH: Common during summer; breeding confirmed on island (Pierson 1983) ISL: Uncommon, breeding suspected (Mittelhauser et al. 1992) but not confirmed	1	MDI BBS – RA increasing 0.3%/year MDI – Increasing on MDI during the past 60 years (Long 1987)	2				4
Aix sponsa **Wood Duck**	Breeding	MDI – Occasional but local; breeding likely, but no recent nesting reported within the park; BBS average RA = 0.2%	2	MDI – 'increasing' 1927-1987 (Long 1987) MDI BBS – RA increasing 0.05%/year	2		MODERATE		2
Ammodramus nelsoni **Nelson's Sharp-tailed Sparrow**	Breeding	MDI: Common but local, breeding at Bass Harbor Marsh (Witt 1997); BBS average RA = 0.05% SCH: Common but local; Breeding in salt marsh along park road (Witt 1997) IAH: Unconfirmed (Manville 1964)	2	MDI BBS – No change	2	2	HIGHEST		1
Anas crecca Green-winged Teal	Breeding Winter	MDI: Occasional breeder and occasional in winter, breeding has been historically reported (Russell 1984); southern limit of breeding range is reached in Maine (Adamus 1987) SCH: Unconfirmed IAH: Rare in winter	1		0	3			4
Anas discors Blue-winged Teal	Breeding	MDI: Uncommon, Breeding confirmed at Seawall Pond (Witt 1997) SCH: Unconfirmed IAH: Unconfirmed	1		0	3			4
Anas platyrhynchos Mallard	Breeding Winter	MDI: Common in summer and winter, Breeding confirmed at Northeast Creek and Lower Breakneck Pond (Witt 1997); BBS average RA = 0.1% SCH: Present IAH: Unconfirmed in summer	1	MDI CBC – Increasing ($P < 0.001$) (mean = 102.3, n = 45) SCH CBC – Increasing ($P < 0.001$) (mean = 28.7, n = 33)	5	3	MANAGEMENT CONCERN		4

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND [2]	TREND CONF [3]	MAINE PRIORITY STATUS [4]	REGIONAL CONCERN [5]	WATERBIRD CONSERVATION CONCERN [6]	PROPOSED ANP PRIORITY [7]
Anas rubripes **American Black Duck**	Breeding Winter	MDI: Common summer and winter, breeding confirmed at many locations SCH: Common in winter, unconfirmed in summer IAH: Uncommon in summer and winter; Breeding suspected (Jones 1987) but not confirmed ISL: Common in winter, Breeding suspected but not confirmed (Hebard 1959)	1	MDI CBC – Increasing (P = 0.008) (mean = 494.3, n = 63) SCH CBC – Declining (P = 0.02) (mean = 240.5, n = 46) REGION – Declining (Rosenberg and Hodgman 2000)	3	2	HIGHEST		1
Ardea herodias **Great Blue Heron**	Breeding (historic)	MDI: Common in summer, breeding historically reported at Somes Sound (Farley 1935), no breeding records since SCH: Uncommon to occasional in summer IAH: Uncommon during summer ISL: Uncommon during summer; Historically nested on Heron Island (Folger 1986), no current breeding records from park islands	1		0	2		HIGH	2
Aythya collaris Ring-necked Duck	Breeding	MDI: Occasional, Breeding reported at many ponds	1		0	3			4
Botaurus lentiginosus **American Bittern**	Breeding	MDI: Common, breeding at many locations	1		0	2	MODERATE	HIGHEST	1
Branta canadensis Canada Goose	Breeding? Winter	MDI: Rare in summer and winter; no recent reports of nesting although nesting is recorded for the island (Bond 1969) SCH: Rare in winter IAH: Status unknown in summer; rare in winter; Breeding not confirmed ISL: Rare in summer and winter, Breeding not confirmed but a summer record exists (Favour 1974)	1	MDI CBC – Increasing (P < 0.001) (mean = 66.2, n = 29) SCH CBC – No Change (+) (P = 0.06) (mean = 10.9, n = 15)	3	3	MANAGEMENT CONCERN		4

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND [2]	TREND CONF [3]	MAINE PRIORITY STATUS [4]	REGIONAL CONCERN [5]	WATERBIRD CONSERVATION CONCERN [6]	PROPOSED ANP PRIORITY [7]
Butorides virescens **Green Heron**	Breeding (Historic)	MDI: Rare, Only record of breeding was on Hamilton Pond during 1968 (Bond 1969); species approaches the northern edge of its breeding range in Maine SCH: Unconfirmed in summer IAH: Historic reference to species on island (Hebard 1959), no recent records	1		0	3		MODERATE	3
Ceryle alcyon Belted Kingfisher	Breeding	MDI: Common, breeding in many areas on MDI (Witt 1997); BBS average RA = 0.03% SCH: Occasional; breeding not confirmed IAH: Uncommon during summer; breeding not confirmed	1	MDI BBS – No Change	2				4
Chlidonias niger **Black Tern**	Summer	MDI: Unconfirmed in summer, one summer record ISL: Rare, breeding not confirmed	2		0	1-E		HIGH	3
Cistothorus palustris **Marsh Wren**	Breeding?	MDI: Rare, Pair and male nests with no eggs observed at Beaverdam Pond in 1968 (Bond 1969, Long 1987), no other evidence of breeding; species reaches northeastern most edge of breeding range in Maine	2	REGION – Significant declines noted in region (Rosenberg and Wells 1999)	0	2			3
Empidonax alnorum Alder Flycatcher	Breeding	MDI: Common breeder, breeding at Sieur de Monts Spring (Long 1987); BBS average RA = 2.2% SCH: Occasional; Breeding not confirmed IAH: Common, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change	2				4
Empidonax flaviventris **Yellow-bellied Flycatcher**	Breeding	MDI: Common breeder throughout MDI; BBS average RA = 0.4% SCH: Occasional; Breeding not confirmed IAH: Uncommon, Breeding not confirmed	1	MDI BBS – No Change MDI – Formerly considered local on MDI, now well distributed on the western half of MDI (Long 1953)	2		MODERATE		2
Empidonax traillii **Willow Flycatcher**	Summer	MDI: Rare, breeding not detected on MDI (Witt 1997); BBS average RA = 0.01% SCH: Rare; Breeding not confirmed	1	MDI BBS – No Change	2	2			3

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY[1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	WATERBIRD CONSERVATION CONCERN[6]	PROPOSED ANP PRIORITY[7]
Gallinago delicata **Wilson's Snipe**	Breeding?	MDI: Occasional; Breeding is suspected (Witt 1997, Long 1987) but not confirmed SCH: Breeding not confirmed IAH: No summer records	1		0		MODERATE		2
Gavia immer **Common Loon**	Breeding Winter	MDI: Common breeder and winter resident, breeding reported at many locations SCH: No records of breeding; Uncommon in summer, Occasional to common in winter IAH: Common in winter and occasional during summer; no records suggesting breeding ISL: Common in winter, breeding not confirmed	2	MDI CBC – Increasing ($P < 0.001$) (mean = 35.5, n = 61) MDI – Reproductive success low on MDI SCH CBC – No Change (-) ($P = 0.30$) (mean = 33.2, n = 46)	3	2	MODERATE	HIGHEST	1
Ixobrychus exilis **Least Bittern**	Breeding (historic)	MDI: Rare, breeding on island at Beaver Dam Pond in 1968 and 1969; recent breeding record from Bass Harbor Marsh (tributary "2 Moose Pond" in 2000; T. Hodgman, MDIFW, pers. comm.) (Bond 1969); species reaches northern edge of its breeding range in Maine	1		0	2-SC		HIGHEST	3
Lophodytes cucullatus Hooded Merganser	Breeding (historic)	MDI: Rare in summer; Breeding has been reported from Breakneck Ponds and Echo Lake (Witt 1997) but no recent evidence of breeding SCH: Unconfirmed	1		0				4
Melospiza georgiana Swamp Sparrow	Breeding	MDI: Very Common breeder throughout MDI; BBS average RA = 0.7% SCH: Uncommon; Breeding not confirmed IAH: Uncommon, Breeding suspected (Pierson 1983) but not confirmed	1	MDI BBS – No Change	2				4
Mergus merganser Common Merganser	Breeding	MDI: Rare, breeding on Jordan Pond and Bubble Pond (Witt 1997) SCH: Unconfirmed	1		0				4

