WATER RESOURCES MANAGEMENT PLAN

ISLE ROYALE NATIONAL PARK
MICHIGAN

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EXECUTIVE SUMMARY

Water is a dominant landscape element for national park units of the Great Lakes region. Given the region's abundance of high quality fresh surface and ground water and the fragility of these resources, proper conservation and management is a paramount concern. The Great Lakes region also is faced with numerous environmental problems from point and nonpoint sources of pollution, ongoing and increasing ecosystem impacts from anthropogenic sources caused by development and land use decisions and the inherent pressures from increases in population density. With this as a backdrop it is clear that the preservation and conservation of water resources is critical to the maintenance of the biological diversity for parks such as Isle Royale.

Isle Royale National Park was authorized by Congress on March 3, 1931," to conserve a prime example of North Woods Wilderness." With Senate Bill S6221 the House and Senate authorized the establishment of ISRO with the provision that, "the United States shall not purchase by appropriation of public monies any lands within the aforesaid area, but such lands shall be secured by the United States only by public or private donation." At that time it was the only national park in the Great Lakes area.

Specific management objectives developed as part of the water resources planning process pertaining to water resources and water-dependent environments within ISRO include:

- Manage water resources of the park in a manner designed to maintain the highest degree of biological diversity and ecosystem health;
- Acquire appropriate information to adequately understand and manage water-related resources;
- Assure that park development and operations do not adversely affect the water resources of the park;
- Recognize the significance of wetland/riparian resources and manage in a manner that will preserve their natural functions and health;
- Perform and/or coordinate water resources research that will contribute to the scientific base for water resources management;
- Promote public awareness of the water resources of ISRO and an understanding of current and potential human impacts on these resources;
- Implement on-going monitoring and research activities necessary to detect water-quality changes in inland lakes and streams that are vulnerable to atmospheric deposition; and
- Promote water resource management and use practices that discourage the invasion of aquatic invasive species.

This Water Resources Management Plan provides a recommended course of management action for achieving these objectives.

Isle Royale National Park (ISRO) is an island archipelago in western Lake Superior. It is primarily a wilderness and maritime park. Wildlife, plants and habitat along with tourism and recreation are directly or indirectly tied to the quality and quantity of water resources of the park. Because of its unique ecosystems, isolation from the mainland and restricted land uses, changes to the Isle Royale landscape as well as land use changes in the Lake Superior watershed have the potential to greatly affect the park's water resources. While it's true that significant information already exists concerning the water resources of the park, the information is not comprehensive and lacks consistency and uniformity. Therefore a systematic and uniform approach to the collection and analysis of water resources data and information for Isle Royale is needed.

The primary purpose of this Water Resources Management Plan (WRMP) for ISRO is to assist park management with water resources-related decisions by providing information on potential threats to the park's water resources and guidance on immediate actions that can prevent or mitigate water resource degradation. In this regard, the plan provides a thorough overview of existing water resource information; identifies and discusses a number of water-related issues and management concerns; and recommends a course of action for addressing high priority water-related issues at the park. Project statements that address critical water resource issues are also included and can be incorporated into the park's Resource Management Plan for future funding consideration. These project statements address the water resource issues within the context of water-related management objectives. This connection between management actions, issues, and objectives is the cornerstone of issue-driven planning.

The WRMP discusses laws, policies and programs relevant to ISRO water resource management issues (see Appendix A), as well as other plans and concurrent planning activities for the park. As with other national parks and other government agencies in general, the park faces many of the same financial complexities resulting from expanding responsibilities in light of decreasing funding sources. ISRO administrators face issues involving maintenance backlogs, deficient funding for demands of basic operations, and a current inability to invest fully in priority resource areas. Other agencies and organizations and programs exist to collaborate with the NPS and promote expanded park participation in areas related to air, land and water resources management particularly as these relate to broader Great Lakes restoration efforts. To meet these ongoing challenges, the Park must seek to diversify its funding sources and develop new operating techniques and innovative strategies in partnership with other organizations and resource sources (see Appendix B).

The park's remote location in the northwestern portion of Lake Superior and lack of coterminous land use make ISRO attractive for long-term ecological monitoring and hypothesis testing. The archipelago consists of one large island (45 miles long by 9 miles wide) that is surrounded by about 400 small islands. Although it is only about 13 miles from the Canadian shoreline (Ontario), the park is under the political jurisdiction of the United States in the state of Michigan, and represents the northern-most point in Michigan. The park is approximately 18 miles from Minnesota and 70 miles northwest of Houghton, Michigan on Michigan's Keewenaw Peninsula.

The park encompasses approximately 571,790 acres, 75 percent of which is aquatic habitat primarily because the park boundary extends from the main island 4.5 miles into Lake Superior. Total land area is 133,781 acres. Aquatic habitats cover a wide spectrum ranging from the deep, cold waters of Lake Superior to ISRO's many inland lakes (259 larger than ¼ acre; the largest is Siskiwit Lake), streams (240 longer than 300 feet), beaver ponds, marshes and bogs of the island. The inland lakes have watershed areas that range from 30 to 14,359 acres. Lake surface area ranges from < 1acre to 4,040 acres, and maximum depth ranges from 5 to 150 feet. The four largest streams by length are concentrated in the southwestern end of the main island, the longest being Washington Creek at approximately 14 miles in length. Wetland environments are common to ISRO.

Over 99 percent of the park land base (approximately 132,111 acres) has been designated as federal wilderness to be managed in accordance with provisions of the Wilderness Act of 1964. In 1980 the park was designated a U.S. Biosphere Reserve under the United Nations Man and the Biosphere Program, giving it global scientific and educational significance. The park visitor season is April 16 to October 31, with full services offered from mid-June to Labor Day. ISRO is the only national park that is closed to visitors over the winter. No vehicles or wheeled devices are allowed in the park including bicycles or canoe portage devices. There are no roads in the park and land motor vehicles are only allowed at the park administration headquarters on Mott Island and developed areas at Windigo and Rock Harbor. There are 165 miles of hiking trails on the main island, with visitor centers at Windigo and Rock Harbor. The lodge at Rock Harbor offers private guest rooms with private baths for overnight stays and weekly cabin rentals. A water treatment facility at Rock Harbor provides water service to the guest lodge and cabins, dormitory and staff housing, restaurant, and park visitor center in the immediate area. Transportation on the main island or between islands is limited to private boat, ferry, or sea plane.

The orientation of the archipelago is roughly parallel to the north shore of Lake Superior, with its long axis oriented northeast to southwest. The main island features a series of ridges and valleys which run parallel to the long axis, with the "backbone" of the island, Greenstone Ridge, running the full length of the island through its center. This ridge/valley topography has created many wetland swale environments in most of the valleys.

The geological history of Isle Royale National Park began approximately 1.2 billion years ago. A series of rifts, running for thousands of miles, buckled and cracked in long lines across the park area. Molten flowing lava rose through the cracks. As these flows stopped and cooled, layers of volcanic igneous rock were formed, building a lava bed that reached over 10,000 feet thick. Later, softer eroded rock and gravel would wash into the low areas, forming layers of softer rocks like sandstone and conglomerates between sheets of the harder volcanic layers (Rennicke 1989).

During the last million years, a series of four major glaciers moved down over the northern United States and Canada, advancing as far south as southern Ohio. The last major glaciation, known as the Wisconsinan, ended in the Superior area approximately ten thousand years ago, forming the ancestral Great Lakes and thousands of surrounding smaller lakes (McNab and Avers 1994). The ridge-valley topographic profile of the island was reinforced as the ice sheet in this last glacial period flowed parallel to the ridges, digging deeper into the soft rock layers.

The vegetation of modern day Isle Royale has been influenced by a number of factors: the remoteness of the island; its thin soils, rugged bedrock and rock outcroppings; short growing season; winds and lake storms; temperatures ameliorated by Lake Superior; and natural and man-made fire. Perhaps the most unique feature of the park is the natural barrier created by Lake Superior which hindered the immigration and emigration of additional plant and animal species. The island has fewer species than adjacent mainland areas, some of which are unique to the island (DuFresne 2002).

The earliest human inhabitants of Isle Royale and its surrounding islands were North American Native American Indian tribes. Native American hunters reached the north shores of Lake Superior as early as 8,000 or 9,000 BC. The Native American way of life has thought to have remained unchanged for several thousand years in the area, until the first European contact came from French explorers from the south and French traders from the east. Economic activity pursued by modern settlers included copper mining (which had the greatest environmental effects) and commercial fishing.

Ground water as a potential source of public water supply specifically on Isle Royale was investigated in 1981 (Grannemann and Twenter 1982). Although the island park is surrounded by the fresh waters of Lake Superior, the quality of water from the lake and associated bays is not always suitable for human consumption without processing through formal water treatment facilities. On Isle Royale, running waters are plentiful but generally small and/or intermittent. Johnson, in his 1980 thesis on the Siskiwit River, stated, "Most of the water draining off the island first flows quickly in rivulets and brooks down ridge slopes, then turns sluggish as it reaches the valleys and drains through swamps and beaver ponds toward Lake Superior…many of the small streams generally proceed toward the ends of the island, with a few assuming routes through narrow cross valleys which have resulted from faulting (Johnson 1980)."

Stream and watershed studies at Isle Royale were initiated in 1982, when NPS established the Watershed Research Program with four ecosystem study sites in Olympic National Park, Rocky Mountain National Park, and Sequoia-Kings Canyon National Park, and the Wallace Lake watershed near Moskey Basin at ISRO. The program was designed to address large-scale stressors such as atmospheric deposition and climate change via an understanding of watershed processes and linkages between land, water and the atmosphere (Hermann and Stottlemyer 1991). ISRO was selected due to its remote location, its history of limited human land use, its representation of a southern boreal forest ecotone, its relatively high atmospheric deposition and its susceptibility to climate changes (Stottlemyer *et al.* 1998). Twenty years of intensive research have generated a wealth of information about how ISRO watersheds function and how atmospheric constituents are cycled through boreal forest, soils, snow, and surface waters. Much of this work was recently compiled and summarized (Stottlemyer *et al.* 1998).

The Great Lakes are the most prominent natural feature of the larger geographic region of which ISRO is a part. The Great Lakes have a combined surface area of about 94,000 mi^2 draining more than twice as much land, and are among the largest, deepest lakes in the world. They are the largest single aggregation of freshwater on the planet, excluding the polar ice caps, holding an estimated six quadrillion gallons of water or 18 percent of the world supply (Glassner-Shwayer 1999).

Lake Superior is the largest (both in surface area and volume), coolest, and most northern of the Great Lakes. The average and maximum depths are 489 and 1,335 feet, respectively. The lake contains 2,934 mi^3 of water with a retention time of 191 years. The total watershed area of Lake Superior is 81,000 square miles (49,300 in land drainage area and 31,700 in water measured at low water datum). Most of the basin is forested, with little agriculture because of cool climate and poor soils. The forests and sparse population result in relatively few pollutants entering the lake, except through airborne transport. The total binational Lake Superior basin population is 607,121 with 425,548 living in the United States portion and 181,573 living in the Canadian portion (USEPA 1995). The only outlet for the lake is the St. Mary's River at the far southeastern corner of the lake at Sault St. Marie, MI.

Despite its large size, Lake Superior is sensitive to the effects of a wide range of pollutants, from both point and nonpoint sources (USEPA 1995). Because of the lake's large surface area, it is vulnerable to atmospheric pollutant deposition onto the lake surface. In addition, the high retention time for the lake's volume of water means that pollutants that enter the lake are retained in the system and become more concentrated over time.

The National Park Service and Isle Royale National Park personnel held a water resources scoping meeting in Houghton, Michigan, in April 2002. The purpose of this meeting was to identify and prioritize water resource issues and management concerns for Isle Royale National Park. The 16 attendees at the meeting included park staff, local stakeholders and Great Lakes Commission (GLC) staff. After a lengthy open discussion with input from all participants, a total of 14 water resources issues were identified and prioritized by the group. This list was refined and modified in subsequent contacts and discussion with staff members. National park staff and GLC staff evaluated the highest priority issues that could be feasibly addressed by the park, given current park funding and personnel constraints. The resulting list of water resources issues for ISRO is as follows:

<u>High Priority</u>

Water resources data, information and monitoring needs for ISRO

ANS (Aquatic Nuisance Species) prevention and control prevention plan for invasive species

Atmospheric deposition of toxic contaminants

Medium Priority

Pollution from Boats / PAHs (polycyclic aromatic hydrocarbons)

Global Climate Change

Bathymetric Mapping

In summary, water is an important resource for the functioning of natural systems and for staff and visitor use in ISRO. Water's interaction with the terrestrial environment produces a variety of geomorphically-based habitats that allow the park to support diverse biological resources. Maintaining this diversity depends at least partially upon careful safeguarding of the park's water resources and water-dependent environments, and minimizing stresses that can affect these resources from both inside and outside of the park's boundaries.

ISLE ROYALE NATIONAL PARK'S WATER RESOURCES MANAGEMENT PLAN AND NEPA

The National Environmental Policy Act (NEPA) mandates that federal agencies prepare a study of the impacts of major federal actions having a significant effect on the human environment and alternatives to those actions. The adoption of formal plans may be considered a major federal action requiring NEPA analysis if such plans contain decisions affecting resource use, examine options, commit resources or preclude future choices. Lacking these elements, this Water Resources Management Plan (WRMP) has no measurable impacts on the human environment and is categorically excluded from further NEPA analysis.

According to Director's Order (DO) #12 Handbook (section 3.4), water resources management plans normally will be covered by one or more of the following categorical exclusions:

- 3.4.B (1) Changes or amendments to an approved plan when such changes have no potential for environmental impact.
- 3.4.B (4) Plans, including priorities, justifications, and strategies, for non-manipulative research, monitoring, inventorying, and information gathering.
- 3.4.B (7) Adoption or approval of academic or research surveys, studies, reports and similar documents that do not contain and will not result in NPS recommendations.
- 3.4.E (2) Restoration of non-controversial native species into suitable habitats within their historic range.
- 3.4.E (4) Removal of non-historic materials and structures in order to restore natural conditions when the removal has no potential for environmental impacts, including impacts to cultural landscapes or archeological resources.
- 3.4.E (6) Non-destructive data collection, inventory, study, research, and monitoring activities.
- 3.4.E (7) Designation of environmental study areas and research natural areas, including those closed temporarily or permanently to the public, unless the potential for environmental (including socioeconomic) impact exists.

These categorical exclusions require that formal records be completed (Section 3.2, D0-12 Handbook) and placed in park files. It is the responsibility of ISRO to complete the documentation for the applicable categorical exclusion(s) when the WRMP is approved and published.

I. INTRODUCTION

Whether supporting natural systems or providing for visitor use, water is a significant resource in units of the national park system. Consistent with its fundamental purpose, the National Park Service (NPS) seeks to protect surface and ground waters as integral components of a park's aquatic and terrestrial ecosystems by carefully managing the consumptive use of water. The NPS also strives to maintain the natural quality of surface and ground waters in accordance with all applicable federal, state, and local laws and regulations. Water-based recreation such as fishing, as well as aquatic ecosystem health is dependent upon the maintenance of adequate water quality and quantity.

Water is a dominant landscape element for national park units of the Great Lakes region. Given the region's legacy of environmental problems, the ongoing impacts from anthropogenic sources, and the increases in population density, it has become paramount that the preservation and conservation of water resources be seen as critical to the maintenance of the parks' biological diversity.

Because Isle Royale National Park (ISRO) is largely a hydrological phenomenon, water-related issues naturally dominate. While information exists concerning the water resources in the park, systematically collected information and adequate analysis addressing water resources is lacking. The primary purpose of this Water Resources Management Plan for Isle Royale National Park is to assist park management with water-related decisions by providing information on existing or potential threats to water resources and guidance on management actions that can address those threats. In this regard, the plan provides an exhaustive overview of existing water resource information; identifies and discusses a number of water-related issues and management concerns; and, recommends a course of action for addressing high priority water-related issues at ISRO. Project statements that address critical water resource issues are included and can be incorporated into the park's Project Management Information System (PMIS) for future funding consideration. These project statements address the water resource issues within the context of water-related management objectives. This connection between management actions, issues, and objectives is the cornerstone of issue-driven planning.

A. Park Location and Description

ISRO is a unique and remote island park located in the northwestern portion of Lake Superior in the Great Lakes Basin (Figure 1). Although it is closer to the Canadian shoreline, the park is under the political jurisdiction of the United States in the state of Michigan, and represents the northern-most point in Michigan. This wilderness archipelago is 45 miles long and 9 miles wide at its widest point. The park is approximately 13 miles from Ontario, 18 miles from Minnesota on the USA mainland, and about 70 miles northwest of Houghton, Michigan in Michigan's Keweenaw Peninsula.

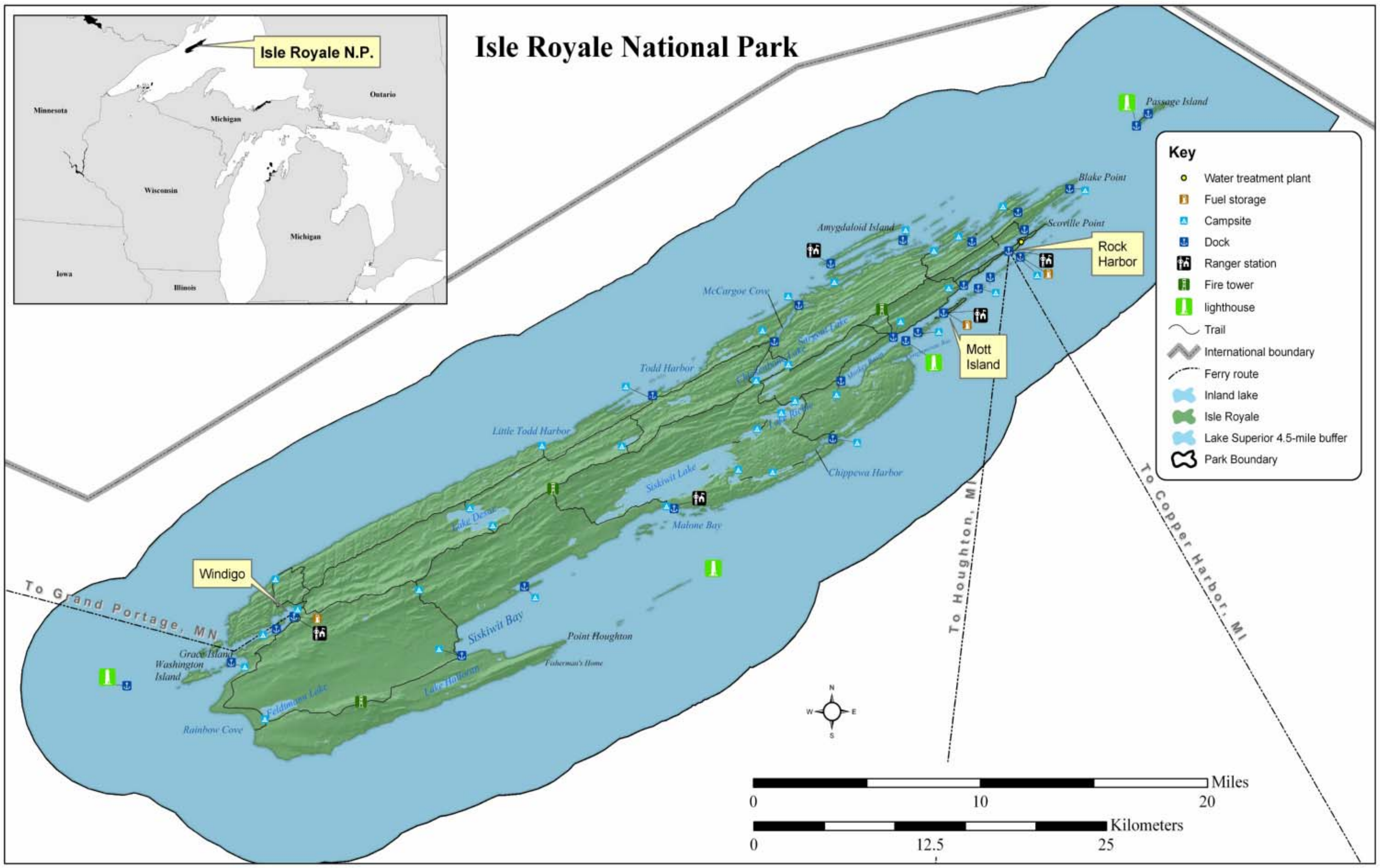


Figure 1. Isle Royale National Park and vicinity.

The park encompasses a total area of 890 mi^2 (571,790 acres) including submerged lands which extend 4.5 miles into Lake Superior. Total land area is 209 square miles (133,781 acres). About 80 percent of ISRO is under water, with aquatic habitats ranging from shallow, warm-water lakes, streams, and rivers, found internally on the park's islands, to cold deep-water areas in Lake Superior. The park consists of one large island ("the island") surrounded by about 400 smaller islands. The archipelago is composed of many parallel ridges formed from ancient lava flows that were tilted and glaciated. The widest area of the island is on the southwest end, coming to a narrow point on its northeastern end. The orientation of the main island and the surrounding islands is roughly parallel to the north shore of Lake Superior, with its long axis running in a northeast to southwest direction. The main island features a series of ridges and valleys which run parallel to the long axis, with the "backbone" of the island, Greenstone Ridge, running the full length of the Island through its center. Along this ridge, Mount Desor at 1394 feet above sea level is the highest point on the island and in the park.

Situated in the northwest corner of Lake Superior, Isle Royale is intersected by several commercial shipping lanes. Ship traffic south out of Thunder Bay, Ontario destined for the lower lakes passes between Blake Point, the most northeastern point of the main island, and Passage Island, the largest easterly island in the archipelago. Traffic from the western port of Duluth, Minnesota for Thunder Bay, passes Rock of Ages Reef on the western corner of the island. Weather conditions can be severe at this latitude during winter months of the year. In all, 10 major shipwrecks have been located and identified around the perimeter of Isle Royale.

As ISRO is completely within Michigan waters, discharge from any vessels navigating in proximity to the island is regulated under Michigan Act 451, Part 95, and "Watercraft Pollution Control." Strictly prohibited is "any litter, sewage, oil, or other liquid or solid materials that render the water unsightly, noxious, or otherwise unwholesome so as to be detrimental to the public health or welfare, or to the enjoyment of the water for recreational purposes." The law applies both to recreational watercraft, and to commercial vessels including domestic cargo carriers, foreign flag ships and passenger ships.

Direct access to the island by non-U.S. registered vessels is regulated, in the case of passenger vessels, by the Passenger Services Act, 46 U.S.C. App. 289, which reserves the right to transport passengers from one U.S. port to another on U.S.-built, U.S. crewed and U.S. flagged vessels. Non-U.S. flag vessel access is also regulated by U.S. Customs, 19 C.F.R., Part 4, as in any other U.S. port.

Other than the ferries that service ISRO, there are no commercial navigation routes calling directly at the island. Occasionally, however, Isle Royale provides protection from harsh weather on Lake Superior for cargo vessels plying the heavily used shipping lanes between the head of Lake Superior and the Soo Locks. There are no U.S. Coast Guard rules or regulations dictating navigation routing in the open waters of the Great Lakes; the decision to reroute a vessel into the proximity of Isle Royale in heavy weather rests solely with the ship's master.

Typically a vessel will seek refuge off the north shore of the island in the face of strong southeasterly or southwesterly winds, and conversely off the south when winds are northwesterly. Such rerouting is rare, occurring only a few times a season and under only the most extreme conditions. Cargo carriers seeking the lee of Isle Royale are physically able to hug the island relatively closely (no closer than 0.6 miles), as there is deep water, up to 195 ft (60 m), and no shoaling throughout the area.

B. Park Authorizing Legislation and Significance

Isle Royale National Park was authorized by Congress on March 3, 1931 "to conserve a prime example of North Woods Wilderness." At that time it was the only national park in the Great Lakes area.

The intent of Congress was further defined when the park was designated part of the National Wilderness Preservation System on October, 1976, and remains today as an example of primitive America. Over 99 percent of the land on Isle Royale is designated wilderness. In 1980, ISRO was designated an International Biosphere Reserve by the United Nations' Man and the Biosphere Programme, giving it global scientific and educational significance.

Purpose statements have been developed base on park legislation and legislative history, other special designations and NPS policies (NPS 2002b). The following purpose statements provide the foundation for park management and use:

- Preserve and protect the park's wilderness character for use and enjoyment by present and future generations;
- Preserve and protect the park's natural and cultural resources and ecological processes;
- Provide opportunities for recreational uses and experiences that are compatible with the preservation of the park's wilderness character and park resources;
- Provide park-related educational and interpretive opportunities for the public; and
- Provide opportunities for scientific study of ecosystem components and processes, including human influences and use, and share those findings with the public.

Significance statements capture the essence of the park's importance to the nation's natural and cultural heritage. Understanding park significance helps managers make decisions that preserve the resources and values necessary to accomplish the park's purposes. Isle Royale National Park is significant because:

- It is a U.S. biosphere reserve that encompasses a remote and primitive wilderness archipelago isolated by the size and power of Lake Superior;
- It is world-renowned for its long-term wolf/moose predator/prey relationship study. The park offers outstanding possibilities for research in a remote, relatively simple ecosystem where overt human influences are limited;
- Park waters contain the most productive native fishery and genetically diverse trout populations in Lake Superior (NPS 2002b).

C. Water Resource Management Objectives

Water is an important resource for the functioning of natural systems and providing for visitor use in ISRO. A diversity of water-based habitats allows the park to support diverse biological resources. Maintaining this diversity depends, at least partially, upon the careful safeguarding of the park's water resources and water-dependent environments, and minimizing stresses that can affect these resources from both inside and outside of the park's boundaries.

Specific management objectives pertaining to water resources and water-dependent environments with ISRO include:

- Manage water resources of the park in a manner designed to maintain the highest degree of biological diversity and ecosystem health;
- Acquire appropriate information to adequately understand and manage water-related resources;
- Assure that park development and operations do not adversely affect the water resources of the park;
- Recognize the significance of wetland/riparian resources and manage in a manner that will preserve their natural functions and health;
- Perform and/or coordinate water resources research that will contribute to the scientific base for water resources management;
- Promote public awareness of the water resources of ISRO and an understanding of current and potential human impacts on these resources;
- Implement on-going monitoring and research activities necessary to detect water-quality changes in inland lakes and streams that are vulnerable to atmospheric deposition; and
- Promote water resource management and use practices that discourage the introduction of aquatic invasive species.

This Water Resources Management Plan provides a recommended course of management action for achieving these objectives.

D. Park Visitation

Although public access to the park is limited by its remote location (it is only accessible by boat or seaplane), ISRO's isolation and wilderness setting attracts visitors from all over the world. Table 1 summarizes annual visitation to the park from 1990 to 2002. Ferry boats providing public access during the park open season operate out of Grand Portage, MN, Houghton, MI and Copper Harbor, MI. Private charter boats for fishing and diving access the park waters on a permit basis. Travel on and around the island is by foot, boat, or seaplane (Table 2). Seaplanes are allowed to land and take off only in designated water areas and only with advance permits. Charter plane access to the island was suspended in 2002; it resumed in 2005. There are no roads in the park. The park operating season runs from April to October, and Isle Royale is the only national park in the country that closes for the winter.

Table 1. Isle Royale National Park annual visitor summary, 1990 to 2002. (http://www2.nature.nps.gov/stats/).										
Year	Recreation Visits	Non-Recreation Visits	Total Visits	Lodging	Camp-grounds	Tent Campers	Back-country Campers	Misc. Campers	Non-Rec Overnight Stays	Total Overnight Stays
1990	23,495	124	23,619	5,822	1,537	6,981	37,489	3,769	706	56,304
1991	22,004	168	22,172	5,850	1,852	6,902	38,148	3,239	876	56,867
1992	22,728	196	22,924	5,964	1,456	7,397	39,663	2,243	915	57,638
1993	21,983	133	22,116	5,689	1,616	8,058	40,690	3,154	784	59,991
1994	24,843	198	25,041	4,994	1,628	8,665	43,673	4,262	1,192	64,414
1995	23,470	104	23,574	5,201	1,397	8,178	45,564	4,474	985	65,799
1996	23,445	135	23,580	8,273	1,432	8,343	46,625	4,035	640	69,348
1997	21,381	122	21,503	7,513	869	6,882	42,112	3,237	987	61,600
1998	23,932	270	24,202	6,722	840	7,748	44,426	2,729	1,487	63,952
1999	23,493	167	23,660	7,642	664	7,096	44,028	3,681	904	64,015
2000	21,096	146	21,242	7,730	591	7,200	40,157	4,170	807	60,655
2001	19,431	133	19,564	6,576	535	6,731	49,077	3,575	477	66,971
2002	19,463	141	19,604	6,682	506	5,720	40,389	3,800	453	57,550

Table 2. Overnight and day use arrivals to Isle Royale National Park, 1999 – 2003 (NPS 1999-2003 Natural Resource Management Files 2003).					
Overnight Arrivals (Number of Passengers)					
	2003	2002	2001	2000	1999
Isle Royale Queen	4593	5119	4814	4753	4889
Wenonah	1354	1441	1455	1360	1457
Concession Plane	N/A	N/A	561	650	704
Private Plane	0	16	3	0	1
Private Boat	2614	2350	2896	2832	3255
Ranger III	1644	1714	1571	1826	1747
Voyager II	1551	1786	1641	1450	1635
Day Use Arrivals (Number of Passengers)					
	2003	2002	2001	2000	1999
Isle Royale Queen	116	76	56	91	94
Wenonah	1569	1436	1490	1655	2030
Concession Plane	N/A	N/A	0	0	0
Private Plane	6	4	7	7	3
Private Boat	214	134	156	274	361

The unique nature of ISRO helps determine the type of park visitor, their distribution and access needs within the park, and recreational use throughout the park. More people visit Yellowstone National Park in a day than go to Isle Royale in a year. It is the least visited national park but, has the most repeat visitors. Though visitation is low compared to other national parks, it is ninth in total number of “backcountry user nights.” By land area consideration and intensity of use, Isle Royale has the highest number of overnight stays in the backcountry per acre of any national park (NPS 2002b).

The Cooperative Park Studies Unit of the University of Minnesota conducted visitor surveys at Isle Royale in 1996 and 1997 (Pierskalla 1997, 1998). The following generalizations are based on those surveys; on the General Management Plan (NPS 2002b); and on observations from park staff.

Isle Royale visitors are well educated and have professional occupations. They tend to have more experience in backcountry settings, place a high value on wilderness attributes, and stay longer than visitors to other NPS sites do. The average stay is four nights, and the majority of visitors are repeat visitors. The most popular activities, as described by visitors, are viewing wildlife, backpacking, boating, fishing, day hiking, and photography. Most visitors desire scenic beauty, being in a natural setting, observing and hearing wildlife, and relaxing.

Boaters account for approximately 25 to 30 percent of Isle Royale visitation. They tend to spend two to four nights, and most are repeat users from the surrounding Lake Superior area. Some boaters are fishing while others use their boat as transportation or lodging for an island experience. Boaters tend to congregate at docks and tend to be more social than other users. Backpackers and paddlers, the majority of which are repeat visitors, have a four-day average stay. While these visitors come from many places, the majority are from the Midwest and the upper-Midwest. These visitors come to Isle Royale using diverse modes of transportation and seek a variety of experiences. Due to ferry logistics, the majority of day visitors are found on the west end of the island. During their few hours on the island, these visitors explore or day hike.

Guests of the Rock Harbor Lodge are a diverse group that includes some visitors from other categories. For example, backpackers may stay a night at the lodge at the beginning or end of their trip. Boaters may use the facility while they fish or recreate during the day. A high percentage of commercial groups and elderly visitors use the lodge. In general, lodge guests remain around Rock Harbor often using developed interpretive trails and attending interpretive programs as presented by the park and the concessionaire.

The park has a relatively short tourist season, with highest visitation, 70 to 75 percent of the total, occurring in the months of July and August. The majority of park visitors stay for several days camping in designated areas. While total visitation has remained generally stable, hiker overnight stays have increased in recent years. The densely used backcountry is the busiest in the peak visitor period for two to three weeks in August. In 2001, approximately 24 percent of visitors needed to share campsites during the 2-week peak in visitation. If visitation were evenly distributed through July and August, 8.7 percent of visitors would need to share sites on any night (Table 3).

The high demand for backcountry campsites by visitors at the height of the season in August has a direct impact on the water resource management decision making for park administrators. Several future planning options for managing backcountry campsite access are discussed in the General Management Plan (NPS 2002b) and Wilderness and Backcountry Management Plan (NPS 2001).

Table 3. Backcountry campgrounds sharing sites, 2001 (NPS 2002d).			
Time of Season in 2001	**Average Number of Permits Issued per Day**	**Average Number of Parties Using Campgrounds per Night**	**Average Percent of Parties Sharing Campsites per Night**
July and August	39	Approximately 150	8.7
2-Week Peak in Visitation	50	Approximately 200	24
May-June and Sept-Oct	12	Approximately 50	0.4

II. LAWS, POLICIES AND PROGRAMS RELEVANT TO THE WRMP

Numerous federal laws and executive orders mandate specific regulatory considerations with regard to protection and management of water-related resources in and adjacent to ISRO. State laws related to water-related resources are limited in scope and only to Lake Superior waters. Additionally, policies and guidelines of the NPS broadly require management and protection of water resources of the national park system in order to maintain, rehabilitate, and perpetuate the integrity of the aquatic resources.

Given the unique geographic setting of ISRO, there are also numerous regional and international agreements, policies and programs that are relevant to the NPS as it manages the water resources of the park. Lake Superior as a shared resource between the United States and Canada has attracted the attention of the two countries and has generated many cooperative efforts to conserve and protect this world famous international resource. As a result of these efforts, important partnerships have developed between the U.S. federal government, the Canadian federal government, regional agencies and associations, the state of Michigan, the province of Ontario, colleges and universities and the nongovernmental sector of the region.

A. Federal Laws Important to the National Park System and ISRO

The National Park Service Organic Act passed by the United States Congress in 1916 established the National Park Service and mandated that it "shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of future generations." Since the passage of this Act (reinforced by the General Authorities Act of 1970) numerous laws have been passed and implemented that directly bear on the operations of the National Park Service and the management of water resources within the National Park system. A summary of the variety of laws with relevance to the both inland and Lake Superior waters of ISRO can be found in Appendix A.

B. Great Lakes Specific Laws and Statutes Relevant to ISRO

The Great Lakes, their connecting channels and the St. Lawrence River collectively comprise the world's largest body of fresh surface water, providing the region's eight states and two Canadian provinces with an abundance of high quality fresh surface water. The Great Lakes ecosystem is fragile and even minor physical, chemical or biological changes can impact the system with lasting implications for the conservation, protection and use of the resource. The need to protect the waters of the Great Lakes has prompted the development of numerous important Great Lakes -- specific laws and statutes that are relevant to the management of ISRO's Lake Superior waters. A summary of these laws and statutes is included in Appendix A.

C. Executive Orders Relevant to ISRO

Executive orders are official documents, numbered consecutively, through which the President of the United States manages the operations of the Federal Government. The text of Executive orders appears in the daily Federal Register as each Executive order is signed by the President and received by the Office of the Federal Register. The text of Executive orders beginning with Executive Order 7316 of March 13, 1936, also appears in the sequential editions of Title 3 of the Code of Federal Regulations.

The Executive Orders Disposition Tables located at the National Archives and Records Administration provide information about, but not the text of, Executive orders beginning with those signed by President Kennedy. The Federal Register at the National Archives and Records Administration has an archive of Executive Orders and related presidential documents. Many old executive orders can be searched at the House of Representatives Law Library.

There are several Executive Orders that have relevance to the operations of the National Park Service and the management of ISRO's water resources, both inland and Lake Superior. These are listed and briefly described in Appendix A. The full text of a limited number of executive orders is available at the following website: < http://www.nature.nps.gov/lawsregulations/executiveorders.cfm >.

D. State of Michigan Statutes Relevant to ISRO

In 1939, the State of Michigan ceded exclusive jurisdiction of Isle Royale including any submerged lands within 4.5 miles of the shoreline of Isle Royale and the immediately surrounding islands to the U.S. However, as part of this agreement the State of Michigan retained the authority to regulate fishing in the Lake Superior waters of the park. Commissioned Officers of the National Park Service, Bureau of Indian Affairs, Tribal Fish and Game Officers and the Michigan DNR all have jurisdiction and authority to enforce fishing regulations in the park's Lake Superior waters. The NPS and the U.S. Coast Guard have jurisdiction & authority to enforce Marine Safety Regulations such as boat registration, required safety equipment, water pollution regulations, etc.

The State of Michigan has passed numerous laws that are relevant to the management of water resources of ISRO, primarily Lake Superior waters. In 1994 the State of Michigan enacted the Natural Resources and Environmental Protection Act (Act 451) to codify, revise, consolidate and classify laws relating to the environment and natural resources of the state. Descriptions and limited annotations of parts of this act that pertain to Lake Superior waters of ISRO, directly or indirectly, are included in Appendix A.

E. Treaties between Native American Tribes and the United States

Treaty rights are exercised today in the Great Lakes region in various ways. In some instances tribes exercise their rights under federal court orders. In entering into these treaties, the tribes kept the right to hunt, fish and gather on lands they sold to the U.S. government in order to provide access to the foods and resources important to the lives of the tribal peoples.

A brief summary of treaties between the Native American Tribes and the U.S. is provided in Appendix A.

F. International and Regional Agreements, Treaties, Conventions and Compacts

Numerous agreements, treaties, conventions and compacts have been entered into between the governments of U.S. and Canada to address issues pertaining to the management and use of the Great Lakes. The Boundary Waters Treaty signed by the two countries in 1909 provides the principles and mechanisms to help resolve disputes and to prevent future ones, primarily those concerning water quantity and water quality along the boundary between Canada and the U.S. Other important international agreements that include the Convention on Great Lakes Fisheries (1955), the Great Lakes Basin Compact (1955) and the Great Lakes Water Quality Agreement (1972, amended 1978 and 1987) have provided a structure for international cooperation and coordination for the Great Lakes. Summaries of these agreements are included in Appendix A.

G. Nonbinding Regional Agreements

Various nonbinding regional agreements between the Great Lakes states and provinces have been entered into such as the Great Lakes Charter and Charter Annex (1985 and 2001), the Great Lakes Toxic Substances Control Agreement (1986), the Great Lakes Ecosystem Charter (1994), and the Great Lakes Action Plan for the Prevention and Control of Nonindigenous Aquatic Nuisance Species (1999). Summaries of these agreements, which provide a series of principles for coordination and collaboration on conserving, protecting and managing Great Lakes water and other natural resources, can be found in Appendix A.

H. Support for ISRO Water Resources Management through Partnerships and Collaboration

Other agencies, organizations and programs exist to support and collaborate with the NPS and promote expanded park participation in areas related to air, land and water resources management particularly as these relate to Great Lakes restoration efforts. Many of these programs will have specific relevance to ISRO as well. For instance, the Great Lakes Basin area and its regional organizations and initiatives can offer financial support and in-kind services to ISRO (and other national parks within the basin) especially in the areas of water resource management and environmental education for the public. An important step has recently been taken by the current administration through the signing of Executive Order 13340 to encourage broader cooperation in the Great Lakes Basin related to Great Lakes restoration. This may provide some opportunities for ISRO to engage in new and expand current collaborative efforts and partnerships within the region. A full discussion of agencies, organizations and programs, including contact information, relevant to water resources management on ISRO is included in Appendix B.

I. Other Plans and Concurrent Planning Activities

A number of federal, state, regional, local and private agencies and groups are involved in planning activities that are relevant to management of water and related resources in ISRO. This section describes those planning activities, and relates them to water resource issues in the park.

General Management Plan

The General Management Plan for ISRO (NPS 2002b) is intended to guide Isle Royale National Park for the next 15-20 years to "provide an overall guide for the future use of resources and facilities, clarify research and resource management needs and priorities, and address changing levels of park visitation and use." This plan replaced an outdated master plan for Isle Royale National Park written in 1963 that did not provide a comprehensive approach to the decision-making process.

In the issues section of this plan, several points are listed that are material to this Water Resource Management Plan.

- Park visitation has increased, impacting park resources and creating campground crowding issues, especially in peak visitation periods in July and August.

- Motor boat use has increased over the past 20 years. Motorboat size, power, and navigation technology have made the remote park more accessible to a larger number of people who previously would not have made the trip across Lake Superior from the mainland.

- Due to budget constraints, park maintenance needs have been increasingly deferred, including boat dock construction and repairs, building maintenance, and utilities including electricity and plumbing. Basic resource inventories and monitoring, environmental education programs, and preservation programs have gone unfunded.

- The fish communities of Isle Royale, which contain a significant recreation element for park visitors, have no long-term monitoring or management strategy and scientific information is incomplete. It was also suggested that historic commercial fishing should be restored for interpretive purposes to educate park visitors on this previous economic activity in park history. A separate Fisheries Management Plan is being developed for Isle Royale by the NPS, with an expected completion date 2006.

- Air- and water-borne pollutants may be having an effect on vegetation and fish populations and warrant further monitoring. There is also the threat of short-term water pollution from toxic spills from private and commercial shipping activities around Lake Superior and within park boundaries.

- Some commercial services at the park are provided by incidental business permits (IBPs), which include charter fishing, sea kayaking, scuba diving, and other water recreation activities. Request for these permits have been increasing and there is an established no limit on the number issued. Without controls, park resources may be impacted and competition for facilities and space within the park may increase.

The General Management Plan divides the park into specific management zones. Each zone is defined by a combination of physical, biological, social, and park management decisions allowing different actions to be taken by park administrators in the different zones. The zones vary from “developed zones” with high public use and access, to “pristine zones” of the park maintaining a pure wilderness setting. Zone management impacts the water resource management plan by controlling and altering development and human access in the park. This would include the availability of water and shower facilities in developed public areas and in the island hotel lodging, and the removal or relocation of boat docks, public access sites, and night shelters in campground areas. The open Lake Superior park waters and protected island bay areas are also zoned for types and levels of public use and access. These uses can range from open water motorized zones with few restrictions on boaters, to quiet/no-wake zones.