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND [2]	TREND CONF [3]	MAINE PRIORITY STATUS [4]	REGIONAL CONCERN [5]	WATERBIRD CONSERVATION CONCERN [6]	PROPOSED ANP PRIORITY [7]
Nycticorax nycticorax **Black-crowned Night-heron**	Breeding (Historic)	MDI: Rare, Several nesting colonies were historically reported on MDI when the species was considered numerous (Tyson and Bond 1941) ISL: Rare in summer; Historically nested on Heron Island (Folger 1986) and possibly one of the Porcupine Islands (Allen 1899), breeding not recently confirmed	1	MDI – Historically considered numerous in summer (Tyson and Bond 1941), now considered rare (Witt 1997)	1	2	HIGH	HIGHEST	3
Pandion haliaetus Osprey	Breeding	MDI: Common, Breeding reported on island, but no confirmed nesting within park reported SCH: Uncommon breeder IAH: Nesting directly adjacent to island on navigational markers, commonly observed in summer ISL: Locally common in summer, Historic breeding on park islands (Farley 1935, Russell 1984), no recent records for nesting on park islands	1	MDI – Declining (Long 1987)	1				3
Podilymbus podiceps **Pied-billed Grebe**	Breeeding (Historic)	MDI: Occasional, No records of breeding recently (Witt 1997), Historically reported as nesting at Seal Cove Pond and Aunt Betty's Pond (Palmer 1949, Bond 1969) SCH: Unconfirmed during breeding season IAH: No confirmed summer records	2		0	2		HIGHEST	3
Porzana carolina **Sora**	Summer	MDI: Uncommon to rare, breeding suspected but not confirmed SCH: Breeding not confirmed; species present as a migrant	1		0	3		HIGH	3
Rallus limicola **Virginia Rail**	Breeding	MDI: Uncommon, Breeding at Great Meadow (Witt 1997) and Seal Cove area (Bond 1969)	1		0	3		MODERATE	2

1 DATA QUALITY: 1) Poorly known: little or no effort to discern population status or distribution throughout ANP; 2) Scattered reports: existing information may or may not correctly estimate status or distribution; 3) Generally well known: scattered anecdotal reports likely reflects status and distribution, but only poor or incomplete data available; 4) Reliable data: park-wide survey with good status and distribution information.

2. POPULATION TREND: To calculate the mean number of birds observed during CBCs, only counts where the species was observed were included. If a species was not reported during a count in a year, that years data was not included in calculating the mean. Sample size reported (n) is the number of years a species was reported.

3 TREND CONFIDENCE: 0: no data available for assessment of trends; 1: anecdotal evidence or no easily discernable trends; 2: slight or no trends evident based on surveys; 3: trends possible or vary over time, mixed evidence; 4: trends significant, based on <10 years data; 5: trends significant, based on > 10 years data.

4 MAINE PRIORITY STATUS: Maine Fish and Wildlife priority codes(Maine Department of Inland Fisheries and Wildlife 2005): **1**: high potential for state extirpation without management intervention and/or protection; **2**: moderate to high potential for state extirpation without management intervention and/or protection; **3** low to moderate potential for state extirpation, yet, there are some remaining concerns regarding restricted distribution, status, and/or extreme habitat specialization. **T**: Threatened in Maine; **E**: Endangered in Maine; **SC**: 'Special Concern' in Maine (Maine Department of Inland Fisheries and Wildlife 1996).

5. REGIONAL CONCERN: Conservation priority categories for birds in BCR 14 (Dettmers 2007).

6. WATERBIRD CONSERVATION CONCERN: Regional waterbird population priorities in the mid-Atlantic, New England, and Maritimes region of North America.

7. Proposed ANP Priority birds for research: 1. Highest; 2. High; 3. Moderate or peripheral; 4. Low.

Appendix 7.

Condition assessment for breeding and resident marine bird populations in Acadia National Park.

Species in bold letters are considered of potential conservation concern in Acadia National Park. Locations referred to in table refer to Mount Desert Island (MDI), Isle au Haut (IAH), Schoodic Peninsula (SCH), and small offshore islands (ISL).

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	WATERBIRD CONSERVATION CONCERN[6]	PROPOSED ANP PRIORITY[7]
Actitis macularia Spotted Sandpiper	Breeding	MDI: Common, many nests found on MDI (Witt 1997) SCH: Occasional; no confirmed breeding IAH: Occasional during summer, Breeding suspected (Pierson 1983) but not confirmed ISL: Common to occasional during summer, breeding suspected (Mittelhauser et al. 1992, Witt 1997) but not confirmed	1		0				4
Alca torda **Razorbill**	Summer Winter	MDI: Rare in summer and winter SCH: Rare in summer, uncommon in winter ISL: Rare in summer and winter	2	SCH CBC – Increasing (P = 0.02) (mean = 5.1, n = 10)	4	2-T	HIGH	HIGH	3
Alle alle **Dovekie**	Winter	MDI: Uncommon SCH: Uncommon IAH: Uncommon in winter	1	MDI CBC – No Change (-) (P = 0.98) (mean = 3.0, n = 15) SCH CBC – Declining (P = 0.04) (mean = 3.4, n = 14)	4			LOW	3
Aythya marila **Greater Scaup**	Winter	MDI: Common winter resident SCH: Sporadic numbers, occasionally common IAH: Rare in winter; no winter records from within park boundaries ISL: Locally common in winter adjacent to park islands (Favour 1970, Witt 1997).	2	MDI CBC – No Change (-) (P = 0.94) (mean = 478.8, n = 51) SCH CBC – No Change (-) (P = 0.53) (mean = 18.1, n = 17)	2	2	MODERATE		2
Bucephala albeola Bufflehead	Winter	MDI: Abundant in winter SCH: Common in winter IAH: Common in winter ISL: Locally common in winter	1	MDI CBC – No Change (+) (P = 0.46) (mean = 336.0, n = 62) SCH CBC – No Change (-) (P = 0.06) (mean = 235.1, n = 46)	2				4
Bucephala clangula **Common Goldeneye**	Winter	MDI: Common in winter; said to have once nested on MDI (Tyson and Bond 1941) although the ANP region is far out of its breeding range SCH: Uncommon in winter IAH: Uncommon to Occasional in winter ISL: Locally common to occasional in winter	1	MDI CBC – No Change (-) (P = 0.37) (mean = 265.9, n = 59) SCH CBC – Declining (P = 0.01) (mean = 195.0, n = 46)	3	3	MODERATE		2

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	WATERBIRD CONSERVATION CONCERN[6]	PROPOSED ANP PRIORITY[7]
Bucephala islandica **Barrow's Goldeneye**	Winter	MDI: Rare in winter SCH: Rare in winter IAH: Unconfirmed	2	MDI CBC – No Change (-) (P = 0.27) (mean = 6.0, n = 32) SCH CBC – No Change (+) (P = 0.92) (mean = 3.7, n = 22)	2	2-SC	HIGHEST		3
Calidris maritima **Purple Sandiper**	Winter	MDI: Common SCH: Common IAH: Common during winter ISL: Common during winter	4	MDI CBC – No Change (+) (P = 0.27) (mean = 120.0, n = 41) SCH CBC – No Change (-) (P = 0.29) (mean = 99.8, n = 38)	2	2	HIGHEST		1
Catoptrophorus semipalmatus **Willet**	Summer	MDI: Unconfirmed within the park during summer (Witt 1997) SCH: Unconfirmed within the park during summer (Glanz and Connery 1999)	1		0	2	MODERATE		3
Cepphus grylle **Black Guillemot**	Breeding Winter	MDI: Common in summer and winter, nesting at Otter Cliffs (Long 1987) SCH: Common in winter; no record of breeding on peninsula IAH: Common summer and winter, no records suggesting breeding on island ISL: Common in summer and winter, common breeder on many islands	3	MDI CBC – Increasing (P < 0.001) (mean = 31.1, n = 58) SCH CBC – No Change (+) (P = 0.29) (mean = 19.1, n = 46)	3	3	HIGH	MODERATE	1
Charadrius melodus **Piping Plover**	Summer	MDI: No evidence of breeding within park; summer records exist in region	1		0	1-E	HIGHEST		3
Clangula hyemalis **Long-tailed Duck**	Winter	MDI: Abundant in winter SCH: Common in winter IAH: Common in deeper waters ISL: Common in deeper waters adjacent to park islands	2	MDI CBC – No Change (+) (P = 0.14) (mean = 615.6, n = 63) SCH CBC – Declining (P < 0.001) (mean = 353.6, n = 46) REGION – Declines noted in the region (Sea Duck Joint Venture Management Board 2006)	3	3	MODERATE		2
Fratercula arctica **Atlantic Puffin**	Summer Winter	MDI: Rare in summer and winter; reportedly used to breed on MDI (Palmer 1949) SCH: Rare in summer and winter	2		0	2-T	MODERATE	MODERATE	3