Government Performance and Results Act Strategic Plan

The Strategic Plan was written to fulfill the requirements of the Government Performance and Results Act (GPRA) passed by Congress in 1993. The plan for Isle Royale National Park covers the fiscal years from October 1, 2001 to September 30, 2005. GPRA is an effort to encourage performance management in federal agencies by setting long- and short term goals to accomplish an organization’s defined primary mission, with performance measurement and evaluation with quantifiable and measurable results and outcomes. It is an attempt to have federal managers measure their organizational performance in terms of results achieved rather than level of activities conducted, products produced, or services provided. This is to be accomplished by use of three documents: the Strategic Plan covering a 5-year period; Annual Performance Plan showing how long-term goals will be accomplished in each year; and an Annual Performance Report to review each year’s successes and failures.

The stated mission of the National Park Service at Isle Royale National Park in the Strategic Plan is as follows:

> The mission of Isle Royale National Park is to preserve and protect the natural, cultural, and wilderness resources of this freshwater archipelago. The park will provide outstanding recreational, research, and educational opportunities. The park will interpret man's interaction with nature and offer the visitor an opportunity to experience a largely undisturbed environment.

This mission is rooted in and grows from the park’s legislated mandate found in its enabling legislation and supplemented by further wilderness designations that designated 99 percent of the park’s land area as federal wilderness. The park’s mission statement is a synthesis of this mandated purpose.

Long-term goals listed in the Strategic Plan that are important to the WRMP include the following:

- Exotic Plant Species - By September 30, 2005 10 percent of the 100 acres of Isle Royale lands impacted by exotic vegetation targeted by September 30, 1999, is contained. [*Status – estimated as completed, but new outbreaks are occurring*]

- Air Quality - By September 30, 2005 air quality in Isle Royale National Park has remained stable or improved. The Clean Air Act holds the NPS responsible for protecting park air quality and air quality-related values from the adverse effects of air pollution. Because park air quality conditions result from the cumulative impacts of regional emission sources, the NPS has limited ability to effect changes in air quality, but it does participate in federal and state regulatory programs and policies that protect park resources. [*Status – stable*]

- Water Quality - By September 30, 2005 Isle Royale National Park has unimpaired water quality. Essential maintenance activities are conducted to operate water and wastewater treatment plants as required in order to maintain water and effluent quality and meet State and Federal requirements. Water and wastewater treatment plants will be operated in accordance with Clean Water Act requirements and potable water and effluent qualities will meet State and Federal standards. [*Status – stable based on tests of treatment plants; ongoing for monitoring and control of aquatic exotics such as Bythotrephes*]

  The park will also be increasing its efforts to reach full compliance with the Oil Pollution Act of 1990 regulations in order to protect park resources including water quality. This will include the purchase of oil spill response equipment, training of personnel and development and revision of facility operations manuals, facility response plans and vessel response plans. [*Status – completed with regular updates*]

- Resource Knowledge - By September 30, 2005 90 percent of the primary natural resource inventories identified in a Resource Management Plan and General Management Plan will be completed.

  The preservation of natural resources requires a wide range of information. This information is contained in 12 data sets: historical database (bibliography); flora and fauna (including threatened and endangered species); species distributions; digitized vegetation maps; digitized cartographic data; digitized soil maps; digitized geological maps; inventory of water bodies and use classifications; water quality and basic water chemistry for key water bodies; identification of nearest air quality monitoring stations and sources; list of air quality related values; and meteorological data. Isle Royale is presently lacking the following datasets listed above: all the flora and fauna species distributions, and basic water quality and chemistry for most water resources. A new vegetation map was completed by The Nature Conservancy (1999). Related to this goal is the park's Geographic Information System program, which for several years has been largely completed through cooperative efforts with the Michigan Technological University's GIS program in the Department of Forestry. [*Status – aquatic vegetation inventory completed in 2005; need inventories for terrestrial flora distribution, exotic flora distribution, and fauna*]

- Vital Signs – By September 30, 2005 Isle Royale National Park will have identified its vital signs for natural resource monitoring. Vital signs indicate key ecological processes which collectively show ecosystem health. They include keystone species, keystone habitats, or key processes such as nutrient cycling or hydrologic regimes. Identifying vital signs of park ecosystems and the well being of other resources of special concern allows tracking the status and trends of NPS natural resources. On this basis the NPS can define "healthy" conditions of park resources, identify recommended treatments, and propose remedial and mitigating actions. In 1999, Isle Royale joined in a network with eight other upper Great Lakes NPS units, as part of the national Inventory and Monitoring Initiative, to identify and ultimately complete needed natural resource inventories for this network. Once these inventories are obtained, the program will shift into the monitoring phase, which will include the identification of vital signs for each park. [*Status – initial monitoring data sets have been identified; methodologies are being developed*]

Wilderness and Backcountry Management Plan

The Wilderness and Backcountry Management Plan (WBMP) will address several issues related to preserving or improving the quality of visitors' experiences on Isle Royale. These include protecting natural and cultural resources, determining the appropriate tools and level of development in designated wilderness areas, and how to manage "visitor carrying capacity", which involves appropriate types and distribution of visitors to the island. The scope of the plan will include: all visitors who use designated wilderness: all campgrounds in the park, visitors permitted for overnight stays in campgrounds (including at docks), visitors camping outside of designated campgrounds, and visitors anchoring out within park waters of Lake Superior.

Several issues were addressed in Isle Royale's General Management Plan (NPS 2002b), including certain issues that are a matter of law, which will not be changed in the Wilderness and Backcountry Management Plan. Many of these issues can apply to and influence the Water Resources Management Plan and include the following:

- Designated wilderness will remain wilderness;
- All Lake Superior waters will be open to boat traffic;
- Regulations for quiet-no-wake zones, generator use, and quiet hours will continue;
- Decisions about boat docks made in the GMP will remain;
- Commercial use policies set in the GMP will not be changed;
- GMP-established Management Zones (Pristine, Primitive, Front Country, etc) will remain; and;
- Ferry, water taxi, and seaplane services will be retained. No expansion of these services will be allowed.

A draft plan for the WBMP was published in the fall of 2005. In 2006, the plan will be revised and finalized based on public comments, feedback, and other information, and released in its final form.

Long-Range Interpretive Plan, Isle Royale National Park

Work on the Long-Range Interpretive Plan (LRIP; NPS 2000) began in late 1998. This plan describes the park's primary interpretive themes and recommends ways to communicate those themes to park visitors. Primary interpretive themes are those ideas or concepts that every visitor to a park should understand. They convey information about the park's nationally significant resources. The LRIP describes visitor experience goals and recommends ways to achieve those goals through facilities, interpretive media, programs, and access to resources. The plan recommends actions that should occur over the next eight to ten years.

Five of the six primary interpretive themes as defined in the LRIP could involve activities and actions taken in the Water Resources Management Plan. They are as follows:

1. Isle Royale's isolation and habitat protects and maintains the biological diversity of the Lake Superior fishery, which provides a native gene pool for the lake's restoration

2. Isle Royale's physical isolation and primitive wilderness challenged human use for centuries; ironically, changing human values have converted isolation and wilderness into the island's main attraction.

3. Isle Royale is a large island with unique geological features dominated by powerful Lake Superior; its relatively simple ecosystem is a living laboratory providing insight into evolution, relationships between species, and biodiversity.

4. Because overt impacts from centuries of use (logging, fishing, and mining) have been curtailed, Isle Royale serves as a benchmark for worldwide indirect human impacts such as air pollution, global change, and exotic species.

5. Isle Royale is one of over 380 National Park units and part of the National Wilderness Preservation System, which together protects and provides enjoyment of this nation's natural, cultural, and wilderness resources.

Fisheries Management Plan

The General Management Plan (NPS 2002b) recognizes the fish populations in the park as a nationally significant resource. The plan further directed the park to prepare a more detailed implementation plan to manage and protect that resource into the future. The goals of this plan are:

- to establish a formal communication process to regularly interact with those agencies and governments that have management and monitoring responsibility within park waters, including the State of Michigan, US Fish and Wildlife Service, US Geological Survey, and Tribal Governments;
- to identify issues associated with the long-term preservation of the fish communities within the park and develop strategies to address those issues;
- to examine the adequacy of the existing fishing regulations for the inland lakes waters within the park;
- to focus the management of fish communities within the park on native species; and
- to identify the information needed to monitor the health of the fish populations into the future.

Concurrent to the development of this Water Resources Management Plan for Isle Royale, a Fisheries Management Plan (FMP) is also being written. This plan involves participation and input from several agencies and entities familiar with Isle Royale fisheries. It will focus primarily on and provide management guidance for lakes and streams of the island but will also provide recommendations for management of Lake Superior waters of the park. The Fishery Management Plan will cover specific fisheries information in much greater detail than this Water Resources Management Plan.

The goals and functions of the FMP are closely tied to the WRMP. The FMP will address fish management issues specific to inland waters of ISRO. Inland waters begin at the mouth of tributaries to Lake Superior and include inland lakes and their tributaries. The plan will also identify opportunities for cooperation with Michigan Department of Natural Resources and other fish management agencies related to fishery information needs and assistance in Lake Superior waters, which are under the jurisdiction of Michigan DNR.

This FMP is expected to guide fish management at ISRO for the next 5-10 years. A draft Fisheries Management Plan for the park is expected to be completed in 2006.

Isle Royale Protection Strategy

The Isle Royale Protection Strategy group is developing an emergency response and clean up strategy in the event of an oil spill impacting the park.

There are two main sources of potential oil spills in the park. First, to meet operational needs of the park, fuel storage sites are located at five different areas in the park: at the Rock Harbor Lodge and marina, Windigo marina, Mott Island park headquarters, Amygdaloid Island (north side), and Malone Bay (south side). The quantities of fuel at each location require response materials and equipment to be available in accordance with Environmental Protection Agency and United States Coast Guard regulations.

Secondly, since the park is located in the northwest area of Lake Superior, park waters are traversed by commercial vessels, along with numerous recreational boats and ferries during the tourist season. Discharges of oil products or hazardous materials by lake freighters and/or recreational boats in or near the waters of Isle Royale could have a devastating impact on the environmentally and ecologically sensitive areas of the park. Emergency response efforts to an oil spill or hazardous materials spill are complicated by the remoteness of the park, seasonal staffing, and the often severe weather conditions.

The protection strategy effort has reviewed existing response strategies for Isle Royale, developed a list of key sites for priority protection, inventoried response resources (booms, skimmers, etc.) and evaluated needs. It has also created a list of potential strategies and a process for coordinating efforts of local, state, federal, and Canadian emergency response teams and equipment. As part of this effort a Net Environmental Benefit Analysis (NEBA) was completed for Isle Royale in the summer of 2004 (Rayburn *et al.* 2004). In the event of an oil spill in ISRO, the NEBA process outlines removal efforts aimed at producing the least negative impact on the park's ecosystem. NEBA is part of the overall strategic framework for protecting the park from spills.

Isle Royale is primarily a wilderness and maritime park. Park wildlife, plant life, and habitat along with tourism and recreational activities are directly or indirectly tied to the quality of water resources of the park. Once it is completed, the Protection Strategy Plan will be an invaluable tool for park administrators and decision makers working with the Water Resources Management Plan. They should be thoroughly familiar with this plan in the event of an oil or hazardous materials spill. NEBA is part of the overall strategic framework for protecting the park from spills. The final strategy is due in 2006.

The Oil Pollution Act of 1990 requires the development and consideration of a worst case scenario spill event when developing spill response plans. The U.S. Coast Guard Marine Safety Office in Duluth has promised to designate ISRO as their worst case scenario spill and will amend their area contingency plan accordingly (personal communication). This will ensure that ISRO is given priority attention in the event of a spill within or near its waters.

III. GEOGRAPHIC AND HISTORIC CONTEXT OF THE PLAN

A. Lake Superior

The Great Lakes are the most prominent natural feature of the region. They have a combined surface area of about 94,000 mi^2 (151,300 km^2) draining more than twice as much land, and are among the largest, deepest lakes in the world (Figure 2). They are the largest single aggregation of freshwater on the planet, excluding the polar ice caps, holding an estimated six quadrillion gallons of water or 18 percent of the world supply (Great Lakes Commission 1999).

Lake Superior is the largest (both in surface area and volume), coolest, and most northern of the Great Lakes. The average and maximum depths are 489 and 1335 feet, respectively. The lake contains 2,934 mi^3 (4,722 km^3) of water with a retention time of 191 years. The total watershed area of Lake Superior is 81,000 mi^2 (49,300 mi^2 in land drainage area and 31,700 mi^2 in water measured at low water datum). Most of the basin is forested, with little agriculture because of cool climate and poor soils. The forests and sparse population result in relatively few pollutants entering the lake, except through airborne transport. The total Lake Superior basin population is 607,121 with 425,548 in the United States and 181,573 in Canada (USEPA and Government of Canada 1995). The only outlet for the lake is the St. Mary's River at the far southeastern corner of the lake at Sault St. Marie, MI and Ontario. The St. Mary's River is the connection to Lake Huron. There are two diversions that bring water from the Hudson Bay drainage into the Lake Superior basin.

Lake Superior's water level undergoes natural variation at the short-term, seasonal and year-to-year scales (Edsall and Charlton 1997). Short-term variation (usually a few inches) takes place over the course of several hours from changes in barometric pressure or wind. Seasonal changes in water level occur in response to the annual cycle of precipitation and runoff. Lake Superior's level typically peaks in October and recedes over the winter, reaching the lowest level in early spring. Year-to-year fluctuations result from fluctuation in precipitation and runoff.

Exacerbating the natural variation is the control of Lake Superior outflow at Sault St. Marie for improved navigation and hydroelectric generation. The regulation of Lake Superior outflows also

Figure 2. Overview of Great Lakes and their watershed (green) (Great Lakes Commission 1999).

depends on the water levels in the lower Great Lakes. The presence of outflow control does not mean that full control of Lake Superior's water level is attainable or desirable, primarily because the effects of water level regulation on the lake ecosystem are not well understood. Lake Superior levels are now higher than they were under natural conditions (considered 1860-1887), but show a smaller range of variation between maximum and minimum values.

Despite its large size, Lake Superior is sensitive to the effects of a wide range of pollutants, both point and nonpoint (USEPA and Government of Canada 1995). Because of the lake's large surface area, it is vulnerable to atmospheric pollutant deposition onto the lake surface. In addition, the high retention time for the lake's volume of water means that pollutants that enter the lake are retained in the system and become more concentrated over time.

In the late 1960s, governments began to respond to public concern about the water quality in the Great Lakes. This response took the form of control and regulation of point source pollutant discharges and the construction of municipal sewage treatment plants. This concern was formalized in the first Great Lakes Water Quality Agreement between Canada and the U.S. in 1972.

Significant strides in the reduction of pollutant discharges were made during the decade of the 1970s. The results were visible and demonstrated that past water quality degradation could be improved. Additionally, beyond the cleanup of local pollution problems, this decade of work put things into more of an ecological perspective – that regional and ecosystem scales are important to consider in attempts to further improve water quality. For example, in order to mitigate algal blooms caused by cultural eutrophication, a lake-wide approach was required to understand the amount of phosphorus entering and leaving each lake and the sources of this nutrient. This mass balance approach was then combined with other research and modeling to set load limits. Additionally, increased monitoring and research on toxic substances, including persistent organic chemicals and metals, found that these substances are a system-wide problem – they still exert negative impacts on the chemical, physical and biological components of the Lake Superior ecosystem. These remaining impacts are related to legacy contamination that results in fish consumption advisories and impairment to aquatic organisms and wildlife.

B. Climate

The weather in the Great Lakes Basin is affected by three factors: air masses from other regions, the location of the basin within a larger continental landmass, and the moderating influences of the lakes themselves. The prevailing movement of air is from the west. The characteristically variable weather of the region is the result of alternating flows of warm, humid air from the Gulf of Mexico and cold, dry air from the Arctic (USEPA and Government of Canada 1995).

Data collected by United States and Canadian weather stations within the Lake Superior basin cannot be easily extrapolated for determining conditions on Isle Royale (NPS 1985). Meteorological conditions on Isle Royale are similar to those described for the southern boundary of the boreal zone. Hare and Hay (1971) provide a general summary of the boreal climate within North America. Since there is no major topographic feature to divert air flow, the relatively flat landscape of central Canada offers the possibility of correlating air mass movement and frontal systems in the Upper Great Lakes Region. These air movements combined with constant local troughs and ridges, result in a high frequency of cyclonic passages, which occur most often in spring and fall (Hare 1968, Hare and Hay 1974).

Within the park itself, summers tend to stay cool and winters cold, but moderate in comparison with the mainland (Table 4). During the summer, temperatures rarely exceed 80^{o} F, with thunderstorms and rain occurring throughout the season. Dense fog appears frequently from about mid July into late summer.

Average annual precipitation ranges from about 20 to 40 in across the four-state area and generally increases going from the northwest to southeast. Precipitation is least in the northwestern part of the area (western Minnesota) because of the orographic effect of the Rocky Mountains, which are hundreds of miles to the west. Isle Royale receives up to 28 in per year annual precipitation. Annual precipitation in excess of 36 in that falls south and east of Lakes Superior and Michigan is a result of the prevailing westerly winds that evaporate moisture from the lakes; this moisture subsequently condenses and falls as precipitation over the land.

Day to day temperature changes are strongly moderated by the surrounding waters of Lake Superior. The average year-round surface water temperature for Lake Superior is approximately 39 ^{o} F, although the surface water temperature in August averages 58 ^{o} F (NPS 2004a). During most of the summer boating season in non-storm conditions, forecasts generally call for no more than three- to six-foot waves. Strongest winds come in October and November near the end of the shipping season, when waves can reach up to 25 to 30 ft in height (Shelton 1997).

In the Isle Royale and northwest Lake Superior area the mean annual precipitation is 27.6 to 31.5 inches per year. The mean daily air temperature for July is 50° F in the summer and 14° F in January in the winter. The mean annual frost-free period is 120 to 140 days per year (USEPA and Government of Canada 1995, Figure 3). *Superior Wilderness* by Shelton (1997) describes winter icing conditions in western Lake Superior, in and around the Isle Royale area as follows:

> "At its maximum extent, ice cover reaches forty to ninety-five percent of the lake. Usually a large area at the east end of the lake and a strip paralleling the south side of Isle Royale and extending northeastward, remain open. Pack ice comes and goes between the island and the Canadian shore. Occasionally, as in the very cold winter of 1993-94, the entire lake freezes over and a solid bridge to Canada forms, making the journey possible for animals so inclined."

The National Oceanic and Atmospheric Administration maintains the National Data Buoy Center (NDBC), a part of the National Weather Service. NDBC develops, operates, and maintains a network of buoy and unmanned weather stations in western Lake Superior where daily readings are recorded. Meteorological data for the Isle Royale National Park area are available from two unmanned sites in the park: Passage Island Light House, northeast of the main island, and Rock of Ages Light House on the southwest end of the main island. Current standard meteorological data and continuous wind data are available for the last 12 months. Historical meteorological data are available from 1984 to present and wind data from 1996 to present. Climate summary tables are also available for wind speed, air temperature, sea level pressure, and wind gust.

Table 4. Monthly temperature and precipitation statistics for Isle Royale National Park (NPS 2004a).

TEMPERATURE (° F)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Normal Daily Maximum	11	20	32	45	54	62	68	69	60	52	33	18
Normal Daily Minimum	-11	-5	9	25	36	43	50	54	47	39	17	-1
Extreme High	48	53	66	70	79	87	89	86	82	72	65	57
Extreme Low	-46	-44	-38	-5	19	32	37	34	29	12	-32	-41
Days Above 90°	0	0	0	0	0	0	0	0	0	0	0	0
Days Below 32 °	31	28	30	22	8	0	0	0	1	6	28	31
PRECIPITATION (in. or as noted)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Normal	1.2	0.9	1.8	2.2	2.5	3.1	2.5	3.2	3.4	2.1	1.7	1.3
Maximum	4.7	2.4	5.1	5.8	7.7	8.0	8.5	10.3	6.6	7.5	5.0	3.7
Maximum 24 Hour	1.7	1.4	2.4	2.3	2.6	2.5	2.3	1.8	4.5	1.8	2.6	2.1
Maximum Snowfall	47	32	46	32	8	0	0	0	4	9	38	44
Days With Measurable Precip.	12	10	11	11	12	13	11	11	12	10	11	12
Average Number of Thunderstorms	0	0	0	0	1	2	2	2	2	1	0	0

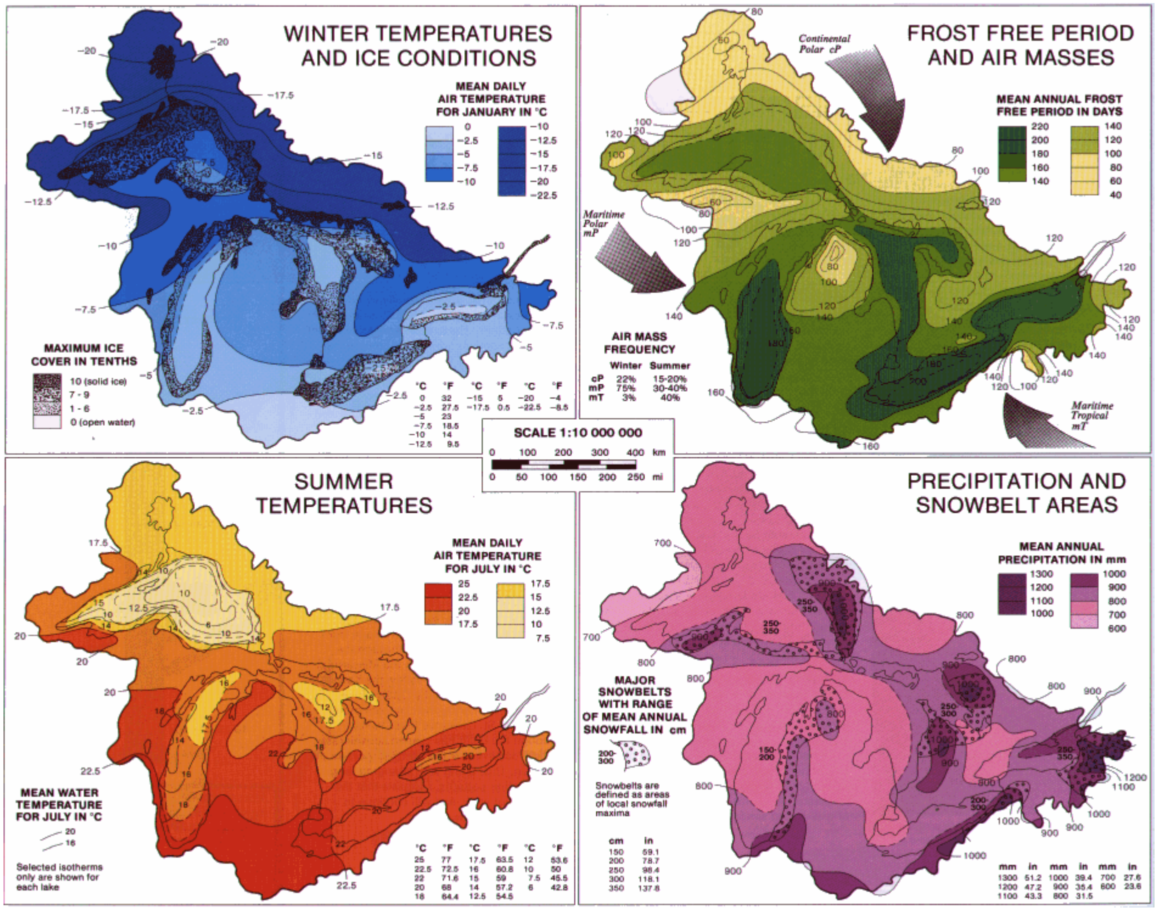


Figure 3. Great Lakes temperature maps (after U.S. Environmental Protection Agency and Government of Canada 1995).

i. Effects of Climate Change on the Great Lakes

There is growing evidence, based on historical records and climate prediction models that the climate for the Great Lakes region is changing and appears to be growing warmer and wetter (Magnuson *et al.* 1997, Meyer *et al.* 1999, Union of Concerned Scientists 2003). Climate scenarios from three general circulation models (GCMs): the Parallel Climate Model (PCM); the Canadian Climate Center Model (CGCM1); and, the United Kingdom Hadley Center Model (HadCM2) suggest that global climate will be 2-4^{o} C (3.6-7.2^{o} F) warmer and about 25 percent wetter by the end of the 21st century (University of Michigan 2000).

These global changes are impacting the Great Lakes region in the following ways (Union of Concerned Scientists 2003):

a. Winters are shorter in duration;
b. Annual average temperatures are increasing;
c. The duration of lake ice cover is decreasing as temperatures rise; and
c. Convective storms and heavy rain events are becoming more common.

The following is a brief summary of how changes in the global climate will likely impact the land and water resources of the Great Lakes region.

Temperatures

Temperatures in the Great Lakes region are expected to increase throughout the 21st century and to show a greater variance by season. By 2025-2035, the Parallel Climate Model (PCM) developed by the U.S. National Center for Atmospheric Research and the HadCM2 model predict that spring and summer temperatures in the Great Lakes region are likely to be 3–4^{o} F (1.5–2^{o} C) above current averages (Union of Concerned Scientists 2003). Predictions for changes in fall and winter temperatures are less clear, but by the end of the century, significant temperature increases are expected for all seasons. Warming is expected to vary across the region. Temperature increases centered over the Great Lakes themselves will be 2–5^{o} F (1–3^{o} C) lower than temperature increases over the southwestern and northern areas of the region (Michigan, northern Minnesota, Wisconsin and Ontario) (Union of Concerned Scientists 2003).

Precipitation, Extreme Events and Runoff

Predictive models suggest that average annual precipitation may increase to above average levels, rising 10 to 20 percent by the end of the century. Variations in the seasonal precipitation cycle are likely to be higher, with winter and spring precipitation increasing and summer precipitation decreasing by up to 50 percent (Union of Concerned Scientists 2003). The largest winter precipitation increases are predicted for areas of higher latitude. Although this may result in more snowfall, higher temperatures are expected to cause a decrease in the average depth of snow cover during the winter. The largest decreases in summer temperatures are expected over the southern and western parts of the Great Lakes region which is where most of the region's agriculture is concentrated.

The frequency of heavy rainstorms, both 24-hour and multi-day events, are expected to increase during the century and may double by 2100 (Union of Concerned Scientists 2003). The intensity of these events may also increase, leading to an increased risk of flooding in some areas.

On average, over the entire Great Lakes region, the amount of water available for runoff is expected to remain about the same or perhaps increase slightly for all seasons except summer. Seasonally, runoff is predicted to increase slightly over the entire region during spring and over the southern Great Lakes region in fall. Changes in the amount of water available for runoff will affect soil moisture which is a key factor in plant growth and soil processes (Union for Concerned Scientists 2003). Soil moisture is projected to increase by as much as 80 percent during winter in some areas, but decrease regionally by up to 30 percent in summer and fall relative to the 1961-1990 averages. This shift will favor crops and ecosystems that rely on recharge of water levels during the winter months. Crops requiring a certain level of summer rainfall and soil moisture may come under substantial stress and some wetland ecosystems may dry up entirely during the summer months (Union of Concerned Scientists 2003). Changes in the seasonal runoff patterns may also affect water quality. Schindler (1997) found that extended droughts in boreal regions have resulted in acidification of streams from oxidation of soil-based organic sulfur pools in soils and this situation may become more common with a warming climate.

Water Resources and Water Level Changes

The Great Lakes have historically enjoyed a relatively small range in lake levels – 6.5 ft from the recorded monthly maximum to the recorded monthly minimum. Seasonal variations of 10-12 inches also occur. The various climate change models have come up with different estimates regarding how changes in climate will impact Great Lakes water levels (University of Michigan 2000). These predictive changes range from no change or even a slight increase in lake levels (HadCM2 model) to a decline in water levels by as much as 8 ft (steady state GCMs) by the end of the 21st century. Output from the CGCM1 model suggests that declines in water levels over the next 30 years may reach magnitudes of 1.5 to 3 ft on the various lakes (University of Michigan 2000).

Despite variation in model prediction for the future, there have been observable trends in the seasonal timing of changing water levels over the past 40 years (Union of Concerned Scientists 2003). In both Lakes Erie and Ontario over the period from the early 1960s to the late 1990s, the seasonal rises are occurring one month earlier than before, while in Lake Superior, the maximum water level is also occurring slightly earlier in the year. These trends are apparently the result of earlier snowmelt and earlier tapering off of summer runoff.

Water Ecology and Changes in Lake Productivity

Aquatic life in the Great Lakes depends critically on how surface nutrients and oxygen are mixed throughout the depth of the lakes. This mixing in turn depends upon the seasonal cycles of lake and air temperatures, light and winds. Both the CGCM1 and HadCM2 models suggest that the Great Lakes will not only remain warmer but will also remain more stable (less mixing) for a longer portion of the year by the end of the century (University of Michigan 2000). As a result, less oxygen will mix down from the surface to greater depths. This would effectively reduce the biomass productivity in the lake by as much as 20 percent.

Land Ecology

Three gradients characterize the natural ecosystems of the Great Lakes region: a southwest to northeast gradient from prairie to forest in Minnesota, a south to north gradient from Eastern deciduous to Northern mixed hardwood forests in Michigan and Wisconsin, and the southern edge of the boreal forest which extends into the region (University of Michigan 2000). The diversity of forest ecosystems in the region has greatly contributed to its prosperity and quality of life, as well as to cleaner air and water and the reduction of soil erosion. With anticipated changes in climate, economically significant trees like quaking aspen (*Populus tremuloides*), yellow birch (*Betula lutea*), jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*) and white pine (*Pinus strobus*) may undergo population and range contraction in the Great Lakes region because summer temperatures may become too warm. Conversely, trees like black walnut (*Juglans nigra*) and black cherry (*Prunus serotina*) may eventually migrate northward into the region. Productivity may ultimately increase, but only after a decline during the transition of dominant species as tree communities adjust to a changing ecosystem. Also, there may be a potential loss of species due to global warming. More information is needed on the impacts that current land management has on the ability of vegetative communities to respond to a change, and how the dynamics of land use and management will interact with a warming climate (University of Michigan 2000). Alterations to plant ecosystems from a warming climate will have implications for managing water resources on ISRO. Impacts to forest health and species diversity could affect water resources through (potential) increases in erosion, impacts to water supply (e.g., stream flow) due to changes in infiltration and runoff, and changes to habitat (both terrestrial and aquatic).

C. Air Quality

Like many national parks, Isle Royale is designated as a Class 1 airshed under the Clean Air Act. Class 1 designation is the highest level of protection offered and is intended to prevent deterioration of visibility. In addition, this designation requires more stringent requirements to be met during the prevention of significant deterioration (PSD) process for evaluating new regional sources of criteria air pollutants (carbon monoxide, nitrous oxides, sulfur oxides, lead, ozone, and particulate matter). These stringent protections and the relative isolation of the island from major industrial sources have kept the park area in attainment for criteria air pollutants.

The U.S. Environmental Protection Agency's Regional Haze regulations require improving visibility in Class 1 air quality areas on the days with best visibility and no deterioration on the days with worst visibility. Recent visibility trend data for Isle Royale were not available. From 1996 through 1998, data from the Boundary Waters Canoe Area site, 80 miles west of the park, showed that the major contributors to visibility impairment (from November through March) were sulfates, followed by nitrates, organics, soil, and light absorbing carbon. In April through October, organics contributed more than nitrates to impairment.

Several plant species present on Isle Royale are known to be sensitive to ozone, including common milkweed and quaking aspen. However, ozone concentrations measured at ISRO and other monitors in northern Michigan, Wisconsin and Minnesota are low enough that ozone-induced foliar injury and/or growth effects are unlikely. An analysis of air pollution data and plant species type and relative abundance ranked Isle Royale as the least susceptible to vegetative damage from air pollution (ozone and sulfur oxides) of 22 mid-western parks evaluated. A portable ozone monitor operated seasonally on Isle Royale from 2002-2004 (Site #26-61-101). Data from this and other ozone monitors in northern Michigan, Wisconsin and Minnesota indicate ozone concentrations are well below the 8-hour National Ambient Air Quality Standard.

Acid deposition is an additional concern at ISRO. A 1995 Baseline Water Quality Data Inventory and Analysis report for ISRO presented summarized data indicating surface waters in the park are not sensitive to acidification from atmospheric deposition (National Park Service 1995). However, the soils on the island are shallow and poorly buffered, leaving them susceptible to acid deposition (Swackhamer and Hornbuckle 2003). Wet deposition is not monitored year-round on Isle Royale and trends are therefore not available for the island itself. National Atmospheric Deposition Program/National Trends Network stations in the Great Lakes region show that wet concentration and deposition of sulfate decreased, while wet concentration and deposition of nitrate and ammonium were variable with no discernable trend.

The impression of Isle Royale as a pristine area unthreatened by air pollution is deceptive. Isle Royale has a storied history of contamination from toxic air pollutants. In fact, research done on Isle Royale has been instrumental in demonstrating the large amount of toxic pollution contributed worldwide by atmospheric deposition (Swackhamer and Hornbuckle 2003). It had been believed that the major source of toxic contaminants to water bodies such as the Great Lakes was the direct discharge of these toxics to the lakes or their tributaries. However, discovery of PCBs and other contaminants in lake trout from an interior Isle Royale lake (Siskiwit Lake) in the late 1970's made clear that atmospheric transport of such substances was significant (Swain 1978). Although there were significant sources elsewhere in the Great Lakes region, there were no sources in the wilderness of Isle Royale. Discovery of toxaphene contamination in Isle Royale fish in 1980 made it clear that long-range transport of such chemicals was occurring (Blumberg *et al.* 2000). Toxaphene, an insecticide that is not a single compound but a mixture of 177 compounds, was used mainly in the southern U.S. with less than 1 percent of use occurring in the Midwest (Glassmeyer *et al.* 1999). Toxaphene depositing on Isle Royale was therefore traveling hundreds or thousands of miles in the atmosphere. Toxaphene concentrates in high levels of the aquatic food chain and is toxic for many aquatic organisms and also shows sublethal effects. Because it bioaccumlates, the presence of toxaphene in fish, especially sport fish at Isle Royale, has important repercussions for human health

In the following decades, the list of toxic contaminants found in the interior lakes of Isle Royale has grown. The lengthy list includes mercury, dioxins, lead, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polychlorinated naphthalene (PCN), atrazine, mirex and others. In many cases, the concentrations of these chemicals are considerable. Many of Isle Royale's inland lakes have mercury contamination significant enough to warrant fish advisories from the state of Michigan. As with toxaphene, the presence of Mirex, one of the most stable and persistent insecticides, is surprising because historic uses within the region were extremely limited (Sergeant *et al.* 1993). Because of a lack of any sources on the island for any of these chemicals (other than PAHs, whose presence can partly be explained by production during forest fires), it is clear that atmospheric transport and deposition is the source. Further evidence has shown that, in many cases, these chemicals originate a long way from the island. For example, models have estimated that more than 80 percent of the dioxins and furans that deposit to Lake Superior originate over 250 miles away (Cohen 2001). Swackhammer and Hornbuckle (2003) provide a thorough review of the history and current knowledge of deposition of toxic substances onto Isle Royale.

Isle Royale's unique situation as a large wilderness island has made it the ideal setting to research atmospheric deposition of toxic substances and there is consequently a large amount of information available on the extent of toxic contamination on the island and historic and recent trends. Sediment cores from Siskiwit Lake show that dioxin deposition increased drastically from the 1930s to 1970s. In the ensuing three decades, deposition rates decreased, but at a slower rate than would be expected based on controls implemented for major combustion sources (Baker and Hites 2000). A study completed in the mid-1990's showed increases in toxic metal concentrations (e.g., zinc, lead, cadmium and selenium) from 62 to 123 percent in two lichen species over 9 years (Bennett 1995).

Although some toxic air contaminants deposit relatively close to their site of release and show a high ratio of urban to remote concentrations, many others travel very long distances in the atmosphere and do not have a strong urban/remote trend. For example, measurements at sites in Minnesota and Michigan's Upper Peninsula show that levels of PCBs at urban sites in Minnesota are similar in magnitude to measurements at Eagle Harbor (Franz and Eisenreich 2000) which receives large amounts of PCBs from at least as far away as Chicago (Subhash and Honrath 1999, Hafner and Hites 2003). PCB concentrations in air have been steadily decreasing at monitoring sites around the Great Lakes; however, this trend is not apparent at the Integrated Atmospheric Deposition Network (IADN) site at Eagle Harbor on the Keweenaw peninsula, the site closest to ISRO (Franz and Eisenreich 2000). Measurements of toxaphene in the surface waters of Siskiwit Lake are similar to the levels found in the surface waters of Southern Lake Michigan, near Chicago (Pearson *et al.* 1997). Studies of toxaphene in lake trout from the Great Lakes showed that fish from the Apostle Islands, in western Lake Superior, had levels as high or higher than sites on the other Great Lakes (Glassmeyer *et al.* 1997). It has also been found that Isle Royale receives deposition of other herbicides, including atrazine, similar to amounts across the rest of the Midwest (Thurman and Cromwell 2000). Such findings dispel the notion that toxic contamination is mainly an urban problem.

It has also been found that the deposition of toxics can affect different portions of the island in very different ways. For example, shallow inland lakes showed relatively short half-lives for triazine herbicides (including atrazine), compared to deeper inland lakes where half-lives can exceed 10 years (Thurman and Cromwell 2000). Mercury levels in lake trout from Isle Royale's inland lakes vary considerably, despite similar water concentrations, and have been shown to be largely determined by food-web structure within the lakes. Terrestrial animal mercury concentrations, such as in deer mouse, have also been shown to vary from one area of the island to another (Vucetich *et al.* 2001).

The occurrence of air toxics in aquatic organisms (especially fish) on Isle Royale, points to aquatic food web contamination. This topic, especially as it relates to the human consumption of fish, is discussed in more detail in the Fisheries Management Plan due out in 2006.

D. Geology/Mineral History/Aquifers

The geological history of ISRO began approximately 1.2 billion years ago. At that time a series of cracks and rifts, running for hundreds and thousands of miles, buckled and cracked in long lines across the area that is now Lake Superior. This rift zone may have bent southward as far as the present day Gulf of Mexico (Shelton 1997). Over millions of years, molten flowing lava rose through the cracks, cooled, hardened, and flowed again for hundreds of miles. As these flows stopped and cooled, layers of volcanic igneous rock were formed, building a lava bed that reached over 10,000 feet thick. Later, softer eroded rock and gravel would wash into the low areas, forming layers of softer rocks like sandstone and conglomerates between sheets of the harder volcanic layers:

> Then, like a deck of cards being slowly bent at the middle, the land began to subside. It bowed, forming what is known as the Superior Basin with the rocks of the Keweenaw Peninsula on one lip and the formations of Isle Royale on the other. The edges lifted, tipping the layers of rock to the southeast at angles as high as fifty degrees forming ridges that slope gently to the south and then fall off steeply on the north (Rennicke 1989, Figure 4).

At the tilted edges of these layered rocks, soft layers of sedimentary rock eroded away leaving ridges of harder volcanic rocks, which are visible on Isle Royale's profile today. The sedimentary layers tilt southeast toward the axis of the Lake Superior basin with the tilt steeper on the north side of the Isle Royale archipelago (Huber 1975). The softer bands of sandstone and conglomerate eroded faster than the higher harder volcanic rock. Precipitation runoff formed streams which flowed into the lower areas of softer rock, cutting deeper trenches and valleys. Thus on Isle

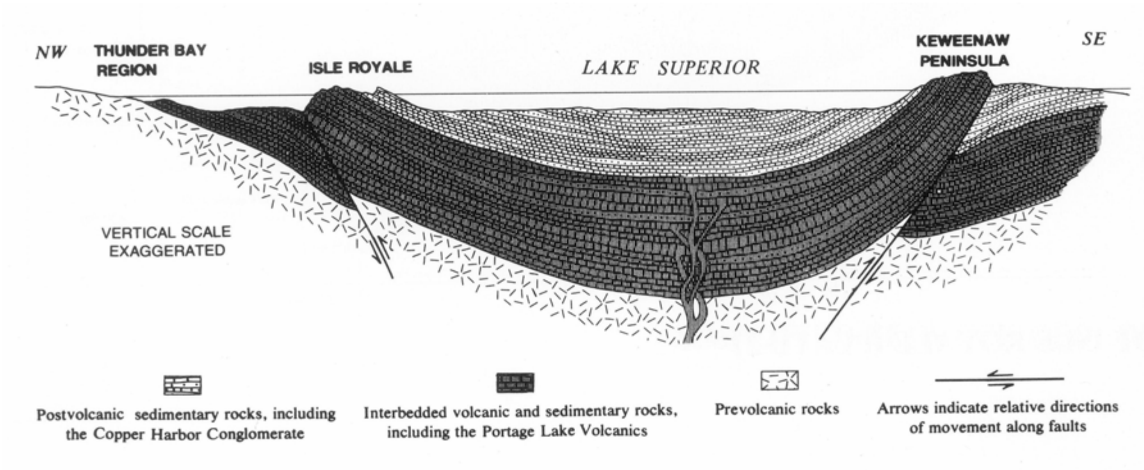


Figure 4. Cross section of Lake Superior Basin (from Huber 1975).

Royale, bands of harder volcanic basalt form the higher upper ridges, while valleys developed on the sandstone and conglomerate between them.

The bedrock formations of Isle Royale consist of a Precambrian succession of lava flows with minor interbeded sandstone, conglomerate, and pyroclastic rock overlain by a thick sequence of conglomerate and sandstone. Present ridge-valley topography parallels this tilted bedrock formation and southeast-facing slopes are gentle when compared to the steep northwest-facing slopes (Figure 5). Secondarily, crosscutting ravines and drainages are determined by a system of fractures developed in the rock formations in response to stresses during the development of the Lake Superior basin. An excellent example of this is McCargoe Cove (Huber 1973).