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY[1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	WATERBIRD CONSERVATION CONCERN[6]	PROPOSED ANP PRIORITY[7]
Fulmarus glacialis Northern Fulmar	Winter	MDI: Rare SCH: Unconfirmed IAH: Extremely rare during winter	2		0			LOW	4
***Gavia stellata* Red-throated Loon**	Winter	MDI: Occasional in winter SCH: Uncommon in winter	1	MDI CBC – No Change (-) (P = 0.13) (mean = 2.0, n = 27) SCH CBC – No Change (+) (P = 0.66) (mean = 2.0, n = 23)	2	3	MODERATE	HIGHEST	2
***Histrionicus histrionicus* Harlequin Duck**	Winter	MDI: Uncommon in winter SCH: Uncommon in winter IAH: Common in winter ISL: Locally common adjacent to some islands	4	IAH – Declining until 1992, then increasing SCH CBC – Increasing (P = 0.04) (mean = 3.6, n = 7)	3	2-T	HIGHEST		1
***Larus argentatus* Herring Gull**	Breeder Winter	MDI: Abundant in summer and winter; no confirmed breeding SCH: Abundant in summer and winter; no confirmed breeding IAH: Abundant summer and winter; no confirmed breeding ISL: Abundant summer and winter, Breeding on many park islands	1	MDI CBC – Increasing (P = 0.03) (mean = 1201.0, n = 63) SCH CBC – No Change (-) (P = 0.13) (mean = 1018.1, n = 45)	3	3	HIGH	HIGH	1
***Larus atricilla* Laughing Gull**	Summer	MDI: Common; no confirmed breeding SCH: Common; no confirmed breeding IAH: Uncommon; no records suggesting breeding on island ISL: Occasional to locally common, no confirmed breeding	1		0	3-SC		HIGH	3
Larus delawarensis Ring-billed Gull	Winter	MDI: Uncommon in winter SCH: Uncommon in winter	1	MDI CBC – Increasing (P < 0.001) (mean = 41.6, n = 40) SCH CBC – Increasing (P < 0.001) (mean = 19.3, n = 31)	5			LOW	4
Larus glaucoides Iceland Gull	Winter	MDI: Uncommon to rare in winter SCH: Uncommon to rare in winter IAH: Occasional in winter	1	MDI CBC – No Change (+) (P = 0.35) (mean = 1.3, n = 9) SCH CBC – Increasing (P < 0.001) (mean = 3.3, n = 25)	3			LOW	4

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND [2]	TREND CONF [3]	MAINE PRIORITY STATUS [4]	REGIONAL CONCERN [5]	WATERBIRD CONSERVATION CONCERN [6]	PROPOSED ANP PRIORITY [7]
Larus hyperboreus Glaucous Gull	Winter	MDI: Uncommon in winter SCH: Rare in winter IAH: Rare in winter ISL: Rare win winter	1	MDI CBC – No Change (+) (P = 0.31) (mean = 1.0, n = 10) SCH CBC – No Change (+) (P = 0.08) (mean = 1.6, n = 10)	2			LOW	4
Larus marinus Great Black-backed Gull	Breeder Winter	MDI: Common to abundant year-round; no confirmed breeding SCH: Common year-round; no confirmed breeding IAH: Common summer and winter ISL: Common summer and winter, breeding on park islands	1	MDI CBC – Increasing (P = 0.001) (mean = 76.7, n = 62) SCH CBC – No Change (-) (P = 0.09) (mean = 68.7, n = 46) IAH – Numerous and increasing by 1958 (Hebard 1959)	3	3		LOW	4
Larus philadelphia Bonaparte's Gull	Winter	MDI: Uncommon, found further offshore (Russell 1984) ISL: Uncommon to rare in winter SCH: Uncommon in winter	1	MDI CBC – No Change (+) (P = 0.06) (mean = 5.1, n = 21) SCH CBC – Increasing (P = 0.02) (mean = 10.4, n = 7)	3	2 breed-ing		MODERATE	3
Melanitta fusca White-winged Scoter	Winter	MDI: Abundant in winter SCH: Common in winter IAH: Common in winter ISL: Locally common in winter	1	MDI CBC – Increasing (P = 0.002) (mean = 492.6, n = 62) SCH CBC – Decreasing (P = 0.004) (mean = 532.1, n = 44) REGION – Declines noted in the region (Sea Duck Joint Venture Management Board 2006)	3	3			3
Melanitta nigra **Black Scoter**	Winter	MDI: Uncommon in winter SCH: Uncommon in winter IAH: Uncommon in winter, but numbers can vary greatly from year to year ISL: Locally occasional in winter	1	MDI CBC – Decreasing (P = 0.03) (mean = 49.6, n = 45) SCH CBC – No Change (+) (P = 0.70) (mean = 15.2, n = 29) REGION – Declines noted in the region (Sea Duck Joint Venture Management Board 2006)	3	3	HIGH		1

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	WATERBIRD CONSERVATION CONCERN[6]	PROPOSED ANP PRIORITY[7]
Melanitta perspicillata **Surf Scoter**	Winter	MDI: Uncommon in winter SCH: Uncommon in winter IAH: Uncommon in winter ISL: Uncommon but local in winter	1	MDI CBC – Decreasing (P = 0.02) (mean = 20.0, n = 41) SCH CBC – No Change (+) (P = 0.16) (mean = 9.1, n = 33) REGION – Declines noted in the region (Sea Duck Joint Venture Management Board 2006)	3	3	MODERATE		1
Mergus serrator Red-breasted Merganser	Breeding Winter	MDI: Occasional breeder, common in winter, Breeding on Little Long Pond, Jordan Pond, and Eagle Lake (Witt 1997) SCH: Common in winter IAH: Common in winter, Breeding historically reported (Manville 1964) ISL: Common in winter, breeding not confirmed on park islands	1	MDI CBC – Increasing (P < 0.001) (mean = 56.1, n = 61) SCH CBC – No Change (+) (P = 0.54) (mean = 49.0, n = 45)	3	3 (breed-ing)			4
Oceanites oceanicus Wilson's Storm-Petrel	Summer	MDI: Uncommon, more common offshore ISL: Uncommon	2		0			LOW	4
Oceanodroma leucorhoa **Leach's Storm-Petrel**	Breeding	MDI: Very rare SCH: Very rare IAH: Uncommonly observed from shore during the day ISL: Uncommon, breeding on Heron Island and Schoodic Island	2		0	3-SC	MODERATE	MODERATE	2
Phalacrocorax auritus Double-crested Cormorant	Breeding	MDI: Abundant SCH: Common to abundant IAH: Common during summer ISL: Abundant during summer, breeding on Schoodic Island	2	ISL: Only established breeding colonies here since about 1920 (Bond 1969)	1			LOW	4
Phalacrocorax carbo **Great Cormorant**	Summer Winter	MDI: Occasional in summer, common in winter SCH: Uncommon in summer, occasional in winter IAH: Uncommon during summer, common to occasional in winter ISL: Uncommon in summer, common to occasional in winter, breeding not confirmed	2	MDI CBC – No Change (-) (P = 0.15) (mean = 27.7, n = 57) SCH CBC – Declining (P < 0.001) (mean = 17.7, n = 46)	3	2-SC	HIGHEST	HIGH	2

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY [1]	POPULATION TREND [2]	TREND CONF [3]	MAINE PRIORITY STATUS [4]	REGIONAL CONCERN [5]	WATERBIRD CONSERVATION CONCERN [6]	PROPOSED ANP PRIORITY [7]
Podiceps auritus **Horned Grebe**	Winter	MDI: Common SCH: Common IAH: Common during winter ISL: Common during winter	1	MDI CBC – No Change (+) (P = 0.14) (mean = 84.3, n = 62) SCH CBC – Declining (P < 0.001) (mean = 58.9, n = 46)	3	3	MODERATE	HIGHEST	1
Podiceps grisegena **Red-necked Grebe**	Winter	MDI: Occasional SCH: Uncommon to occasional IAH: Occasional during winter, numbers can vary from year to year ISL: Occasional during winter	1	MDI CBC – Increasing (P < 0.001) (mean = 32.1, n = 58) SCH CBC – No Change (+) (P = 0.07) (mean = 21.4, n = 45)	3		HIGH	HIGH	1
Rissa tridactyla **Black-legged Kittiwake**	Winter	MDI: Uncommon, generally found further offshore SCH: Uncommon although a good place to observe this species IAH: Uncommon in winter	1	MDI CBC – No Change (+) (P = 0.10) (mean = 8.2, n = 11) SCH CBC – Increasing (P < 0.001) (mean = 4.8, n = 23)	3		MODERATE	LOW	3
Somateria mollissima **Common Eider**	Breeding Winter	MDI: Abundant during summer and winter SCH: Abundant during summer and winter IAH: Abundant during summer and winter ISL: Abundant during summer and winter; Breeding on Schoodic Island and Heron Island (Mittelhauser 1992, Folger 1986)	2	MDI CBC – Increasing (P < 0.001) (mean = 3078.5, n = 61) SCH CBC – No Change (-) (P = 0.45) (mean = 1768.7, n = 46)	3	2	HIGHEST		1
Sterna dougallii **Roseate Tern**	Summer	MDI: Rare SCH: Uncommon to rare ISL: Locally rare, breeding not confirmed	3		0	1-E	HIGH	HIGHEST	3
Sterna hirundo **Common Tern**	Summer	MDI: Common SCH: Common IAH: Uncommon during summer ISL: Common, breeding not confirmed	3	IAH – Used to be abundant, now less so in the area (Hebard 1959)	1	2-SC	HIGH	HIGHEST	3
Sterna paradisaea **Arctic Tern**	Summer	MDI: Uncommon SCH: Uncommon IAH: Uncommon in summer ISL: Uncommon, breeding not confirmed	3		0	2-T	HIGH	HIGHEST	3
Uria aalge **Common Murre**	Winter	MDI: Uncommon to rare in winter ISL: Rare in winter	1		0	2		MODERATE	2