The island area between Siskiwit Bay northeast to Rock Harbor is pushed up or domed in an area of extensive faulting. The fault lines run generally in a northeast to southwest direction, creating ravines characteristic of the islands today. One of these fault lines runs along the center of the Keweenaw Peninsula on the northern shore of Michigan's Upper Peninsula projecting into Lake Superior, southeast of the park. Smaller faults cracked across the island, forming depressions in the earth's surface such as McCargoe Cove and the valley near Huginnin Cove (Shelton 1997).

As materials were displaced along the cracks in the earth surface, this faulting process forced hot magma solutions up into the cavities and cracks in the rock layers above, forming minerals as the magma cooled and crystallized. One of these minerals, copper, would play an important role in the history of human intervention into the island archipelago as early Native Americans, and later European explorers, sought to quarry island deposits. The copper found on the island was pure native copper, part of one of the world's most extensive deposits in the Keweenaw Peninsula area of Upper Michigan. Its purity and malleable form made it valuable to prehistoric Native Americans who used it to make spear points, knives, awls, and ornaments. Minong Ridge is pocked with hand-dug pits where Indians extracted the metal. Archeologists estimate that between 280 and 375 tons of copper were removed from the thousand known pits on the Island (Rennicke 1989).

A6 GEOLOGY OF ISLE ROYALE NATIONAL PARK, MICHIGAN

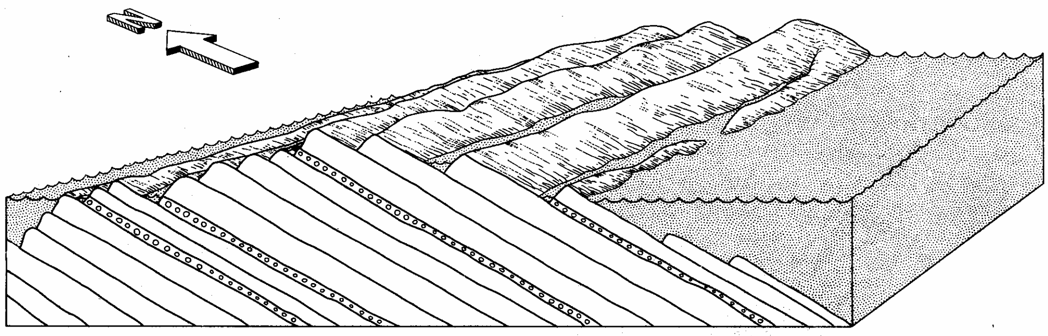


FIGURE 4.—Relation between ridge-and-valley topography and tilted lava flows and sedimentary rocks. Stippled areas indicate water; open circles, sedimentary deposits.

Figure 5. Relationship of tilted lava flows and sedimentary rocks in the Ridge-and-Valley topography (from Huber 1973).

In 1847, the U. S. Congress authorized a land survey of the Lake Superior area to determine its mineral potential. The results of this survey were the first series of comprehensive reports on the geology of the Isle Royale region (Huber 1983). There were three general periods of modern mining activity on the island: from 1847 to 1855, during the post Civil War era from 1873 to 1885, and from 1885 to 1892 when a British company purchased 84,000 acres of Isle Royale and did extensive exploration. The island's potential for copper production was explored as late as 1943, when a Bureau of Mines team was sent to the island to evaluate its possible mining to support the war effort during World War II.

A semiprecious stone called chlorastrolite also formed from the island lava flows, better known as Isle Royale greenstone; it is the official state gem of Michigan. Other minerals such as quartz; white, red or yellow heulandite; white or yellow stilbite; and banded agate can be found on the island's pebble beaches today (Shelton 1997).

The following discussion is based on the USGS Ground Water Atlas of the United States for the USGS Segment 9 area, which covers the states of Minnesota, Iowa, Wisconsin, and Michigan (USGS 1992). This segment abuts the Canadian boarder in the upper Midwest and lies adjacent to or surrounds four of the Great Lakes, including western Lake Superior and the Isle Royale area.

There are two major aquifer systems and seven major aquifers in the northwest Great Lakes Area generally covering the four-state area. An aquifer system consists of two or more aquifers that are hydraulically connected, and that function similarly in response to changes in hydrologic conditions. These aquifers have rock types that range in composition from unconsolidated glacial deposits to hard crystalline rocks. Because rock types generally correlate with geologic age in the area, most aquifer systems and aquifers have been designated by age, according to local usage.

The northwestern Great Lakes Area lies on the periphery of the Canadian Shield, which is a vast province of extremely old (Precambrian) and predominantly crystalline rocks in central Canada, northern Minnesota, northern Wisconsin, and the Upper Peninsula of Michigan. The surface formed by the Precambrian crystalline rocks is present throughout the states of Minnesota, Wisconsin, Michigan, and Iowa as a floor or basement for the overlying Cambrian and younger sedimentary-rock sequence. The crystalline-rock surface is an ancient erosional surface that yielded vast quantities of sediments through geologic time. The sediments derived from the weathering of the crystalline rocks were transported into multiple ancient seas that periodically encroached onto the crystalline-rock surface during the Precambrian and the Paleozoic. The sediments were deposited as extensive sequences of sandstone, shale, and limestone or dolomite that comprise the present-day sedimentary rock aquifers and confining beds.

The crystalline-rock aquifer in this area forms the bedrock surface throughout a large area in the northwest Great Lakes region. Of the nine major aquifers delineated in Segment 9, the crystalline-rock aquifer is the least productive for ground water in the four-state area (USGS 1992). A variety of types of Precambrian crystalline rocks underlies the entire four-state area. These rocks crop out in northern Minnesota and Wisconsin and in the Upper Peninsula of Michigan; elsewhere, however, they are buried beneath younger sedimentary rocks to depths as much as 14,000 ft (in the Michigan Basin). Crystalline rocks normally are considered a barrier to ground-water movement because their permeability is at least an order of magnitude less than that of most sediment that overlies them. Where no other aquifers are available, however, crystalline rocks are an important source of water, especially for domestic and farm wells.

Precipitation is the primary recharge of aquifer waters in the upper Great Lakes area. Average annual runoff in rivers and streams generally reflects average annual precipitation patterns. Runoff represents water from precipitation that runs directly off the land surface to streams and water discharged to streams that was stored in lakes, marshes, reservoirs, or aquifers. Runoff generally increases from less than one inch per year in the northwest part of Segment 9, to more than 20 in per year in the southeast part in Lower Michigan.

E. Glaciation

The basic profile of Isle Royale National Park after the lava flows had ceased and the Superior Basin subsided, may have been recognizable to today's park visitor, except for one very important difference. At that point in its geological history, the park was not a series of islands. Geologists theorize that for much of the time between the subsiding of the Superior Basin and the advance of the glaciers, the park area was part of an immense river basin (Huber 1975).

During the last million years, a series of four major glaciers moved down over the northern United States and Canada, advancing as far south as southern Ohio. The last major glaciation, known as the Wisconsinan, ended in the Superior area approximately ten thousand years ago, forming the ancestral Great Lakes and thousands of surrounding smaller lakes (McNab and Avers 1994). The ridge-valley topographic profile of the island was reinforced as the ice sheet in this last glacial period flowed parallel to the ridges, digging deeper into the soft rock layers, deepening valley areas, and gorging out deep sockets for inland island lakes. Glacial quarrying is responsible for most of the inland lakes (Zumberge 1955), excluding Feldtmann and Halloran, whose existence results from the formation of barrier beach bars from postglacial lakes Minong and Nippising (Hutchinson 1957). Effects of Pleistocene glaciations are seen in the rounded, fluted, and striated bedrock surfaces, which parallel the length of the island (Bastian 1963).

As the ice sheet melted and retreated, silt and debris were deposited in the general southwest area of the island in small linear hills, forming the basis for deeper soils that exist in that area today

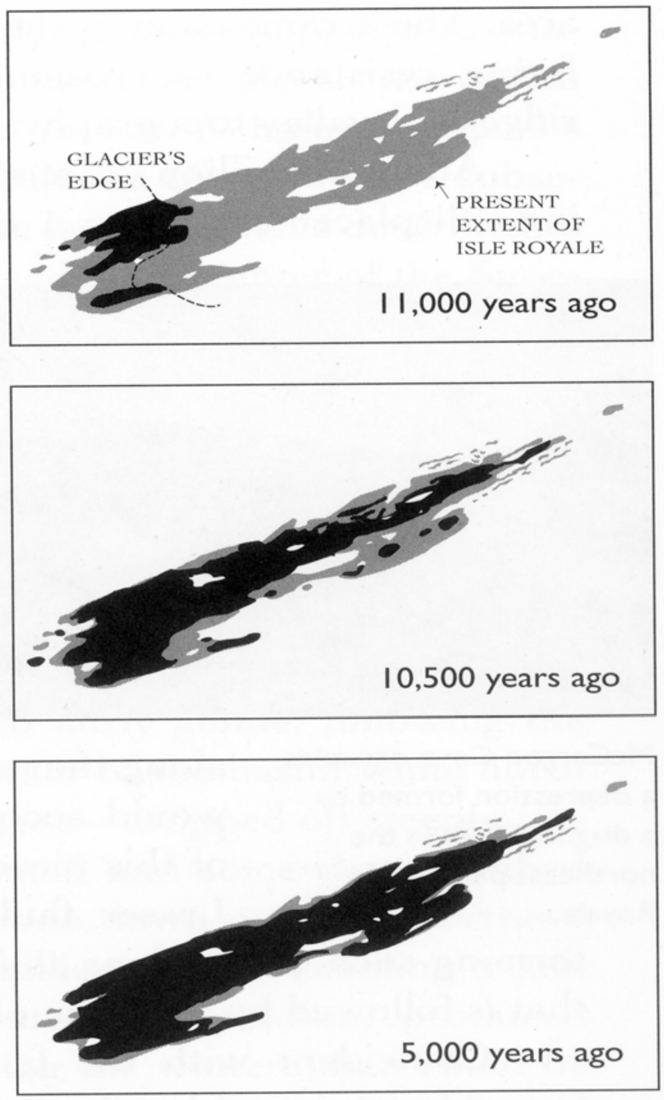
(Rennicke 1989). Where melting had been slow at this point during a long pause, more material and rock debris were deposited. As the glacier resumed its faster melting retreat northward from this point, little material was deposited on the central and northeast sections of today's Isle Royale. Some 11,000 years ago, when the ice front edge ended in the southwest corner of today's main island, the shoreline then stood at the present 800-foot contour. The park has been gradually rising up out of Lake Superior waters, emerging as the land mass rebounds from its depressed state under glacial ice, and as the Great Lakes cut successively lower outlets (Figure 6). The land continues to rise today at a rate of a foot or more per century (Shelton 1997).

F. Soils

The rock formation on Isle Royale is divided into two major layers. The lower older layer is composed of early lava flows and their minor interposed layers of sedimentary and pyroclastic rocks and is named the Portage Lake Volcanics. The volcanic rock on Isle Royale is described as "flood basalts" (Huber 1983). In most volcanic areas, true volcanoes in the classic cone shaped mountain are often absent. In such areas, large volumes of lava well up through fissures not connected to a volcanic cone, to form extensive sheets of flood basalts or plateau basalts. The lava flows cool, repeat over again and pile up, flow upon flow, to thicknesses of thousands of feet. It is estimated that there are over 100 individual lava flows in the Isle Royale area, with about 25 sedimentary layers of at least one foot or more in thickness sandwiched between flows. The basalts on Isle Royale and in the Lake Superior region exhibit variations in texture which is reflected in the grain size, shape, and the distribution of minerals in the rock. These variations in texture are a result of differences in cooling history of various lava flows, as well as in chemical composition of individual lava flows. The mineral content of Isle Royale volcanic rock is plagioclase feldspar, pyroxene, and lesser amounts of olivine, magnetite, and other minerals (Huber 1983).

The upper younger layer of rock formation on Isle Royale is referred to as the Copper Harbor Conglomerate. This layer contains sedimentary rocks, is mostly conglomerate, but also includes sandstone. It is thought that none of the soils on the island are from the Precambrian volcanic substrate. This is a result of the Pleistocene glaciation and the geologically relative recent emergence of significant portions of Isle Royale from Lake Superior (NPS 1985). As previously noted, most island soil was the result of deposits of glacial till left by retreating glaciers, with larger deposits on the southwestern one-third of the island, and extensive but scattered layers of till on the remaining two-thirds of the island. The tills are alkaline in character with high carbonate content, probably carried in deposits brought south from Hudson Bay (NPS 1985).

Isle Royale National Park represents one of the few boreal conifer-northern hardwood areas in the United States in wilderness condition, protected from development and modern exploration. Typical soil type in boreal regions is podzols, which develops on sandy or coarser substrates such as granite. As these soils develop in areas with adequate levels of precipitation, the more soluble monovalents potassium and sodium along with divalent calcium ions are washed from soils by water movement. Iron and aluminum generally are removed form the A horizon to the B horizon, and biomass accumulates as litter on the soil surface, with considerable humus lenses as deep as the B horizon (NPS 1985). This "podzolization" process is more intense in the southern boundary



Since the last glaciation, Isle Royale has gradually been emerging from lake waters as the land rebounds from its depressed state under glacial ice and the ancestral Great Lakes cut successively lower outlets. At the rate of a foot or more per century, the land continues to rise today.

Figure 6. Water level response at Isle Royale after retreat of the last glacier (Shelton 1997).

of the boreal zone where precipitation is abundant, and in the Great Lakes region where there is acid sandy glacial deposits. In the upper Great Lakes Region in areas of recent glaciation, the time for soil development has been much shorter (NPS 1985). A modification of this soil formation process exists where topography and soil conditions inhibit leaching and an elevated water table exists. In many areas of Isle Royale there is poor drainage due to island topography, with many small valleys occupied by swamps, bogs, and in some case numerous small inland lakes (Huber 1983). These are areas of soil enrichment rather than soil leaching, resulting in grey-wooded soils.

The most recent soil survey of ISRO was completed in 1991 by Shetron and Stottlemyer (Shetron and Stottlemyer 1991, Figure 7). The survey included a mapping of soil types with a description of the soil, location, and evaluation of suitability, limitations, and management of soils for specific use. Some seventeen different soil types were listed and mapped for Isle Royale. Two map intensities were used for the inventory. Level two (high intensity) was used within a quarter mile wide corridor in the areas of hiking trails, campgrounds, and other high use areas. Level four (lower intensity) was used for all other areas of the island that were not expected to experience future high use or development in the park. A level two survey is appropriate as a park management tool for future planning and land use decision making (Shetron and Stottlemyer 1991). Land use issues such as hiking trail relocation within the one quarter mile corridor, expansion of campsites, location of future sanitary facilities, and other water resource decisions could be guided by soil data provided in this survey.

The park is undergoing an intensive soil survey, building on the earlier work. The current survey, a joint effort of the NPS and Natural Resources Conservation Service, will map soils across the entire park, and incorporate new digital mapping technology (LIDAR). This survey will be completed in 2009.

G. Vegetation

The vegetation of modern day Isle Royale (Figure 8) has been influenced by a number of factors including: the remoteness of the island; its thin soils, rugged bedrock and rock outcroppings; short growing season; winds and lake storms; temperatures ameliorated by Lake Superior; and natural and man-induced fire. Perhaps the most unique feature of the park is the natural barrier created by Lake Superior. The solitude and protection of the lake has hindered the immigration and emigration of additional plant and animal species. The island has fewer species than adjacent mainland areas, some of which are unique to the island, and have existed in relatively undisturbed natural harmony, despite the intervention of humans (DuFresne 2002).

Early vegetation maps indicate that Isle Royale lies in a transition zone between the hemlock-hardwood forest of the Great Lakes Area and the boreal conifer forest of eastern Canada (Transeau 1948). The southwestern end of the island completes the northern limits of the hardwood forest and is populated by sugar maple (*Acer saccharum)* and red oak (*Quercus rubra*). The spruce and fir on the northeast end form the southern limits of the boreal forest (Rennicke 1989). Included in ISRO are some 700 species of vascular plants—24 kinds of trees, 28 kinds of ferns, 32 varieties of orchids, and over 100 types of forbs and grasses.

Shelton notes that the rocky shores and small islands between Blake Point and Scoville Point on the northeast of the main island are of special interest for their unique arctic-alpine plant species.

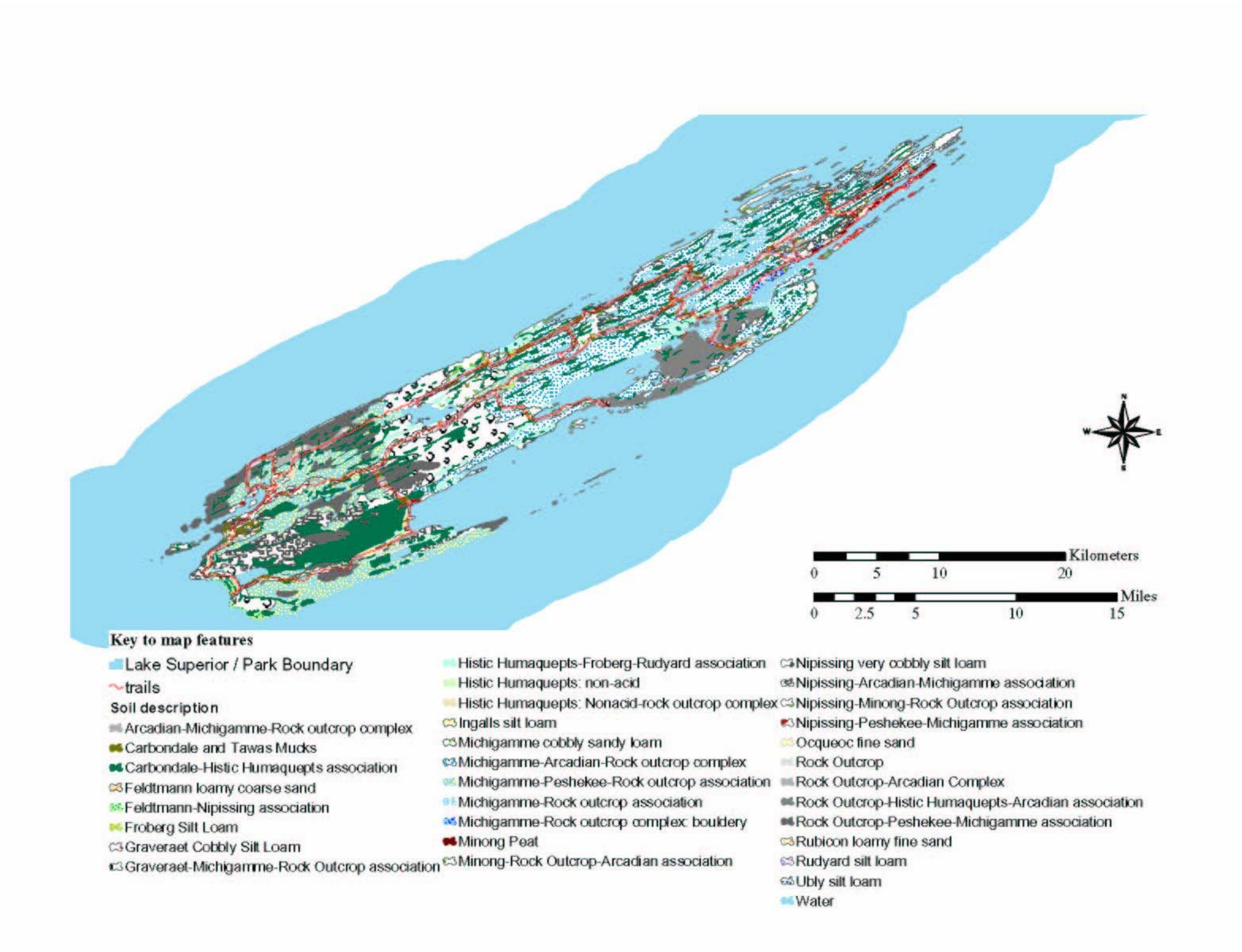


Figure 7. Isle Royale soil survey.