SPECIES	RESIDENCY	ABUNDANCE & DISTRIBUTION IN ACADIA NATIONAL PARK DATA QUALITY	DATA QUALITY[1]	POPULATION TREND[2]	TREND CONF[3]	MAINE PRIORITY STATUS[4]	REGIONAL CONCERN[5]	WATERBIRD CONSERVATION CONCERN[6]	PROPOSED ANP PRIORITY[7]
Uria lomvia Thick-billed Murre	Winter	MDI: Occasional to uncommon SCH: Uncommon IAH: Rare during winter ISL: Rare in winter	1		0			LOW	4

1 DATA QUALITY: 1) Poorly known: little or no effort to discern population status or distribution throughout ANP; 2) Scattered reports: existing information may or may not correctly estimate status or distribution; 3) Generally well known: scattered anecdotal reports likely reflects status and distribution, but only poor or incomplete data available; 4) Reliable data: park-wide survey with good status and distribution information.

2. POPULATION TREND: To calculate the mean number of birds observed during CBCs, only counts where the species was observed were included. If a species was not reported during a count in a year, that years data was not included in calculating the mean. Sample size reported (n) is the number of years a species was reported.

3 TREND CONFIDENCE: 0: no data available for assessment of trends; 1: anecdotal evidence or no easily discernable trends; 2: slight or no trends evident based on surveys; 3: trends possible or vary over time, mixed evidence; 4: trends significant, based on <10 years data; 5: trends significant, based on > 10 years data.

4 MAINE PRIORITY STATUS: Maine Fish and Wildlife priority codes(Maine Department of Inland Fisheries and Wildlife 2005): **1**: high potential for state extirpation without management intervention and/or protection; **2**: moderate to high potential for state extirpation without management intervention and/or protection; **3** low to moderate potential for state extirpation, yet, there are some remaining concerns regarding restricted distribution, status, and/or extreme habitat specialization. **T**: Threatened in Maine; **E**: Endangered in Maine; **SC**: 'Special Concern' in Maine (Maine Department of Inland Fisheries and Wildlife 1996).

5. REGIONAL CONCERN: Conservation priority categories for birds in BCR 14 (Dettmers 2007).

6. WATERBIRD CONSERVATION CONCERN: Regional waterbird population priorities in the mid-Atlantic, New England, and Maritimes region of North America.

7. Proposed ANP Priority birds for research: 1. Highest; 2. High; 3. Moderate or peripheral; 4. Low.

Appendix 8.

Potential threats to land bird populations of conservation concern in Acadia National Park.

Topics in bold are considered a potentially important threat in Acadia National Park, deserving additional study.

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Accipiter cooperii Cooper's Hawk		**Bioaccumulation of pesticides and other contaminants** (Curtis and Rosenfield 2006) DDE (e.g., dieldrin, PCBs, mercury and other heavy metals reported in eggs with unknown effects (Curtis and Rosenfield 2006)	Collisions with man-made objects (Curtis and Rosenfield 2006) Shooting and trapping (Curtis and Rosenfield 2006)
Accipiter gentilis Northern Goshawk	Timber harvest is primary threat to nesting populations (Squires and Reynolds 1997) Harvest methods that create large areas of reduced forest canopy cover (<35–40%) (Squires and Reynolds 1997)		Human disturbance and development near nest site (Squires and Reynolds 1997)
Asio otus Long-eared Owl	Loss of open habitats to urbanization and forest succession (Marks et al. 1994)	Contaminants including heptachlor and dieldrin (Marks et al. 1994)	
Bonasa umbellus Ruffed Grouse	Loss of early-successional deciduous forests (Rusch et al. 2000)	Pesticides including DDT can cause mortality or reduce survival (Rusch et al. 2000)	Overharvest (Rusch et al 2000)
Buteo lineatus Red-shouldered Hawk	Forest fragmentation (Crocoll 1994)	DDE, DDD, DDT, dieldrin, heptachlor epoxide, hexochlorobenzine, mercury, chlordane, dieldrin, Furadan 10, and organochlorine and polychlorinated biphenyls detected in some populations (Crocoll 1994)	Human disturbance near nest (Crocoll 1994)
Buteo platypterus Broad-winged Hawk	Habitat alteration, fragmentation, or elimination, particularly on wintering range (Goodrick et al. 1996)	Increased use of DDT south of U.S. may affect birds with a diet of insects (Goodrick et al. 1996)	
Caprimulgus vociferus Whip-poor-will	Habitat loss to agriculture and **closing of forest openings** (Cink 2002)		Vehicle collisions (Cink 2002)
Carpodacus purpureus Purple Finch	Reduction of habitat quality (Dettmers 2007)		**Predation at nests** (Wootton 1996) Human disturbance occasionally causes nest abandonment (Wootton 1996)
Catharus fuscescens Veery	**Loss of dense understory in maturing forests**; browsing by white-tailed deer may be significant (MDIFW 2005, Bevier et al. 2004) Loss or degradation of wintering habitat (Bevier et al. 2004)		**Nest parasitism by Brown-headed Cowbird** (Bevier et al. 2004) Nocturnal collisions with human-made towers (Bevier et al. 2004)
Certhia americana Brown Creeper	Loss of old growth forests and forest fragmentation (Hejl et al. 2002)	Affected by spraying of DDT (Hejl et al. 2002)	Collisions (Hejl et al. 2002)
Chaetura pelagica Chimney Swift	**Loss of nesting habitat – new or rebuilt chimneys too narrow for nesting** (MDIFW 2005, Cink and Collins 2002)	Aerial spraying for spruce budworm (*Choristoneura fumiferana*) has been implicated in declines of prey species (Cink and Collins 2002)	**Gas from fires in chimneys during the nesting season** (Cink and Collins 2002) Collisions with vehicles (Cink and Collins 2002)
Charadrius vociferus Killdeer		Susceptible to pollutants, pesticides, and oil (Jackson and Jackson 2000)	Killed by hunters who mistake them for Mourning Doves (Jackson and Jackson 2000) Prone to collisions with human-made towers and vehicles (Jackson and Jackson 2000)
Chordeiles minor Common Nighthawk		Pesticide spraying for control of mosquitoes implicated in population declines in species (Poulin et al. 1996)	**Susceptible to predators**, especially domestic cats (Poulin et al. 1996) Collisions with vehicles (Poulin et al. 1996)
Circus cyaneus Northern Harrier	**Loss of open habitat and degradation of habitat through increasing predators** are the primary causes of the population decline (MacWhirter and Bildstein 1996)	Organochloride pesticide contamination documented in species (MacWhirter and Bildstein 1996)	**Terrestrial mammals appear to be important predators of eggs and nestlings** (MacWhirter and Bildstein 1996) Human disturbance at nest sites (MacWhirter and Bildstein 1996)