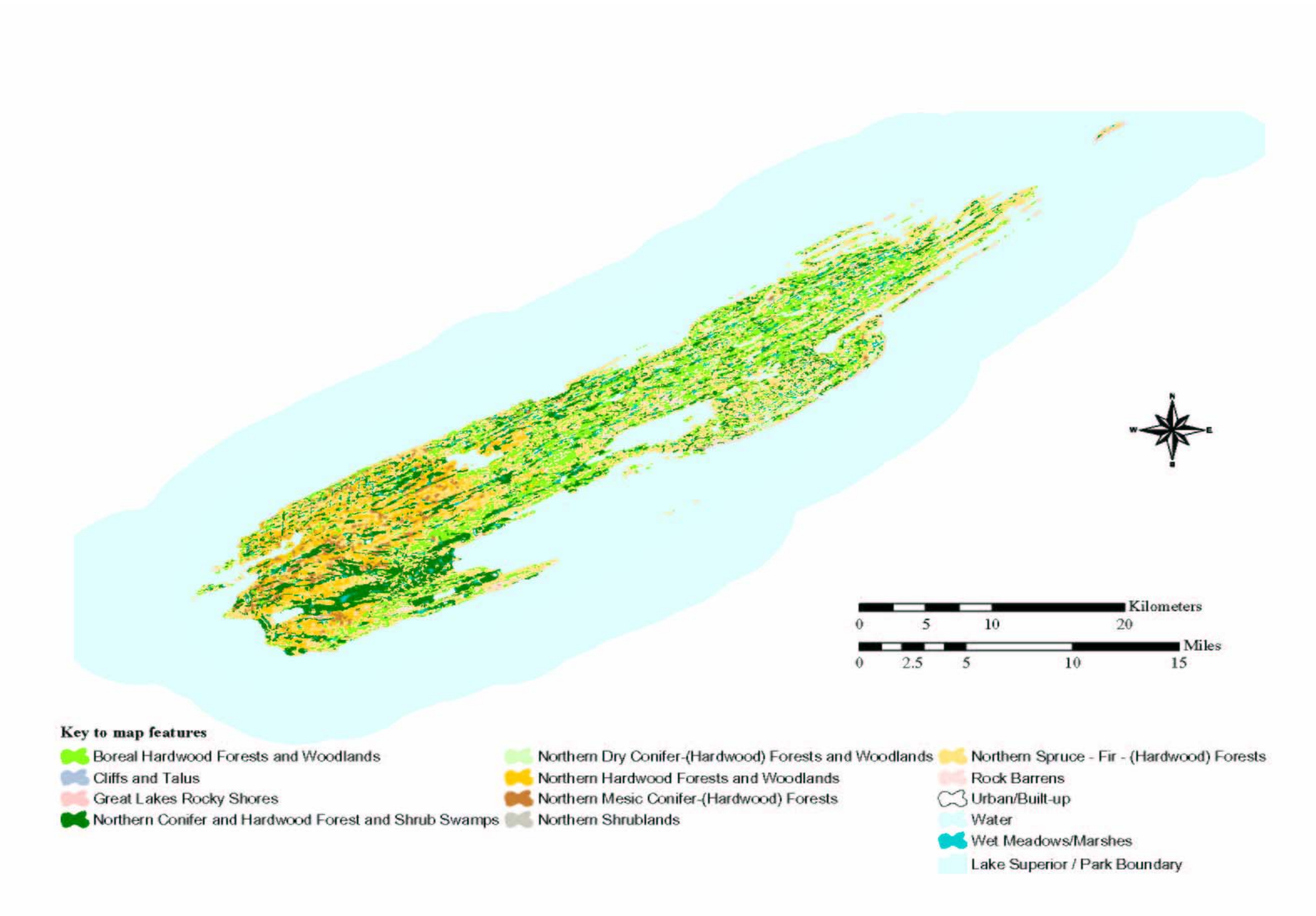


Figure 8. Isle Royale vegetation.

These include three-toothed cinquefoil *(Sibbaldia tridentate* or *Potentilla tridentate)*, birds-eye primrose *(Primula farinosa)*, yellow mountain saxifrage *(Saxifraga aizoides)*, and the rare black crowberry *(Empetrum nigrum)* and alpine berry *(Fragaria vesca),* which are usually found to the north or west in colder tundra climates (Shelton 1997). Judziewicz (1994) surveyed all Isle Royale shorelines and found the greatest number of arctic-alpine plants on the south side of the northeast part of the island. This may be due to the sloping nature of the rock, creating a microhabitat for the plants, and the greater exposure in this area of the island to cold winds and fog from Lake Superior. Most of these species are relics of the ice age that invaded from the south shortly after the glaciers retreated. Judziewicz (1994) estimated that perhaps as many as a third of the species could have been brought in as seeds by birds migrating from the Arctic.

Janke (1984) studied the vascular plant life along the outer shoreline of Isle Royale in the northeast portion of the main island and on several of the smaller northeastern islands in the park. Vegetation was studied at different elevations along the shoreline, in effect studying primary plant succession following emergence of the substrate above lake levels. Results showed that vegetation in this shoreline environment does demonstrate primary succession, and the environment contains many plant species not found elsewhere in the park, including the many arctic tundra species. He noted that the rock shore communities are an outstanding natural feature of the park, and because of the severe environment, they are a very fragile system that requires proper management (Janke 1984).

Developed on young, highly organic soils, the forests of Isle Royale can be roughly characterized by two major forest types. The first, covering the northeastern third of the island, is boreal in nature. Greatly influenced by the cool-moist conditions of Lake Superior, this boreal-conifer association is dominated by white spruce *(Picea glauca)*, balsam fir *(Abies balsamea)*, white birch *(Betula papyrifera)*, quaking aspen *(Populus tremuloides)*, and mountain ash *(Pyrus americana)*. The second, covering the southwestern third of Isle Royale, is the northern hardwood-white pine association dominated by sugar maple *(Acer saccharum)*, yellow birch *(Betula lutea)*, and to a lesser extent, white pine *(Pinus strobus)*. In between these two climax forests, successional stands of white birch, quaking aspen, white pine and jack pine *(Pinus banksiana)* occur, the result of fires and wind throw. The valleys between parallel ridges contain northern bogs in every successional stage from young to senescent (Linn *et al.* 1966). McKaig (1978) suggested that changes in species composition indicate that the modern forests are successionally less mature than recorded in the Original Land Office Survey of Isle Royale National Park in 1847. He further noted that the modern boreal forests showed a marked reduction in the percent composition of balsam fir, an increase in white birch and quaking aspen, and a decrease of white cedar *(Arbor vitae)* and tamarack *(Larix laricina)*. The sugar maple-yellow birch association increased as well during this sample time period. McKaig attributes this change to a combination of factors, including fire, herbivory, insect usage, and slight modifications in the local climate.

Isle Royale has had a long history of forest fire events, both natural, and man made from forest and mining operations. Fire replenishes vegetation, recycles nutrients back to the soil, and encourages diversity in plant species. Prior to settlement and logging, the vegetation consisted of hardwood forests (sugar maple, yellow birch) at the southwest end of the island, and boreal, mixed and coniferous forests at the northeast end (Cole *et al.* 1997). Periodic fires both before and after settlement favored the aspen-white birch forests, as well as the fire-dependent pines on ridges. Some species such as the jack pine require fire to release its seed. Species such as aspen, white birch, and willows, are pioneer trees that first established themselves after fire events, and helped to support the moose population of Isle Royale.

Evidence from sediment core samples indicates the southwest end of the island with a northern hardwood forest cover has seen little fire over the past 4,500 years. Samples from the northeast end indicate fire was more frequent and/or severe and occurred at about 100-year intervals prior to settlement (Flackne and Cole 1995). Deliberate burning to expose copper veins, the effects of logging, and careless campers contributed to the frequency of fires in the past 140 years (Hansen *et al.* 1973). Two major fires have occurred in recent history, burning a quarter of the island. In July, 1936, a fire started near a lumber camp at the western end of Siskiwit Bay. This burn, presumably set by a careless camper, covered roughly 20 percent of the island (26,000 acres). This fire had a greater affect on the vegetation and animal life of the island than any other single historical event (Hansen *et al.* 1973). Almost the entire large island, and many of the smaller islands, were disturbed by logging, mining operations, or fires prior to park establishment in 1940. More than half of the forest on Isle Royale is in some state of recovery not yet reaching a mature state where one species achieves long-term dominance. Furthermore, natural forces in the form of strong winds act as a disturbance to taller aging trees, hindering the development of a mature stable forest across the entire island (Shelton 1997).

In addition to windstorms and spruce-budworm disease, moose herbivory and beaver activity are other disturbance factors acting in the park (Hansen *et al.* 1973, Cole *et al.* 1997). These mammal species have dramatically influenced their surroundings. Browsing by large populations of moose and beaver (which modify streams, wetlands and bogs), are significantly changing current successional patterns and altering future forest composition (Cole *et al.* 1997). The moose exert significant pressures on the plant life, especially aspen, white birch, mountain ash, balsam fir, water lilies (family *Nympheaceae*) and ground hemlock *(Taxus canadensis)*, which has all but disappeared except for a thriving population on Passage Island, which is devoid of moose (Linn *et al.* 1966).

H. Rare, Threatened, and Endangered Species

Isle Royale National Park has two federally listed species and a number of state listed species as reported by the Michigan Natural Features Inventory for Keweenaw County (http://web4.msue.msu.edu/mnfi/data/county.cfm). The Bald Eagle (*Haliaeetus leucocephalus*), federally listed as a threatened species, is a migrant to Isle Royale, nesting and spending summers on the island. Other avian migrants that nest and spend summers on Isle Royale are the Common Loon (*Gavia immer*) and the Osprey (*Pandion haliaetus*), both listed as state threatened species. Three packs of gray wolves (*Canis lupus*) permanently reside on the island and are federally listed as threatened species. The primary food source for these wolves is the moose (*Alces alces*), a state-listed species of special concern. As of March 2004, the number of moose on Isle Royale was around 750 individuals with 90 percent confidence intervals 863 (upper) and 645 (lower) (Peterson and Vucetich, 2004). The boreal chorus frog (*Psuedacris triseriata maculata*), a state listed species of special concern, on Isle Royale are geographically isolated and thought to be genetically distinct from adjacent mainland boreal chorus frogs. The Siskiwit Lake cisco (*Coregonus bartlettii*), a state listed fish species of special concern, is the only inland lake population of the deepwater cisco species in the United States (T. Todd, pers. comm., U.S. Geological Survey, Great Lakes Science Center 2004). The black rat snake (*Elaphe obsoleta*

obsoleta) is also a state listed species of special concern due to its rarity in the northern extreme of its distribution.

A number of unique and noteworthy species exist on Isle Royale, but are not formally listed at the federal or state level. Isle Royale is home to many arctic disjunct plants. These plants are typically found in arctic and alpine communities, and are a rarity outside of their frigid home range. Throughout the Great Lakes region, many native mussels have disappeared due to pollution and exotic species invasion; however, a number of freshwater mussels thrive near Isle Royale, including the Higgins' eye pearly mussel (*Lampsilis luteola*), the eastern lamp mussel (*L. radiata*), the eastern floater (*Pyganodon cataracta*), and the giant floater (*P. grandis*). Isle Royale also provides habitat and spawning runs for the coaster brook trout (*Salvelinus fontinalis*), an anadromous form of brook trout that prefers the shoreline of the upper Great Lakes. This fish was once abundant along the coast of Lake Superior, but due to over fishing and stream alteration only a few remnant populations support a fishery of unknown size.

I. Past and Present Land Use

Historical Perspective

The earliest human inhabitants of Isle Royale and its surrounding islands were native North American Indian tribes. Native American hunters reached the north shores of Lake Superior as early as 8,000 or 9,000 BC. The exact date that they first entered Isle Royale is not known, but there is good archeological evidence that by at least 3,500 BC they were mining copper on the island (Shelton 1997). They worked several small pits, perhaps in small groups during the summer months, using primitive stone hand tools. They may have used fire to heat the rock and make it more friable, and may have burned off vegetation to find copper veins more easily. The period from 800 to 1600 AD saw the peak of Indian activity on the islands, with copper mining activity as late as 1500 AD. It is believed that full-time or long-term settlements by Indians on the island were rare. Other than several mining pits, Native Americans left few signs or evidence of permanent habitation (DuFresne 2002). During the nineteenth century small Ojibwa groups remained on the island hunting, fishing, and tapping sugar maples (Shelton 1997). By the 1840's, the only American Indian encampments white miners encountered were a maple sugaring camp on Sugar Mountain and a seasonal fishing camp on Grace Island.

The Native American way of life has thought to have remained unchanged for several thousand years in the area, until the first European contact came from French explorers from the south and French traders from the east. Early European contact on Isle Royale centered in the fur trade and some commercial fishing activity. The short-lived influence of the French in the area was overtaken by the British after The Royal Proclamation of 1763 ended The Seven Years' War. The British Hudson Bay Company was in turn displaced by The American Fur Company with the passage of The Northwest Ordinance, following the resolution of the British North American Colonial wars with colonists.

As the world fur market collapsed in the early 1800's, John Jacob Astor and his American Fur Company began to try other ways of making money from their holdings in the area. Several geological surveys were dispatched to catalog the mineral wealth of Isle Royale, along with a few ill-fated fishing operations. After the survey of Douglass Houghton, a mining boom enveloped the entire Upper Peninsula of Michigan and eventually found its way to Isle Royale. Three periods of mining operations spanned the 1800's, with none of the 18 separate ventures taking significant quantities of ore, except for the Siskiwit Mining Company, which took 95 tons of refined copper ore in a six year period starting in 1849.

Of various economic activity pursued by modern white settlers in and around Isle Royale, copper mining had the greatest environmental effects. Prospectors burned thousands of acres to aid their search for copper ore. Miners also cut island forests for fuel, building materials, and mine props, and cleared the and for settlements. The effects of human-induced fire, while mining on the island, have been documented by Janke *et al.* (1978). Additional studies and reports on the effects of fire on vegetation can be found in Janke (1984).

In the period from 1873 to 1881, the largest mining operation was the Minong Mine near McCargoe Cove. At its peak, the operation involved upwards of 150 men and their families who lived in a substantial settlement. The settlement included a blacksmith shop, a stamp mill, an ore dock, and railroads between mine, mill, and dock (Shelton 1997). The remains of this settlement can still be seen on the island today. Another mining operation from this period was Island Mine, about two miles northwest of the head of Siskiwit Bay. A small town was laid out which became the county seat of then Isle Royale County, which is now part of Keweenaw County. From 1890 to 1892, the town of Ghyllbank was built on the present site of Windigo, at the head of Washington Harbor. This settlement included a two-story company building, storehouses, and sheds. The community numbered 135 residents, with a second smaller community built two miles inland from the site for workers and single men (DuFresne 2002).

Commercial fishing has been one of the mainstay economic activities on the island throughout historic times. It began before 1800, to feed the fur trade. The major economically important species were lake trout, whitefish, and herring, found along miles of Isle Royale shoreline. The American Fur company used the ancient method of gill netting to take whitefish, lake trout, and siscowet. This tradition has been handed down through the fishermen's families. In 1837 the American Fur Company built a fishing camp at Belle Isle and eventually had seven camps and a crew of 33 fishermen. The largest camp on Siskiwit Bay had a storehouse, salt house, cooper's shop, and a barracks.

Since about 1840, commercial fishing has been a largely individual enterprise. Commercial fishing by individuals continued in the island waters but large commercial fishing activity declined through the 1900's. In 1972, only four commercial fishermen operated from the island; the last of these fishermen died in September, 1994.

Isle Royale has shallow soil and a short growing season, which does not allow for large stands of tall trees to develop on the island. These natural limitations along with the general isolation and remoteness of the islands have saved them from extensive logging and lumbering activity. There were two major attempts at lumbering activity. In 1890, a Dutch company cut white cedar and pine along Washington Creek, to be floated down to Washington Harbor. A severe storm caused local creek flooding and the harvest was lost into the lake. In the early 1930s, the Consolidated Paper Company was logging at the head of Siskiwit Bay. The 1936 fire destroyed the logging camp and burned one-fifth of the island. Commercial timber harvest was never attempted again at Isle Royale.

Economic interest in Isle Royale switched from consumptive use of natural resources to interest in the island as a summer retreat because of its cool summers, clean air, and scenic beauty. With the construction of lighthouses at Isle Royale, Passage Island, Rock of Ages, and Rock Harbor, navigation became slightly less dangerous, and ship service began to travel from places such as Port Arthur (Thunder Bay, Ontario) and Duluth, MN to Isle Royale's Rock, Washington, and Tobin harbors. Fish, consumer goods, and tourists were regularly transported to ports throughout Lake Superior at this time. Likewise, during the 1900's as Midwestern cities expanded, tourism increased on Isle Royale. Resorts were built on Washington Island, Windigo, Belle Isle, Tobin Harbor, and Rock Harbor. Private citizens acquired cottage sites, especially on individual islands and on the long peninsulas at the northeastern end of the main island. While fishing, tourism, and shipping still prospered throughout Lake Superior in the 1920's, the public focus shifted toward the creation of Isle Royale National Park.

Present Use

Today, 99 percent of the land in Isle Royale is federally-designated wilderness. Even first-time visitors quickly develop an appreciation for the resources and the value of this one of a kind maritime park.

No vehicles or wheeled devices are allowed on the island including bicycles or canoe portage devices. There are no roads in the park. There are 165 miles of hiking trails on the main island, with visitor centers at Windigo and Rock Harbor. The lodge at Rock Harbor offers private guest rooms with private baths for overnight stays. A water treatment facility at Rock Harbor provides water service to the guest lodge, weekly cabins, restaurant, and park visitor center in the immediate area. Transportation on the main island or between islands is limited to boat, ferry, or sea plane.

Current-day visitors come to Isle Royale for a number of different reasons. Boaters, backpackers, scuba divers, day visitors, lodge guests, paddlers, anglers and sailors can be found enjoying the park. Recreational fishing occurs in the Lake Superior waters in and around the islands, and in inland lakes and streams. Canoeists and kayakers use the nearshore Superior waters, streams and inland lakes. The challenge for the NPS is to provide these differing visitor groups with recreational opportunities which are compatible with the preservation of park resources and the needs of different users.

Boaters have been coming to Isle Royale to enjoy the clean clear waters, the protected harbors and bays, the dramatic shorelines, and recreational fishing for more than 100 years. Many Isle Royale boaters make repeat trips to the island, and some can trace their island connections back for generations. Private boaters can access numerous campgrounds or camp at the docks, located at Beaver Island, Belle Isle, Birch Island, Caribou Island, Chippewa Harbor, Daisy Farm, Duncan Bay, Duncan Narrows, Grace Island, Hay Bay, Malone Bay, McCargoe Cove, Merritt Lake, Moskey Basin, Rock Harbor, Siskiwit Bay, Three Mile, Todd Harbor, Tookers Island, and Windigo. The Rock Harbor Lodge operates a marina with fuel sales, docks with hook ups for vessels up to 65 ft in length, pump-out service and motor boat and canoe rentals. There are no commercial boat repair facilities within the park. Among the services provided at Isle Royale, fuel is sold from mid-May to mid-September at Rock Harbor and mid-June to early September at Windigo. Diesel fuel is only available at Rock Harbor. Early and late season service may be obtained at Windigo and Mott Island if personnel are available. Head pump-out service is available at Windigo and Rock Harbor when the concession operation is open. Federal regulations prohibit the discharge of any waste, including gray water, into park waters. Vessels may carry spare fuel only in legally-approved containers. Fuel may not be stored by boaters on docks (NPS 2002c).

The majority of the park's visitors are backpackers. There are 36 campgrounds located on the main island and surrounding islands offering overnight camping in Adirondack-type shelters or at tent sites. With the exception of campgrounds located in developed areas, backpackers do not have access to potable water, showers, or flush toilets.

Although commercial fishing was closed in 1962 in Michigan waters of Lake Superior, including Isle Royale National Park, limited assessment fisheries have occurred around the Park for the last 40 years. These assessment fisheries are based in Washington and Rock harbors. Private commercial fishermen operate the Washington Harbor fishery. This assessment permit is issued by the State of Michigan and allows for the annual harvest of up to 600 lean lake trout, 10,000 pounds each of lake whitefish and lake herring, and 16,000 pounds of chubs. The Rock Harbor (Edison) fishery is a demonstration fishery used for interpretive purposes by ISRO. ISRO is the permittee for this assessment fishery. This permit allows the annual harvest of 400 lean lake trout, 1,000 pounds of lake whitefish, and 1,000 pounds of other coregonines.

As noted earlier in this document, other than the ferries that service ISRO, there are no commercial navigation routes calling directly at the island. Commercial vessels frequently pass through the park, however, on established routes, especially between Passage Island and the main island. Also, Isle Royale occasionally provides safe harbor from harsh weather on Lake Superior for cargo vessels plying the heavily used shipping lanes between the head of Lake Superior and the Soo Locks.

J. Current Park Operations

Isle Royale National Park is under the exclusive jurisdiction of the United States Government. Federal regulations guide budgeting and financial management at the Park. Park rangers are legally responsible for the enforcement of all park regulations, US Coast Guard marine safety regulations, the criminal laws of the United States, and applicable laws of the State of Michigan. The Michigan DNR, US Coast Guard, and US Customs Service may, at times, have officers in the park to enforce laws and regulations.

In total, Isle Royale National Park employs approximately 110 individuals, 25 full-time, 27 full-time subject-to-furlough, and 58 seasonal employees (51 percent of the total). In FY2001, the park used the services of 137 volunteers who donated more than 15,000 hours of time to work projects. These donated services equaled approximately seven percent of the park's appropriated budget for the year, and equaled 5,207 annual volunteer hours (NPS 2002c).

The 2001 Park Business Plan divides park activities into five functional areas of business for which the park is responsible. These five areas with their percent of total funds are:

- Resource Protection - 9 percent
- Visitor Experience and Enjoyment - 18 percent
- Facility Operations - 28 percent

- Maintenance - 25 percent
- Management and Administration - 20 percent.

Under Facility Operations, 43 percent of that part of the budget is in transportation systems and fleet operations, and 18 percent is in utility operations (NPS 2002c).

The park operates its own infrastructure of utility systems as commercial utilities are unavailable in its remote location. These operations include a power generator, water treatment, and waste water management systems at three locations on the island. The park maintains three major community-sized developed areas to provide seasonal housing for employees. One area serves up to 500 people. There are nine generators, seven water treatment facilities, one wastewater treatment plant, and eight residential septic systems as part of the utility infrastructure. The park has almost 450 structures. These include 193 buildings, 51 residences, 88 shelters, and 115 privies. Of this total, over 70 structures are either eligible for or already on the historic register. There are also five remote ranger and research stations in the Park with individual solar electric and water treatment systems (NPS 2002c). The island utility operations have minimized environmental impacts on the park. The park recently received a national EPA award for its waste water treatment facility located at Rock Harbor. The facility requires daily operation and monitoring. Frequent sampling and testing at the island's state certified laboratories are conducted to ensure compliance with Federal and State clean air and water regulations.

As noted previously, the park is a remote water-based island park which faces complex logistical problems in its day-to-day operations. The park operates the largest vessel in the NPS, the 165 foot *Ranger III*. This 46-year old vessel provides the primary transportation and logistical support for park operations. This includes making about 2,000 to 2,500 passenger-trips for park staff and family, and approximately 4,000 visitor passenger-trips per year. According to the Isle Royale National Park Business Plan, the *Ranger III* removes 60 tons of solid waste from the island each year, and transports 80 tons of refrigerated and freezer cargo, 1600 tons of dry cargo, 10 to 15 tons of hazardous materials such as propane, and 100,000 gallons of fuel oil per year, to operate park power generators (NPS 2002c). The park also maintains an 81-foot fuel barge, the *Greenstone*, which is moored off shore on the north shore of Mott Island, just east of the park headquarters. Within the park archipelago, the park operates a fleet of 35 boats which are needed for all aspects of park operations, including maintenance, research, visitor transport, and visitor safety. These boats must be maintained and serviced by park personnel and properly stored over the harsh winter season. Fuel for these boats is transported by barge from the mainland two to three times per year.

On shore, park staff maintains more than 165 miles of hiking trails and 36 campgrounds. Due to harsh winter conditions, employees must remove on average 1,000 to 1,600 windfall trees that block trails and campgrounds at the start of each spring season. The park trail system includes about 5.3 miles of bridges and 14,000 erosion control devices located throughout the park The 36 campgrounds include 90 pit toilets, 88 shelters, and 112 individual tent sites. Maintenance crews inspect and repair over 70 docks, two-thirds of which provide day or overnight use for visitors (NPS 2002c). The Park maintenance efforts often require complex boat and hiking logistics to get personnel and equipment to remote work areas. Because of the weather conditions, maintenance efforts are restricted to approximately six months of the year, and must avoid conflict and interference with a relatively short tourist season for the park. The park is open to visitors from mid April to the end of October.

The seasonality of the park operations creates infrastructure-related inefficiencies and increased startup and shutdown cost. The major tourist / visitor period is concentrated in the three summer months of the year. Only 25 percent of the park staff is employed year-round. There can be a lack of employment continuity from year to year, increasing training, recruitment, and retention cost for the park.

Water resource management activities, along with air-quality, and all flora and fauna issues are administered under the Natural Resources Division in the park administration. In 2003, Natural Resources became a distinct division with a division chief who reports to the Superintendent. Until that time, natural resource operations were under the management of the Chief Ranger. With division status, the Chief of Natural Resources is more involved in overall management decisions for park operations. However, the switch to division level for natural resources did not include additional staffing (Jean Battle, Isle Royale National Park, pers. comm. 2004).

Permanent staffing for the Natural Resources Division is as follows:

- Full-time Division Chief (also functions as the Natural Resource Specialist for the park)
- Full-time Lead Biological Science Technician.
- Full-time Fire Management Officer.

The Isle Royale National Park Business Plan for Fiscal Year 2001 noted that the park lacks the staff necessary to monitor and manage human impacts on the natural resources of the park. There is an increasing problem with exotic species such as zebra mussels which have been found within 30 miles of Park boundaries. The report also notes that the Park cannot adequately monitor the federally endangered and threatened species in the Park. It is estimated that two natural resource specialists and two biological technicians are required to address these concerns (NPS 2002c). In 2001, Resource Protection only represented nine percent of the Park's operating budget. If it were to meet the Park's resource protection mandate, it would have to make up a 58 percent budgetary shortfall. Within the Resource Protection area, resource management has the largest shortfall, totaling approximately 80 percent (NPS 2002c).

The NPS' Natural Resource Management Assessment Program (NR-MAP) is an assessment tool providing an objective workload analysis of natural resource program tasks to assist with planning, formulating, and allocation of funding (http://www.science.nps.gov/nrmap). As part of the NR-MAP process, park staff complete a "profile" of information used to consider natural resources programmatically and to identify the allocation of existing staff time for resource stewardship. An initial servicewide compilation of NR-MAP profiles was completed in 1994. Park units recently completed a third update and the resulting database was compiled in 2003.

Table 5 represents a download of water resource management information from NR-MAP for the nine parks in the Great Lakes area of the NPS's Midwest Region. ISRO is the largest of the Great Lakes parks. Overall, water-based resources for ISRO cover approximately 75 percent of the total acreage for the park – this ranks 1st of 55 parks in the Midwest Region (Table 5). The majority of recreational activities in the park are water oriented. Approximately 0.35 Full Time Equivalents (FTE) are dedicated to the management of park water resources; this ranks 6th out of the nine Great

Table 5. Results from a download of NR-MAP, a NPS database (http://www.science.nps.gov/nrmap), for the nine parks in the Great Lakes area of the NPS's Midwest Region. Percentage of water resources in parks is based on available acreage for water resources divided by the park acreage. It should be considered a minimum percentage because only miles and not acreage are given for rivers/streams and acreages for lakes between 2.5 and 1000 acres are not provided. Abbreviations are as follows: ISRO=Isle Royale National Park; VOYA=Voyageurs National Park; SLBE=Sleeping Bear Dunes National Lakeshore; PIRO=Pictured Rocks National Lakeshore; APIS= Apostle Islands National Lakeshore; INDU= Indian Dunes National Lakeshore; SACN=Saint Croix National Riverway; CUVA=Cuyahoga River National Park; GRPO=Grand Portage National Monument; Bound=boundary; Impound=impoundments; FTE=Full-time equivalent; Manag=management.

PARK	PARK ACREAGE WITHIN BOUND.	MILES OF PERMANENT FLUVIAL SYSTEMS	NUMBER OF LAKES > 2.5 ACRES BUT <1000 ACRES	NUMBER OF LAKES ≥ 1000 ACRES	ACRES OF LAKES ≥ 1000 ACRES	# OF IMPOUND.	ACREAGE OF IMPOUND.	MILES OF GREAT LAKES SHORELINE	PALUSTRINE WETLAND ACREAGE	% OF PARK IN WATER RESOURCES	FTE IN WATER RESOURCES MANAGE.*
ISRO	571,790	265	37	3	401,482	0	0	338	28,050	**75.1**	**0.35**
VOYA	218,061	62	185	0	0	2	84,000	0	40,256	**57.0**	**1.4**
SLBE	71,174	12	18	3	10,848	0	0	65	11,869	**31.9**	**0.6 ****
PIRO	73,188	42	0	0	0	2	14	39	8.788	**12.0**	**0.5**
APIS	69,372	6	8	1	27,232	0	0	154	1,015	**40.7**	**0.08**
INDU	15,062	69	29	0	0	0	0	8	5,100	**33.9**	**0.88**
SACN	66,643	280	29	0	0	3	1,486	0	7,300	**13.2**	**1.2**
CUVA	32,859	212	1	0	0	8	34	0	1,669	**5.2**	**0.13**
GRPO	710	1	0	0	0	0	0	1	17	**2.4**	**0.08**

* The number is a combination of the stated FTE for physical, chemical and biological aspects of water resources management. It should be considered a minimum estimate because, for certain categories (e.g., threatened and endangered species), it was impossible to partition out the work for water-related management.

** Not from NR-MAP, but based on estimate in the park's water resources management plan.

Lakes parks (Table 5). At least 0.1 of the 0.35 FTE represents work performed by two regional aquatic resource professionals that assist all parks in the Great Lakes region, and varies depending on the year. The 0.35 FTE does not represent a formalized program in water resource management, but efforts to link cooperators to inventory and assessment needs or assistance to researchers.

IV. AQUATIC SYSTEMS AND COMMUNITIES

A. Hydrology at Isle Royale

1. Ground Water

Ground water wells in the aquifer covering Isle Royale and the western Upper Peninsula generally yield less than 5 gallons of water per minute (USGS 1992). Although the crystalline rocks extend throughout the area, they are not considered to be an aquifer except in northern Minnesota, northern Wisconsin, and part of the Upper Peninsula of Michigan where they are not deeply buried. These rocks yield small to moderate quantities of water from fractures in the upper part of the rocks. However, since few fractures are at lower depths, the rocks form an impermeable boundary at the base of the aquifer sequence. Although the aquifer is the least productive aquifer in the four-state area (USGS 1992), it is considered to be a major aquifer because it is the only source of ground water in many parts of the region.

The first major historical report relating to water-bearing and transmitting ability of rock formations was done by Lane (1898) for the Windigo area of Isle Royale. Lane's studies related to copper deposits and mining activities two to three miles east and northeast of Windigo. Doonan *et al.* (1970) showed that bedrock on the Keweenaw Peninsula, which is similar to the Isle Royale Windigo area, yielded only small quantities of water. Reporting on general park-wide geologic conditions, Huber (1973, 1975) provided indirect information on ground water in Isle Royale.

Ground water as a potential source of public water supply specifically on Isle Royale was investigated in 1981 (Grannemann and Twenter 1982). Grannemann and Twenter suggested that economic water supplies could be developed for public-use areas. Initially, they believed there were no glacial deposits of significant thickness or suitable lithology, near island water-storage and power facilities, that could be potential sources of water for public supply. Wells deeper than 150 feet were not thought to be suitable as a ground water source on Isle Royale because of the following: fractures and joints in the bedrock generally decreased in size and number with greater depth and were probably scarce below 150 ft; glacial deposits were not expected to be more than 100 ft thick; and water from 200 ft or deeper was likely to be salty (Grannemann and Twenter 1982).

Grannemann and Twenter (1982) drilled three test holes in the Windigo area for the sole purpose of locating potential public water supplies (Figure 9). Samples of rock material were taken every 5 ft and no water samples were collected. The water yield in gallons per minute for each test hole is shown in Table 6.

Table 6. Isle Royale water supply test drilling results for 1981 (Grannemann and Twenter 1982).

Hole	Depth of Hole (feet)	Water Yield (gal/minute)
one	135	< 1.0
two	175	< 0.5
three	71	0.1

The 1981 study conclusions, based on lithology, indicated that bedrock at a depth of less than 150 ft would not yield sufficient water for a public supply. No sedimentary or pyroclastic rocks, or subsurface fracture or joint systems were found. No major change in lithology of the bedrock could be expected, at least to a depth of 175 ft. Even then there was no assurance that water from that depth, if available, would be of good quality. Glacial deposits appeared to offer the only opportunity for developing a ground-water based water supply sufficient for public needs at Windigo. Granneman and Twenter (1982) suggested that the two most promising sites were along the unnamed creek near Test Hole #1 (Figure 9), and along Washington Creek.

A sufficient ground water supply may have been developed near Washington Creek, but constraints from the NPS prohibited drilling additional test wells after the 1981 study. Smaller test drilling equipment is now available that would allow smaller test wells to be drilled with much less impact on the environment. Better analysis of the water resources in undeveloped parts of the island could be made using small-scale surface geophysical methods, limited small test wells, and analysis of the base flow data for the gauging station on Washington Creek at Windigo (N. Grannemann, U.S. Geological Survey, pers.comm. 2003). However, while the technology exists, the potential direct and indirect impacts on the overall surface and subsurface hydrology of the island have not been thoroughly investigated. Also, the wilderness status of the park raises issues about whether additional hydrologic manipulations are appropriate, especially in the backcountry. In addition, public health requirements may still result in pre-treatment. This could add infrastructure (pipes, etc.) and ultimately increase environmental impacts over the current water system.

2. Surface Water

Isle Royale receives up to 28 in per year annual precipitation. Annual precipitation in excess of 36 in that falls south and east of Lakes Superior and Michigan is a result of the prevailing westerly winds that evaporate moisture from the lakes; this moisture subsequently condenses and fails as precipitation over the land.

Average annual runoff for Isle Royale is 5 to 10 in per year. Runoff also tends to be substantial downwind from Lakes Superior and Michigan. However, in the overall Lake Superior basin, runoff does not exceed precipitation. Much of the water from precipitation is returned to the atmosphere by evaporation from the land and water surfaces and transpiration by plants. Some of the water is stored in aquifers through ground-water recharge or is stored on the land surface in lakes, marshes, and reservoirs.

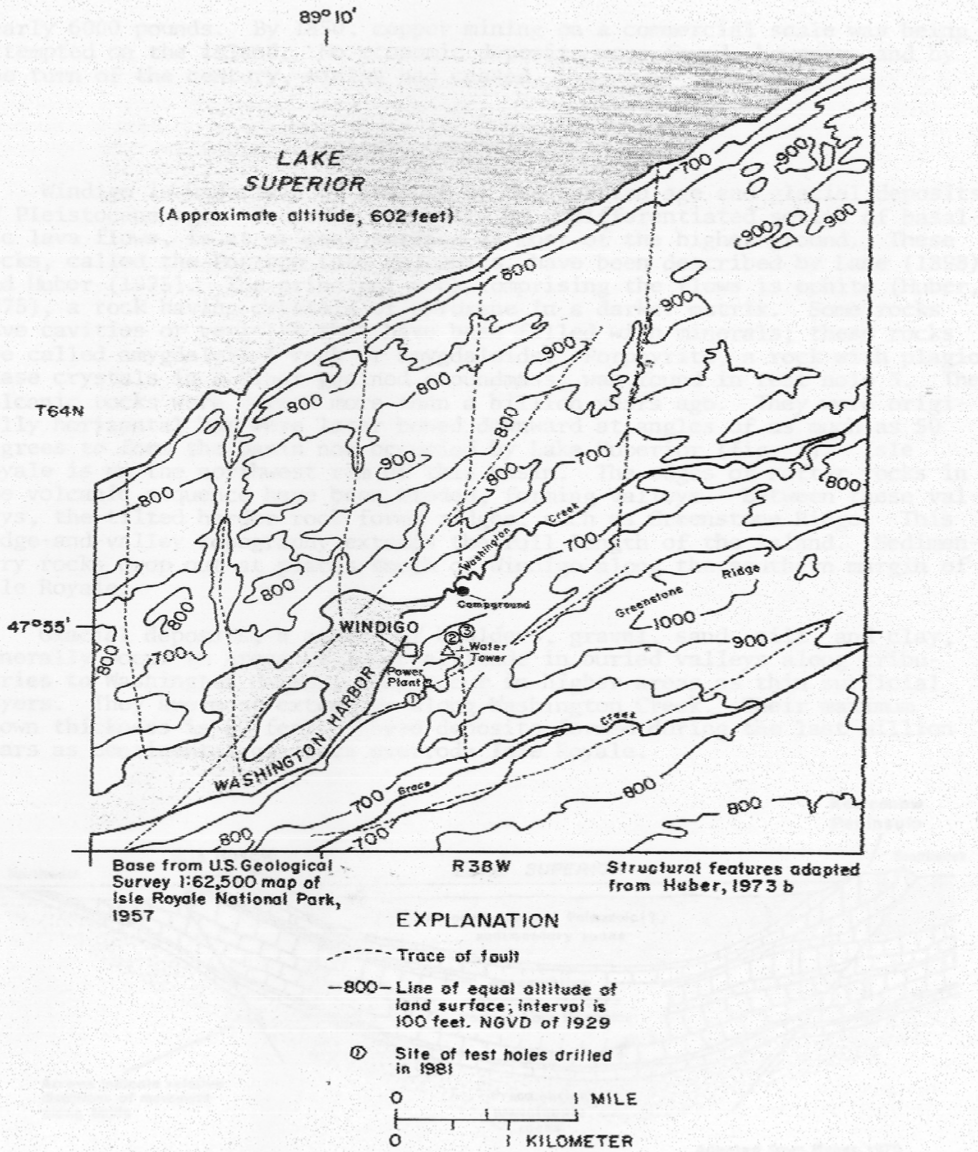


Figure 2.--Windigo area and location of 1981 test holes for water supply.

Figure 9. Test drill sites in Grannemann and Twenter (1982).

B. Streams

1. Stream Ecology Background

Rivers and streams vary widely in their characteristics but share certain features including unidirectional flow, linear form, fluctuating discharge, unstable channel and bed morphology and substrates, high spatial and temporal heterogeneity, and a metabolism supported mainly by organic matter from sources beyond the stream channel (Winterbourn and Townsend 1991, Wetzel 2001).

These dynamic systems are typically organized across the landscape based on watershed or drainage basin units. Common types of drainage networks have been identified. Isle Royale waters drain in a roughly parallel fashion due to the structure of underlying bedrock formations (Figure 10).

Watersheds link terrestrial and aquatic ecosystems through the movement of water and materials to streams and lakes (Wetzel 2001). Consequently, characteristics of the terrestrial environment significantly influence the flow, water chemistry, community composition and ecosystem functions of receiving waters. Topographical features and the composition of vegetation and soil, for example, influence both the quantity of water runoff and the quality of the organic matter therein. At Isle Royale, land-water linkages have been addressed in detail with respect to atmospheric deposition, terrestrial processes, and stream water chemistry (e,g., Stottlemyer *et al.* 1997; also see sections IV-B, IV-F, and V-A)

Riparian zones are hot spots for land-water linkages (Winterbourn and Townsend 1991, Allen 1995). They effectively filter nutrient and sediment inputs from terrestrial runoff, serve as habitat refugia for aquatic, amphibious, and terrestrial wildlife, and are among the most biologically diverse aquatic habitat types. Vegetation in riparian zones contributes dissolved and particulate organic matter to streams and also helps moderate stream temperatures via shading. Riparian areas may also affect channel morphology and thus the instream habitat of a stream.

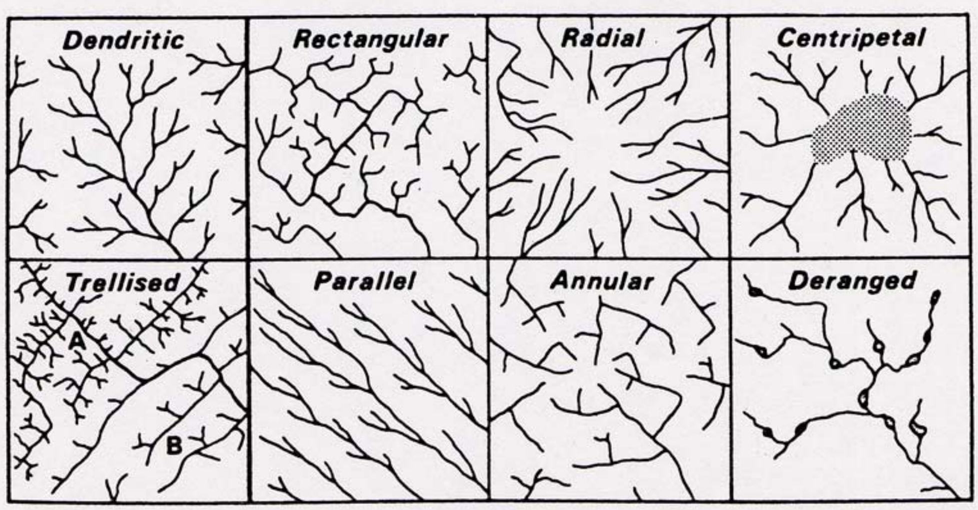


FIGURE 3-4 Common types of drainage networks. (From Gregory, K. J. and Walling, D. E.: *Drainage Basin Form and Process*. 1973. Edward Arnold Ltd., London, by permission.)

Figure 10. Common types of stream drainage networks (from Wetzel 2001). Isle Royale streams generally drain in parallel fashion due to the configuration of underlying bedrock.

In small forested streams such as those of Isle Royale, food webs are largely supported by external inputs of energy from dead leaves and wood; primary production by algae and macrophytes is minimal (Winterbourn and Townsend 1991). As stream size increases, floodplains become important as mechanisms for storing and re-releasing these sources of energy during periodic flood events. Within streams, inputs of nutrients and organic matter are processed by aquatic animals and microbes and exported downstream. Some have suggested a generalized pattern for this process, called the river continuum concept (Vannote *et al.* 1980). This framework suggests a shift in organic matter inputs from coarse particulates in forested headwater areas to fine particulates in more open-canopied downstream areas. Accompanying shifts in substrate characteristics and the structure and function of benthic invertebrate communities are also predicted. A similar longitudinal pattern of benthic invertebrate composition was described by Bowden (1981) in his studies of three Isle Royale streams.