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Cistothorus platensis Sedge Wren	Habitat loss through development and agriculture practices and wetland alteration (MDIFW 2005) Draining and degradation of wetlands and wet-grass habitats (Herkert et al. 2001)		Adverse weather on wintering grounds (MDIFW 2005) **Predation** appears to be a major source of nest failure (Herkert et al. 2001)
Coccyzus erythropthalmus Black-billed Cuckoo	May be susceptible to habitat fragmentation or modification (Hughes 2001)	Potentially susceptible to pesticide-residue accumulation (Hughes 2001)	Species closely tied to fluctuations in tent caterpillar populations (MDIFW 2005) Collisions with towers and buildings (Hughes 2001)
Colaptes auratus Northern Flicker	Loss of mature trees and suitable nest cavities (MDIFW 2005, Moore 1995) Any removal of snags, dead limbs, and diseased trees (Moore 1995)		**Competition for nest sites with starlings** (MDIFW 2005, Moore 1995) Collisions with vehicles a potential threat (Moore 1995)
Contopus cooperi Olive-sided Flycatcher	Habitat loss on wintering grounds (MDIFW 2005, Altman and Sallabanks 2000) **Decline of postfire habitat** (Altman and Sallabanks 2000)	No data, but spraying of pesticides may be detrimental to food supply (Altman and Sallabanks 2000)	**Increasing predation rates at edge habitats** (MDIFW 2005)
Contopus virens Eastern Wood-Pewee		Potentially susceptible to forests sprayed with the insecticide diflubenzuron (to control gypsy moth *Lymantria dispar*) (McCarty 1996)	High populations of deer (> 4–8 deer/km^2) may lower breeding populations (McCarty 1996)
Dendroica caerulescens Black-throated Blue Warbler	Removal of forest shrub layers or reduction of relatively complete canopy cover (Holmes et al. 2005)		Human disturbance during nest building (Holmes et al. 2005)
Dendroica castanea Bay-breasted Warbler	Loss of mature spruce-fir habitat (MDIFW 2005, Williams 1996) Forest fragmentation (MDIFW 2005)	Spraying (especially fenitrothion) for spruce budworm may be partially responsible for recent population declines (Williams 1996)	Global climate change (MDIFW 2005) Population is naturally cyclic with spruce budworm outbreaks (MDIFW 2005) Collisions with towers and lighthouses (Williams 1996)
Dendroica fusca Blackburnian Warbler	Loss of Hemlock stands because of the introduced Hemlock Wooly Adelgid (*Adelges piceae*) (MDIFW 2005, Morse 2004) Forest fragmentation or removal of large conifers (Morse 2004) Deforestation on tropical wintering grounds (Morse 2004)	Persistent pesticides, DDT application, and application of fenitrothian for spruce budworm control (Morse 2004)	
Dendroica palmarum Palm Warbler	Disturbance of habitat (Wilson 1996)		Collisions (Wilson 1996) Predation (Wilson 1996)
Dendroica pensylvanica Chestnut-sided Warbler	Habitat loss because of development and **decline of early successional habitat** (MDIFW 2005)	Fenitrothion, Bt (*Bacillus thuringiensis*), and other insecticides may decrease productivity or cause abandonment of area (Richardson and Brauning 1995)	**Predation** (MDIFW 2005) Collisions with towers (Richardson and Brauning 1995)
Dendroica striata Blackpoll Warbler			Collisions with towers, lighthouses, and other tall structures (Hunt and Eliason 1999)
Dendroica tigrina Cape May Warbler	Loss of mature conifer forest perhaps through climate change or shortened harvest rotations (MDIFW 2005)	Aerial spraying of spruce forests with organophosphate insecticides (phosphamidon, trichlorfon, fenitrothion) (Baltz and Latta 1998)	Spruce budworm suppression efforts (MDIFW 2005) Collisions with towers and other tall structures (Baltz and Latta 1998)
Dendroica virens Black-throated Green Warbler	Fragmentation of forests (Morse and Poole 2005)	DDT applications and application of fenitrothian in spruce budworm control (Morse and Poole 2005)	

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Dolichonyx oryzivorus Bobolink	**Loss of nesting fields** (Martin and Gavin 1995)		Increased predation rates because of habitat fragmentation (MDIFW 2005) **Mowing nesting fields before young have fledged** (Martin and Gavin 1995) Shooting and trapping on wintering grounds (Martin and Gavin 1995)
Eremophila alpestris Horned Lark	Habitat loss by reforestation of agricultural lands and development (COSEWIC 2003, MDIFW 2005)	Sensitive to Fenthion, an organophosphorus cholinesterase-inhibiting insecticide (Beason 1995)	Predation (COSEWIC 2003) Human disturbance (COSEWIC 2003)
Euphagus carolinus Rusty Blackbird	Loss of wet forested habitat (MDIFW 2005; Avery 1995)		Competition from other species for open habitat (MDIFW 2005)
Falcipennis canadensis Spruce Grouse	Loss of habitat (Boag and Schroeder 1992)		**Nest predation by red squirrels *(Tamiasciurus hudsonicus)*** (Boag and Schroeder 1992)
Falco peregrinus Peregrine Falcon		**Organochlorine pesticides, particularly DDT and HEOD (dieldrin, aldrin); also PCBs, mercury, and lead** (White et al. 2002)	**Human disturbance or aircraft at nest sites** (MDIFW 2005; White et al. 2002) Electrocutions and wire strikes (White et al. 2002) Collision with buildings or moving vehicles (White et al. 2002)
Haliaeetus leucocephalus Bald Eagle	Loss of habitat (MDIFW 2005, Buehler 2000)	Declining water quality (MDIFW 2005) **Organophosphorus and carbamate pesticides, heavy metals, and other environmental contaminants (DDT, Dieldrin, PCBs, mercury, lead** (Buehler 2000)	**Human disturbance** (MDIFW 2005, Buehler 2000) Human caused deaths in injuries (MDIFW 2005) Oil Spills (Buehler 2000)
Hirundo rustica Barn Swallow	**Loss of open barns for nesting** (MDIFW 2005, Brown and Brown 1999)		
Hylocichla mustelina Wood Thrush	Forest fragmentation (Roth et al. 1996) **Loss of breeding habitat – scrub understory layer** (MDIFW 2005) Loss of wintering habitat (MDIFW 2005)	Ca^{+} depletion via acid rain (MDIFW 2005) Contaminants (MDIFW 2005)	Collisions with towers or windows (Roth et al. 1996)
Icterus galbula Baltimore Oriole		Sensitive to DDT, Sevin, and arsenate of lead (Rising and Flood 1998)	Collisions with towers (Rising and Flood 1998)
Loxia curvirostra Red Crossbill	Forest fragmentation and loss of old growth habitats (MDIFW 2005, Adkisson 1996) Boreal forest habitat degradation and change (COSWIC 2004) Exotic pests of conifers such as Hemlock Wooly Adelgid (MDIFW 2005)		Competition with and predation by red squirrels (COSEWIC 2004) Predation by Gray Jays (Adkisson 1996) Vehicle collisions (COSEWIC 2004)
Mniotilta varia Black-and-white Warbler	Habitat loss and forest fragmentation resulting in patches <10 ha in size (Kricher 1995)	Pesticides such as fenitrothion and phosphamidon; chlorinated hydrocarbons (Kricher 1995)	
Myiarchus crinitus Great Crested Flycatcher	Loss of dead snags and natural nesting cavities (MDIFW 2005, Lanyon 1997)	Aerial spraying of pesticides (Lanyon 1997)	**Potential competition for nest sites with other cavity nesters** (Starlings) (MDIFW 2005)
Parula americana Northern Parula	Air pollution has adversely affected the growth of the epiphytic lichens used for nest construction in some regions of the northeast (MDIFW 2005, Moldenhauer and Regelski 1996)	Susceptible to DDT (Moldenhauer and Regelski 1996)	Collisions with towers (Moldenhauer and Regelski 1996)
Perisoreus canadensis Gray Jay			Very vulnerable to traps set for terrestrial furbearers (Strickland and Ouellet 1993)

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Petrochelidon pyrrhonota Cliff Swallow			Competition with House Sparrows (Brown and Brown 1995)
Pheucticus ludovicianus Rose-breasted Grosbeak	**Loss of edge habitat and young forests** (MDIFW 2005, Wyatt and Francis 2002) Decline of hardwood species (Dettmers 2007)		Collisions with towers and lighthouses (Wyatt and Francis 2002)
Picoides arcticus Black-backed Woodpecker	**Fire suppression** (Dixon and Saab 2000)		
Pinicola enucleator Pine Grosbeak	Deforestation (Adkisson 1999)		Collisions with cars in winter (Adkisson 1999)
Pipilo erythrophthalmus Eastern Towhee	**Loss of early successional habitat** (Greenlaw 1996)		**Predation on ground nests** (Greenlaw 1996)
Piranga olivacea Scarlet Tanager	Sensitive to forest fragmentation on breeding grounds (Mowbray 1999, MDIFW 2005)		**High rates of nest predation and brood parasitism by cowbirds** (Mowbray 1999)
Poecile hudsonica Boreal Chickadee	Availability of winter habitat (especially old black spruce stands) (Ficken et al. 1996)		
Pooecetes gramineus Vesper Sparrow	Human activities that remove vegetation cover (MDIFW 2005) Loss of grasslands (Jones and Cornely 2002)	Declines have been attributed to pesticides (Jones and Cornely 2002)	
Progne subis Purple Martin			**Displacement from nesting sites by House Sparrows and European Starlings** (Brown 1997)
Riparia riparia Bank Swallow	Loss or stabilization of bank habitat (Garrison 1999)		
Scolopax minor American Woodcock	**Habitat loss and degradation through forest maturation** (MDIFW 2005) Human development (Dettmers 2007)	High levels of DDT, dieldrin, PCBs, mercury, heptachlor epoxide, and mirex have been reported in some populations (MDIFW 2005, Keppie and Whiting 1994)	Migration barriers (MDIFW 2005) **Predation** (MDIFW 2005) Over-hunting (Keppie and Whiting 1994)
Seiurus aurocapillus Ovenbird	Forest fragmentation (Van Horn and Donovan 1994)		Predation (Van Horn and Donovan 1994)
Setophaga ruticilla American Redstart	**Ageing of forests** (Sherry and Holmes 1997)	DDT spraying (Sherry and Holmes 1997)	Collisions (Sherry and Holmes 1997) **Nest predators** (Sherry and Holmes 1997)
Sphyrapicus varius Yellow-bellied Sapsucker	Loss of nesting cavities (MDIFW 2005) **Loss of early-successional habitats** (Walters et al. 2002)		
Spizella pusilla Field Sparrow	Loss of suitable habitat (Carey et al. 1994)		Sensitive to human disturbance during nest building (Carey et al. 1994)
Strix varia Barred Owl	Habitat loss through deforestation, timber harvesting, and forest fragmentation (Mazur and James 2000)	Significant levels of organochlorines and PCBs detected in some regions; possibly sensitive to heptachlor (Mazur and James 2000)	
Sturnella magna Eastern Meadowlark	**Loss of grassland, agricultural, and old field habitats** (MDIFW 2005) **Mowing of fields before August, or mowing of fields more often than every 3-5 years** (Lanyon 1995)	Pesticides (Lanyon 1995)	**Disturbance at nesting sites; extremely sensitive to the presence of humans in breeding territory** (MDIFW 2005, Lanyon 1995)

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Tachycineta bicolor Tree Swallow	Loss of standing dead snags for nest sites (Robertson et al. 1992)	**Mercury, PCBs, and DDE** (Longcore and Haines 1998, Robertson et al. 1992)	Acid precipitation may reduce reproductive success of some populations (Robertson et al. 1992) **Displacement from nest sites by European Starling and House Sparrow populations** (Robertson et al. 1992)
Toxostoma rufum Brown Thrasher	**Loss of shrubby, edge habitats through maturation of forests** (Cavitt and Haas 2000)	Organophosphate or carbamate pesticides (Cavitt and Haas 2000)	Collisions with cars and towers (Cavitt and Haas 2000) Disturbance at nest sites during incubation (Cavitt and Haas 2000)
Tyrannus tyrannus Eastern Kingbird	**Habitat loss resulting from human development, Reforestation of abandoned farmland, and natural plant succession** (MDIFW 2005, Murphy 1996)	Pesticides (Murphy 1996)	Collisions with automobiles (Murphy 1996)
Wilsonia canadensis Canada Warbler	Habitat loss and fragmentation (MDIFW 2005, Conway 1999) Appears sensitive to **reduction of understory vegetation by forest ungulates or forest management practices** (MDIFW 2005, Conway 1999)		

Appendix 9.

Potential threats to marsh bird populations of conservation concern in Acadia National Park.

Topics in bold are considered a potentially important threat in Acadia National Park, deserving additional study.

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Aix sponsa Wood Duck	Loss of forested wetlands (Hepp and Bellrose 1995)		**Overharves**t (Hepp and Bellrose 1995)
Ammodramus caudacutus Saltmarsh Sharp-tailed Sparrow	Management activities in saltmarshes (MDIFW 2005) Marsh degradation and loss due to development, diking, and drainage (Greenlaw and Rising 1994)	**Contaminants especially methyl mercury** (MDIFW 2005) Oil spills (MDIFW 2005)	
Ammodramus nelsoni Nelson's Sharp-tailed Sparrow	Loss and degradation of saltmarsh habitat (MDIFW 2005) Sea level rise (MDIFW 2005) Marsh degradation and loss due to development, diking, and drainage (Greenlaw and Rising 1994)	Oil spills (MDIFW 2005) Industrial discharge (MDIFW 2005) **Contaminants, mercury** (MDIFW 2005)	
Anas rubripes American Black Duck	Loss and degradation of wetland habitat (MDIFW 2005, Longcore et al. 2000) Sea level rise (MDIFW 2005)	Contaminants (MDIFW 2005) Duck plague (duck virus enteritis) caused by a herpesvirus, avian botulism (*Clostridium botulinum*), and avian cholera (*Pasteurella multocida*) (Longcore et al. 2000) Blooms (red tide) of the dinoflagellate *Gonyaulax tamarensis* can cause significant mortality (Longcore et al. 2000) Lead shot ingestion (Longcore et al. 2000)	**Overharvest** (Longcore et al. 2000) Sensitive to human disturbance at breeding sites (Longcore et al. 2000) Disturbance at wintering habitats during severe weather (MDIFW 2005) Competition with Mallards suspected (MDIFW 2005) Aquaculture (MDIFW 2005)
Ardea herodias Great Blue Heron		Contaminants including DDE, PCB, dioxins, dieldrin, and endrin (Butler 1992)	Human disturbance and construction within 300 meters of breeding colonies (Butler 1992) **Predation by Bald Eagles** (MDIFW 2005) Nest-site predators (Parsons et al. 2007)
Botaurus lentiginosus American Bittern	Marshland invasion by purple loosestrife (*Lythrum salicaria*), may substantially alter habitat, but how this effects bitterns has not been assessed (Gibbs et al. 1992a) Loss of wetland habitat and habitat degradation (Gibbs et al. 1992a)	Prey species may be vulnerable to agricultural pesticides (Gibbs et al. 1992a) Avian disease (Parsons et al. 2007) Contaminants (Parsons et al. 2007)	Human disturbance (Parsons et al. 2007) Over-harvest (Parsons et al. 2007)
Butorides virescens Green Heron		Contaminants (Parsons et al. 2007)	**Nest-site predators** (Parsons et al. 2007) Human disturbance (Parsons et al. 2007)
Chlidonias niger Black Tern	Fluctuating water levels (MDIFW 2005) Overwinter survival may be limited by declines in fish populations (MDIFW 2005) Loss and/or degradation of wetlands (Dunn and Agro 1995)	Pesticides may reduce favored insect foods (Dunn and Agro 1995)	Chick predation (MDIFW 2005)
Cistothorus palustris Marsh Wren	Loss or degradation of marsh habitat (Kroodsma and Verner 1997)		**Nest predation thought to be significant** (Kroodsma and Verner 1997) Collisions with towers and other structures during migration (Kroodsma and Verner 1997)
Empidonax flaviventris Yellow-bellied Flycatcher	Forest fragmentation that leads to dessication of ground cover (Gross and Lowther 2001)		
Empidonax traillii Willow Flycatcher	Breeding Habitat destruction or degradation (Sedgwick 2000)		Collisions with towers and other tall structures (Sedgwick 2000)
Gallinago delicata Wilson's Snipe	Loss of wetland habitat (Mueller 2005)	Contaminants (Mueller 2005)	**Overharvest** (Mueller 2005) Collisions (Mueller 2005)

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Gavia immer Common Loon	**Human disturbance and boat traffic near nest sites** (McIntyre and Barr 1997, Parsons et al. 2007) Extreme shoreline development (T. Hodgman, MDIFW, pers. comm.) **Fluctuation of water level during breeding season** (Parsons et al. 2007)	Oil spills (MDIFW 2005) Contaminants – PCBs (McIntyre and Barr 1997) **Heavy metals: mercury, lead poisoning** (MDIFW 2005, Evers et al. 2003, McIntyre and Barr 1997) Avian disease (Parsons et al. 2007)	By-catch in commercial fisheries (MDIFW 2005)
Ixobrychus exilis Least Bittern	Destruction or alteration of wetland habitat (large (>10 ha), shallow wetlands with dense growth of robust, emergent vegetation) (Gibbs et al. 1992b, MDIFW 2005) Invasion of wetlands by purple loosestrife (*Lythrum salicaria*) and phragmites (*Phragmites australis*) (Gibbs et al. 1992b, MDIFW 2005)	Avian disease (Parsons et al. 2007) Contaminants (Parsons et al. 2007)	Collisions with motor vehicles and transmission lines (Gibbs et al. 1992b)
Nycticorax nycticorax Black-crowned Night-heron	Habitat loss (MDIFW 2005) Coastal marsh degradation (Parsons et al. 2007)	**Organochlorines, PCBs, and heavy metals are potentially a problem** (Davis 1993)	Human disturbance (MDIFW 2005) Nest-site predators (Parsons et al. 2007)
Podilymbus podiceps Pied-billed Grebe	Loss of large (>10 ha) wetland habitats (Muller and Storer 1999) Large fluctuations of water level (T. Hodgman, MDIFW, pers. comm.) Invasive plants (Parsons et al. 2007)	Significant DDE and PCB residues detected in eggs (Muller and Storer 1999) **High mercury concentrations** in some populations (Muller and Storer 1999)	Over-harvest (Parsons et al. 2007)
Porzana carolina Sora	Inland wetland loss (Parsons et al. 2007) Invasive plants (Parsons et al. 2007)		Collisions (Parsons et al. 2007) Human disturbance (Parsons et al. 2007)
Rallus limicola Virginia Rail	Inland wetland loss (Parsons et al. 2007) Invasive plants (Parsons et al. 2007) Coastal marsh degradation (Parsons et al. 2007)	Contaminants (Parsons et al. 2007)	Collisions (Parsons et al. 2007) Human disturbance (Parsons et al. 2007)

Appendix 10.

Potential threats to marine bird populations of conservation concern in Acadia National Park.

Topics in bold are considered a potentially important threat in Acadia National Park, deserving additional study.

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Alca torda Razorbill	Reduced integrity of nesting islands as development, recreational use, timber harvesting, and aquaculture increase (Hipfner and Chapdelaine 2002) Changes in food availability (MDIWW 2005)	Oil pollution represents most serious threat (Hipfner and Chapdelaine 2002) Butyltin, a component of antifouling paints used on large ships, found to accumulate in Razorbill livers, but consequences unknown (Hipfner and Chapdelaine 2002) **Contaminants** (Parsons et al. 2007)	Predation from gulls (MDIFW 2005) Limited numbers and distribution of breeding colonies (MDIFW 2005) Entanglement in fishing gear (Hipfner and Chapdelaine 2002) Very sensitive to human disturbance; approaching tour boats cause adults to abandon nests (at least temporarily (Hipfner and Chapdelaine 2002)
Alle alle Dovekie		Highly vulnerable to oil – spills or illegally discharged from vessels when pumping bilges (Montevecchi and Stenhouse 2002) DDT and PCB contaminants and heavy metals detected in liver, kidney, muscle, and fat, consequences unknown (Montevecchi and Stenhouse 2002)	Entanglement in fishing gear (Montevecchi and Stenhouse 2002)
Aythya marila Greater Scaup		Pesticides and other contaminants/toxins (MDIFW 2005) Fuel oil and other hydrocarbons transported by commercial vessels a constant risk (Kessel et al. 2002) Organochlorine compounds (including DDE and PCBs), Aroclor 1260, and heavy metals detected in some populations (Kessel et al. 2002)	Sensitive to human disturbance (Kessel et al. 2002) **Overharvest** (MDIFW 2005)
Bucephala clangula Common Goldeneye	Declines in habitat quality on both breeding and wintering grounds (Eadie et al. 1995)	**Contaminants including PCBs, DDE, and mercury** (Eadie et al. 1995)	Overharvest (Eadie et al. 1995)
Bucephala islandica Barrow's Goldeneye	Displacement from foraging areas by aquaculture development (MDIFW 2005) Habitat degradation through alterations of river beds, increased sediment loads from agricultural and industrial practices, and loss of coastal and interior wetlands (Eadie et al. 2000)	Oil spills (MDIFW 2005) Oil spills and pollutant exposure are a potential threat (Eadie et al. 2000)	Overharvest (Eadie et al. 2000, MDIFW 2005)
Calidris maritima Purple Sandiper		Oil spills (MDIFW 2005, Payne and Pierce 2002) High levels of organochlorine contaminants (HCH, HCB, PCB, and particularly DDT) reported in this species (Payne and Pierce 2002)	Human disturbance (MDIFW 2005) Limited number and distribution of global populations (MDIFW 2005) Rockweed (*Ascophyllum nodosum*) harvesting may be degrading feeding habitat (Payne and Pierce 2002)
Catoptrophorus semipalmatus Willet	Development (MDIFW 2005) Ditching of wetlands (Lowther et al. 2001)	Oil spills (MDIFW 2005) Botulism outbreaks (bacterium *Clostridium botulinum* type C) reported in some populations (Lowther et al. 2001) Arsenic (elevated levels), selenium, mercury, DDE, and other organochlorines have been reported in some populations (Lowther et al. 2001)	Human disturbance (MDIFW 2005) Collisions with vehicles (Lowther et al. 2001)
Cepphus grylle Black Guillemot		**Contaminants such as mercury, pesticides, and other residues** (Parsons et al. 2007, Eadie et al. 1995) Oil spills (Eadie et al. 1995)	**Nest site predators** (Parsons et al. 2007) Human disturbance on nest sites (Eadie et al. 1995)

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Charadrius melodus Piping Plover	Loss and degradation of habitat at staging areas from development and contaminants (MDIFW 2005)	Oil spills (MDIFW 2005)	Human disturbance (MDIFW 2005) Avian and mammalian predators during nesting (Haig and Elliott-Smith 2004)
Clangula hyemalis Long-tailed Duck		Fowl cholera (*Pasterulla multocida*) and an adenovirus have been implicated in large die-offs (Robertson and Savard 2002) **Increasing cadmium, selenium, and mercury levels have been reported** (Robertson and Savard 2002) Vulnerable to oil (Robertson and Savard 2002) High levels of butyltin (active ingredient in antifouling marine paint) reported in liver of this species (Robertson and Savard 2002) Ingestion of lead shot (Robertson and Savard 2002)	**Overharvest** (Robertson and Savard 2002) By-catch in commercial fishing (Robertson and Savard 2002)
Fratercula arctica Atlantic Puffin	Habitat loss (MDIFW 2005) Collapse of fish stocks (especially of prey species such as herring) near breeding colonies (Lowther et al. 2002)	Oil spills (MDIFW 2005) Mercury (in some populations), high mercury load not found in Gulf of Maine populations (Lowther et al. 2002)	Predation from gulls (MDIFW 2005) Nest predators such as rats, mink, gulls, Incidental take during fishing (MDIFW 2005) Limited number and distribution of nesting sites (MDIFW 2005) Human disturbance during incubation (Lowther et al. 2002)
Gavia stellata Red-throated Loon		Marine oil spills (Parsons et al. 2007) **Contaminants such as mercury** (Parsons et al. 2007, Barr et al. 2000)	Collisions (Parsons et al. 2007)
Histrionicus histrionicus Harlequin Duck	Wintering habitat degradation from shoreline development, aquaculture, and algae-harvesting are concerns (Robertson and Goudie 1999)	Oil spills (Wickett 1999, Robertson and Goudie 1999) **Bioaccumulation of heavy metals** (Robertson and Goudie 1999)	**Factors lowering adult survival rates** (MDIFW 2005) Limited distribution (MDIFW 2005) Human disturbance (Wickett 1999)
Larus argentatus Herring Gull		Contaminants (Parsons et al. 2007)	Nest-site predators (Parsons et al. 2007) Human disturbance (Parsons et al. 2007)
Larus atricilla Laughing Gull		**Susceptible to Organochlorine compounds, lead, and mercury** (Burger 1996)	Human intrusions at colonies (Burger 1996) Competition for nesting habitat with Herring Gulls (Burger 1996)
Melanitta nigra Black Scoter	Increasing commercial harvest of mussels (Bordage and Savard 1995)	**High levels of lead, cadmium, PCBs, DDE, and mercury** have been detected in some populations (Bordage and Savard 1995) Very susceptible to oil spills (Bordage and Savard 1995)	**Over-hunting** (Bordage and Savard 1995)
Melanitta perspicillata Surf Scoter		**High levels of cadmium and mercury** detected in some populations (Savard et al. 1998) Susceptible to oil spills (Savard et al. 1998)	**Over-hunting** (Savard et al. 1998)
Oceanodroma leucorhoa Leach's Storm-Petrel		Vulnerable to pollution from organochlorine compounds (Huntington et al. 1996) Oil spills (Huntington et al. 1996) **Heavy metals including selenium and mercury** (Huntington et al. 1996)	Species is vulnerable to introduction of predatory mammals (Huntington et al. 1996) **Trampling of burrows or erosion resulting from human visitors or domestic sheep** (Huntington et al. 1996)

SPECIES	HABITAT DISRUPTION	CONTAMINANTS, SPILLS, DISEASE, PARASITISM	OTHER INDICATORS OR STRESSORS
Phalacrocorax carbo Great Cormorant	Habitat loss (MDIFW 2005) Changes in food availability (MDIFW 2005)	Oil spills (Hatch et al. 2000)	Predation from gulls and eagles (MDIFW 2005) **Very susceptible to disturbance, especially where nesting in mixed colonies with gulls** (Hatch et al. 2000, MDIFW 2005) Birds drowned in fishing gear (Hatch et al. 2000)
Podicips auritus Horned Grebe		Marine oil spills (Parsons et al. 2007, Stedman 2000) Avian disease (Parsons et al. 2007) Contaminants including DDE (Stedman 2000)	
Podicips grisegena Red-necked Grebe		Marine oil spills (Parsons et al. 2007) Avian disease (Parsons et al. 2007) **Contaminants including organochorines, mercury, and other heavy metals** (Parsons et al. 2007, Sout and Nuechterlein 1999)	Over-harvest (Parsons et al. 2007)
Rissa tridactyla Black-legged Kittiwake		Marine oil spills (Parsons et al. 2007) Contaminants (Baird 1994)	
Somateria mollissima Common Eider	Habitat loss (MDIFW 2005) Commercial harvesting of blue mussels, sea urchins, and marine algae (Goudie et al. 2000, MDIFW 2005)	Oil spills, especially during molt (MDIFW 2005, Goudie et al. 2000) Fowl cholera (*Pasturella multocida*) outbreaks (Spencer 1980, Goudie et al. 2000) **Heavy metals** (Goudie et al. 2000)	**Over-hunting** (MDIFW 2005, Goudie et al. 2000) **Human disturbance of nesting islands** (MDIFW 2005) Aquaculture development (MDIFW 2005) **Predation by Great Black-backed Gulls and Bald Eagles** (MDIFW 2005)
Sterna dougallii Roseate Tern	Habitat loss (MDIFW 2005) Changes in food availability (MDIFW 2005)	Oil spills (MDIFW 2005) **Organochlorines, PCBs, lead, mercury, cadmium, and selenium** detected in some colonies (Gochfeld et al. 1998)	Predation by gulls and mink (MDIFW 2005) Predation by Peregrine Falcons (Drennan 1986) Human disturbance on nesting islands (MDIFW 2005, Gochfeld et al. 1998) Limited number and distribution of breeding colonies (MDIFW 2005)
Sterna hirundo Common Tern	Habitat loss (MDIFW 2005) Competition for nesting sites with gulls (MDIFW 2005) Changes in food availability (MDIFW 2005) Human development, building, recreational activity, and other degradation of habitat (Nisbet 2002)	**High levels of DDE, PCBs, other Organochlorines, mercury (Hg), lead (Pb), cadmium (Cd), chromium (Cr), and selenium (Se)** reported from some populations; especially sensitive to embryotoxic effects of DDE and dioxin-like toxic effects of PCBs (Nisbet 2002)	Predation from gulls and mink (MDIFW 2005) Predation by Peregrine Falcons (Drennan 1986) Human disturbance on nesting islands (MDIFW 2005) Limited number and distribution of breeding colonies (MDIFW 2005)
Sterna paradisaea Arctic Tern	Habitat loss and disturbance (MDIFW 2005, Hatch 2002) Competition for nesting sites with gulls (MDIFW 2005) Changes in food availability; competition with commercial fisheries (MDIFW 2005, Hatch 2002)	**DDE, PCBs, oxychlordane, Mercury (Hg), and Cadmium** detected at some populations (Hatch 2002)	Predation and displacement by gulls (MDIFW 2005, Hatch 2002) Predation by Peregrine Falcons (Drennan 1986) Limited number and distribution of breeding colonies (MDIFW 2005)
Uria aalge Common Murre		**High levels of DDE, PCB, dieldrin, and mercury** reported in some populations (Ainley et al. 2002) Significant mortality from oil pollution and spills (Ainley et al. 2002)	Mortality associated with commercial fishing nets (Ainley et al. 2002) Direct conflict with commercial fisheries (Ainley et al. 2002)

Appendix 11. Stressors affecting or partially affecting resident birds in ACAD.

Codes are as follows:

EP – existing problem based on direct evidence

PP – potential problem but not backed up with data or documentation

OK – Not currently or expected to be a problem

? = not enough information available to assess threat level

Blank = not applicable

STRESSOR	***LAND BIRDS***	***MARSH BIRDS***	***MARINE BIRDS***
HABITAT ALTERATION, LOSS, DEGRADATION			
Aquaculture, commercial fishing		?	?
Collisions with made-made objects	?	?	?
Loss of open habitats through succession or fire suppression	PP	PP	EP[3]
Loss of old chimneys or open barns as nesting habitat	?		
Loss of hemlock stands from non-native adelgid	?		
Mowing fields before young have fledged	?		
PESTICIDES / HERBICIDES			
Organochlorine contaminants	EP[1]	PP	PP
Organophosphate contaminants	PP	?	?
OTHER CONTAMINANTS			
Oil spills	PP	PP	EP[4]
Heavy metals	EP[2]	PP	PP
DISTURBANCE			
Approaching too close (boat or on foot)	PP	PP	PP
DISEASE /PARASITISM			
Avian cholera, avian botulism, virus	?	?	PP[5]
Red tide blooms		?	?
Parasitism by Brown-headed Cowbirds	?		
PREDATION			
By Gulls			EP[4]
By Mink			PP
By Eagles		?	PP
By domestic cats	?	?	OK
STRESSOR	***LAND BIRDS***	***MARSH BIRDS***	***MARINE BIRDS***
HARVEST			
Overharvest through hunting	PP	EP	EP
Illegal shooting	?	OK	?
COMPETITION			
For nesting habitat (gulls)			EP[6]
For nesting habitat (starlings, House Sparrows)	PP		

1. Based on study of organochlorines in Bald Eagles by Matz (1998) and Welch (1992).

2. Based on study by Longcore and Haines (1998) on bioaccumulation of mercury in Tree Swallows on Mount Desert Island and mercury in Bald Eagles by Welch (1992).
3. Folger (1986) describes park islands with nesting seabirds and threats to each colony.
4. See Shenton (1973) for a summary of local oil and gas spills in the region.
5. Cholera has been problematic in local seabird colonies in the past (Spencer 1980, Korschgen et al. 1978, Elliot 1983).
6. See Folger (1986). In 1952, 1103 gull eggs were destroyed by being sprayed with an oil mixture on Schoodic Island to assist in Gull Control (Maine Department of Inland Fisheries and Wildlife 1969).

Appendix 12.
Growth and physiological response to varying levels of ozone.

Responses are measured via photosynthesis (P_n), stomatal conductance (g_s), dark respiration (R_s), and carbon allocation of common tree species found in ACAD.
(Based on Chappelka and Samuelson 1998 Tables 1, 2). Ambient ozone levels range from 0.02-0.045 µl l^{-1} (National Research Council 1991).

Species	Ozone Treatment (~ 0.05 – ~ 1.00 µl l^{-1} over 1-3 growing seasons)	*Physiological Response (multiple studies)*
Acer rubrum (red maple)	~0.05 µl l^{-1} and up to 2 x 77 µl l^{-1}	*No effect on growth to 15% decrease in growth; 25% decrease in P_n; 30% decrease in g_s*
Acer saccharum (sugar maple)	Up to 4 x 1.85 µl l^{-1}	*No effect on growth; no influence on P_n and R_s; P_n reduced by 56%; reduced chlorophyll concentrations; increased foliar R_s*
Quercus rubra (red oak)	Up to 2 X ~ 0.04 µl l^{-1}	*No effect on growth; No effect on P_n and g_s on seedlings; P_n reduced up to 50% in mature trees; reduced foliar starch, foliar nitrogen and increased foliar carbon; no effect on foliar R_s; no effect on fine root respiration to reduction in fine root production*
Picea rubens (red spruce)	~ 1.00 µl l^{-1}	*No effect on growth; no ozone effects on P_n, g_s or chlorophyll nutrition/chlorophyll and wax content in seedlings and mature trees; Reduction in P_n seedlings and mature trees; no effect on needle or whole tree P_n and water-use efficiency*

Species	**Ozone Treatment (~ 0.05 – ~ 1.00 µl l^{-1} over 1-3 growing seasons)**	***Physiological Response (multiple studies)***
Populus tremuloides (quaking aspen)	~0.05 µl l^{-1}; 0.073 to 50 and 2 x 50 µl l^{-1}	*12-24% reduction in above-ground biomass; 18-55% decline in P_n; higher rates of decline associated with nutrient and water stress; clone, leaf age, date reflect response level*
Prunus serotina (black cherry)	~0.05 µl l^{-1}	*No effect on growth to 30% decrease in shoot biomass; premature senescence; decline in root/shoot ratio; up to 50% decline in P_n*
Pinus strobus (white pine)	~0.05 µl l^{-1}	*20% decrease in height*
Robinia pseudoacacia (black locust)	*~0.05 µl l^{-1}*	*18% decrease in height to no effect on growth*

(Appendix 12, continued)

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