Food web components, energy sources and pathways have been mapped for a simplified forest-stream ecosystem by Winterbourn and Townsend (1991, Figure 11). The model describes inputs to stream ecosystems in terms of light energy and organic matter contributions from upstream, subsurface and overland flow. Components of the in-stream organic pool include periphyton, coarse and fine particulate matter and dissolved organic matter. Processing components of the food web (such as fish, benthic invertebrates, fungi, and bacteria) influence the movement of energy through the system. Outputs from streams include dissolved organic matter in subsurface flow, particulate matter in downstream flow, and losses to insect emergence, drift and heterotrophic respiration.

Factors controlling community structure have been researched extensively in stream ecosystems, and have received some attention at Isle Royale. Some factors are abiotic (such as temperature, substrate, flow, environmental variability), while others are biotic (such as competition and predation). The relative influence of biotic and abiotic factors varies from stream to stream. In Isle Royale streams, abiotic factors such as winter freeze and snowmelt likely influence community composition for much of the year, but biotic factors may be more important in the summer months as environmental conditions become more moderate (Allan 1995).

Human influences on stream ecosystems are many, and include physical alteration of flow via dams, diversions and channelization, transformation of landscapes through farming, urban development and timber harvest, accidental and intentional spread of exotic species, inputs of excess nutrients and contaminants, and shifts in thermal and rainfall regimes due to global climate change (Allan 1995). Geographic isolation and national park status protect aquatic systems at Isle Royale from some of the more obvious human influences, but atmospheric deposition of contaminants and threats from exotic species and global climate change remain a reality.

2. Isle Royale Streams

On Isle Royale, running waters are plentiful but generally small and/or intermittent. Johnson (1980), in his thesis on the Siskiwit River, stated "Most of the water draining off the island first flows quickly in rivulets and brooks down ridge slopes, then turns sluggish as it reaches the valleys and drains through swamps and beaver ponds toward Lake Superior …many of the small streams generally proceed toward the ends of the island, with a few assuming routes through narrow cross valleys which have resulted from faulting." The largest and most rapid streams on Isle Royale include Washington and Grace Creeks flowing to the west, Big Siskiwit, Little Siskiwit and Siskiwit Rivers entering Siskiwit Bay, and Tobin Creek draining into Tobin Harbor. Similarly, Wallace (1966) stated, "The streams are mostly small, sluggish and intermittent in nature although there are several larger streams on the island." Washington Creek is the longest creek on the island and has been monitored intensively as part of the national Hydrologic Benchmark Network. Running waters of the Wallace Lake watershed have been monitored since 1982 as part of a long-term ecological research initiative focusing on quantification of ecosystem structure and function and determination of the response of watersheds to atmospheric inputs and climate change. Siskiwit River was the focus of an intensive thesis study on invertebrates. While streams on Isle Royale flow predictably toward Lake Superior through narrow valleys, apparent flow alterations occasionally occur as a result of Lake Superior seiche (resonant oscillations in an enclosed body of water) events. Such events back lake water up into streams and affect the usually unidirectional transfer of nutrients, energy and organic matter between streams and Lake Superior.

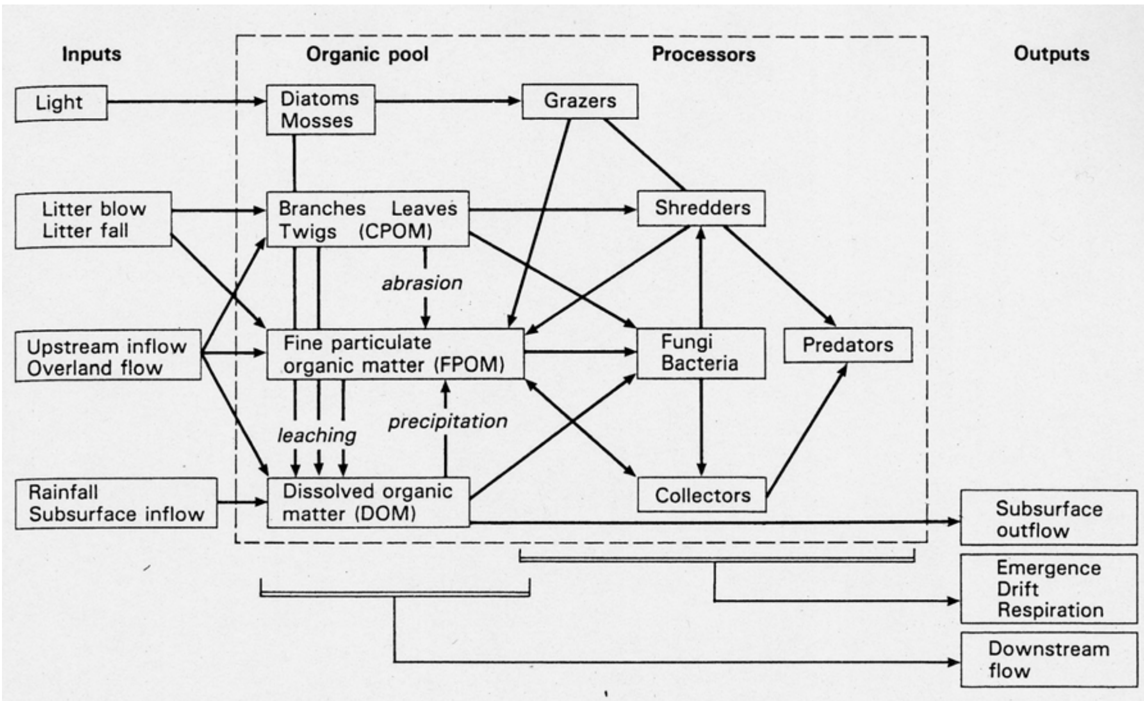


Figure 11. Simplified model of a forest-stream ecosystem showing the principal biological components, energy components and material pathways (from Winterbourn and Townsend 1991).

3. Water Quantity and Quality

Washington Creek at Windigo

Isle Royale's Washington Creek extends 6.8 miles upstream from the gauging station near Windigo, and has an average stream gradient of 19.8 m/mi. The Washington Creek watershed is 13.1 mi^2 (34 km^2) in size and ranges from 603-1394 ft (184-425 m) in elevation. As one of approximately 50 stations in the national Hydrologic Benchmark Network, Washington Creek at Windigo was monitored by U.S. Geological Survey between 1967 and 1995 for discharge and water chemistry parameters. This site represents Isle Royale's longest-running and most extensive source of water quality data; 81 percent of all Isle Royale data found in the Environmental Protection Agency's Storage and Retrieval database (STORET) were collected from Washington Creek at Windigo (NPS 1995). Most of the 25 other water quality sampling sites recorded in STORET were located elsewhere in the Washington Creek drainage or in Lake Superior nearshore waters (Figure 12).

Long term data from the Washington Creek site were recently summarized by Mast and Turk (1999). From 1965-2001, mean monthly discharge varied from below 4 cubic feet per second (cfs) in February to nearly 70 cfs in April during snowmelt (Figure 13). A second peak in flow generally occurred in October and November due to increased precipitation and low evapotranspiration.

Stream water in Washington Creek had intermediate conductance and was well buffered; specific conductance ranged from 57-250 $\mu S\ (cm)^{-1}$ and alkalinity averaged 400 meq l^{-1} (Table 7). Most weathering-derived constituents had strong inverse correlations with discharge. Seasonal Kendall trend analysis identified statistically significant upward trends in pH from 1967-1995 and downward trends in flow-adjusted concentrations of potassium, calcium, magnesium and chloride. Mast and Turk noted that trends in pH and potassium may be related to changes in methods rather than environmental factors.

Screening criteria (published EPA water quality criteria and other values established by the National Park Service Water Resources Division) were seldom exceeded at any of the Isle Royale sites (NPS 1995). However, a pH of 6.3, below the EPA chronic criteria for freshwater life, was recorded once in 1965 at Washington Creek, and total and fecal coliform criteria were exceeded on about 10-15 percent of sampling occasions at this site. Occasional acute freshwater criterion exceedences also occurred for cadmium, copper, lead, and zinc. These exceedences were attributed to natural processes. Using Washington Creek as the benchmark, ISRO stream waters appeared to be minimally impacted by human activities and of very good quality (NPS 1995).

Aside from the long-term study of Washington Creek, insights into the chemistry of Isle Royale's running waters are limited to a U.S. Geological Survey synoptic study in 1992 (Mast and Turk 1999), a thesis study of chemistry and invertebrates in three streams (Bowden 1981), an island-wide water chemistry survey conducted by Stottlemyer in 1981-82 (Stottlemyer *et al.* 1998), and the Wallace Creek watershed research (see following subsection).

Nine sites in the Washington Creek watershed were sampled during a U.S. Geological Survey synoptic study in September 1992 (Mast and Turk 1999). Tributary streams were similar in chemical composition to the main stem Washington Creek site, although color and organic acid content were likely higher in tributaries. While most constituents varied little among sites, stream water sulfate concentrations ranged substantially, perhaps due to differences in wetland sulfur cycling among sub-basins.

Bowden investigated three streams (Grace and Washington creeks and the Little Siskiwit River) from May through October in 1979 (Bowden 1981). Both upstream and downstream sampling locations were represented for each stream. Discharge rates ranged considerably both within and among streams. Lowest discharge rates were encountered on upstream portions of Grace Creek and the Little Siskiwit River and highest discharge rates were found on the lower reaches of

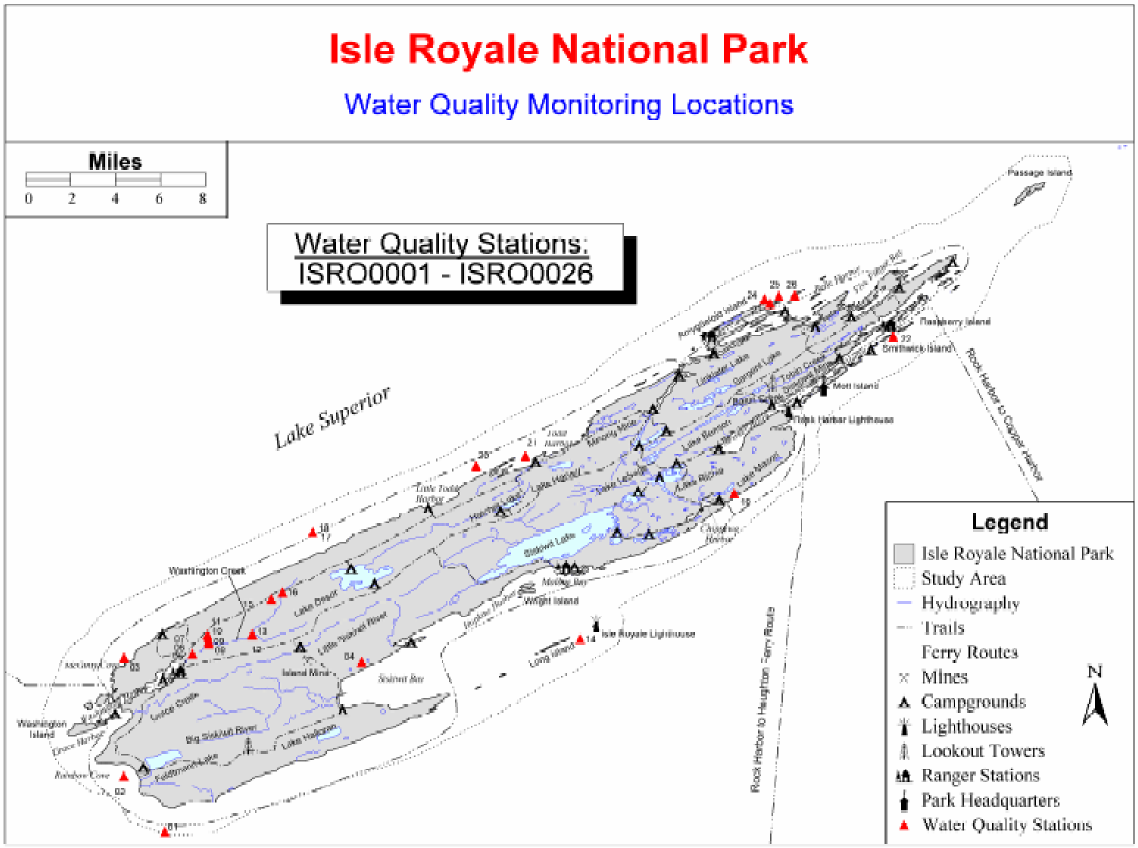


Figure 12. Locations of known water quality monitoring stations on Isle Royale (from NPS 1995).

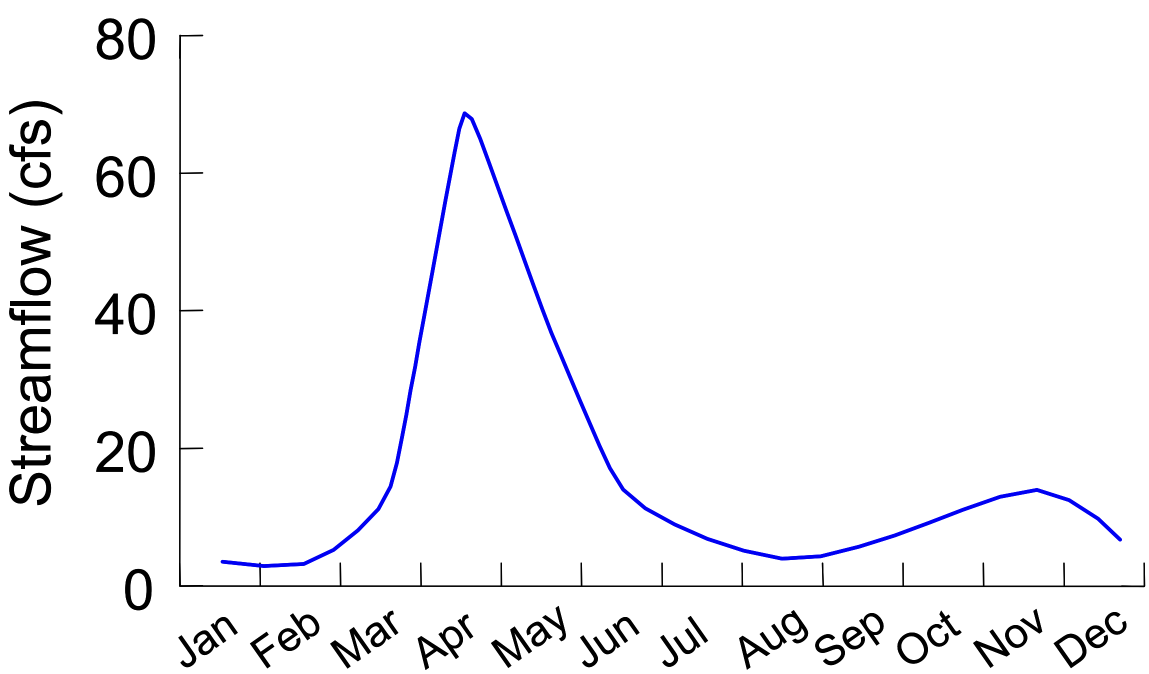


Figure 13. Smoothed hydrograph for Washington Creek using average mean monthly flows from 1965-2001 (http://waterdata.usgs.gov/nwis/discharge/?site_no=04001000).

Table 7. Median, minimum and maximum values of physical properties and major dissolved constituents measured in water quality samples from Washington Creek, September, 1967-August, 1995 (Mast and Turk 1999). Concentrations are given in units of micro equivalents per liter, discharge in cubic meters per second, specific conductance in micro siemens per centimeter, pH in standard units, and silica in micromoles per liter. n=number of stream samples. Precipitation values (inches) are given as volume weighted means for 1985-95 at the Wallace Lake NADP site.

	Median	Minimum	Maximum	n	Precipitation
Discharge	0.15	0.01	4.40	145	--
Specific Conductance	130	57	250	141	13
Field pH	7.5	6.6	8.1	145	4.8[a]
Calcium	900	360	1600	145	7.9
Magnesium	420	180	800	145	2.2
Sodium	130	39	360	145	1.4
Potassium	13.0	<2.6	31.0	145	0.7
Ammonium	2.1	<0.7	26.0	61	17
Lab Alkalinity	1220	400	2120	145	--
Sulfate	120.0	8.3	460.0	142	29
Chloride	85.0	<2.8	420.0	146	1.6
Nitrite+Nitrate	7.1	<0.7	15.0	102	17[b]
Silica	200	98	270	146	--

[a] Laboratory pH
[b] Nitrate only

Washington Creek. Discharge varied seasonally, with mid-summer low-flows occurring across sites and higher flows occurring in May and October. Stream temperatures varied seasonally and showed marked diurnal fluctuations, particularly in June prior to the onset of full foliage. Alkalinity and pH were generally lowest in May and October, greatest in July and August, and lower in headwater areas than at downstream sites. Most cations (Ca^{2+}, Mg^{2+}, Na^{+}) showed inverse relationships to discharge, consistent with the long-term Washington Creek data. Cations also had generally high stream water concentrations, which increased toward downstream sites.

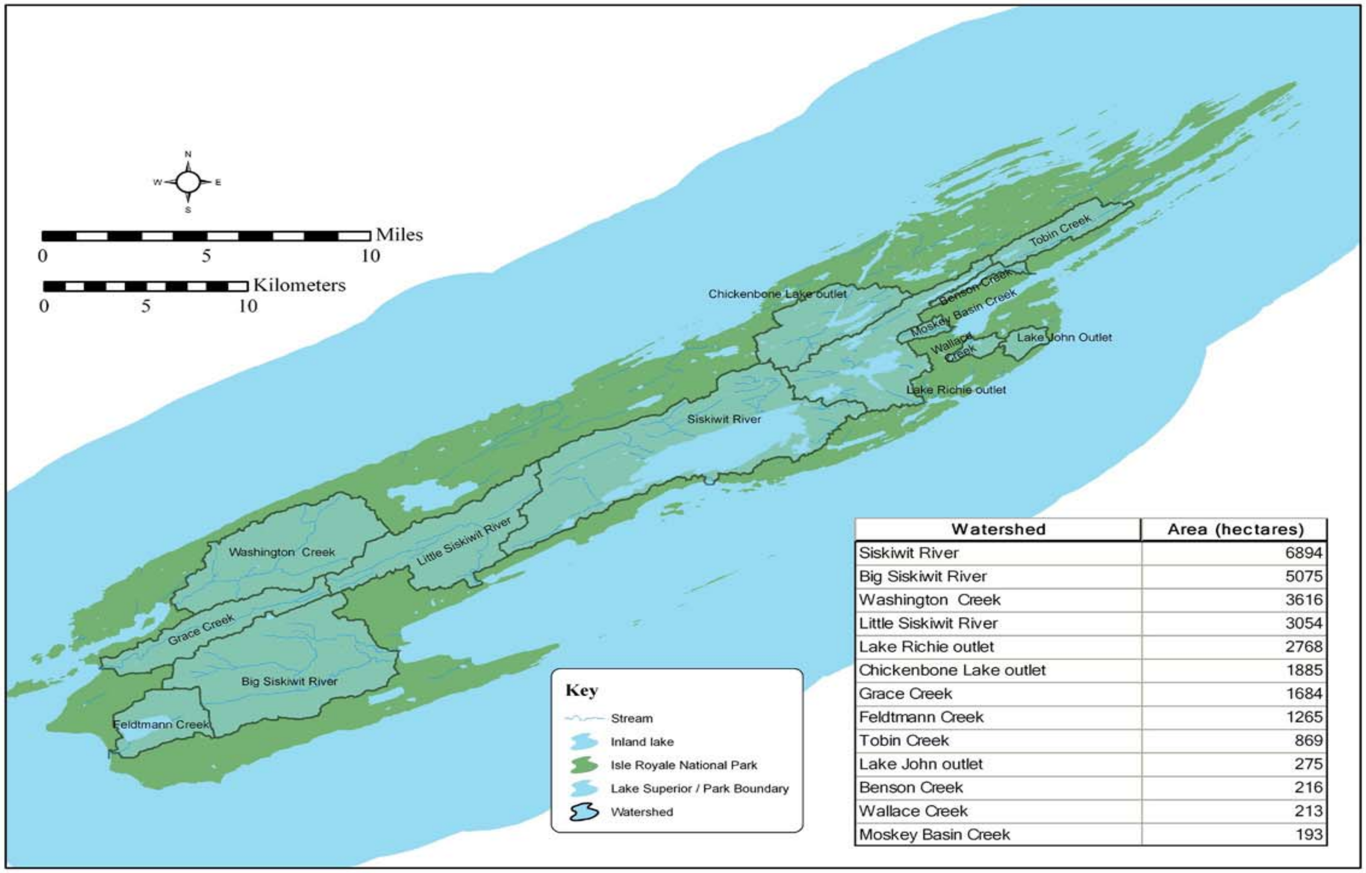
Stottlemyer sampled 26 stream sites prior to embarking on long-term research in the Wallace Creek watershed (Table 8, Stottlemyer *et al.* 1998). Some streams were sampled at only one location; others were sampled at several sites from headwaters downstream. Average pH and conductivity across all sampled stream sites was 6.9 and 95 $\mu S\ cm^{-1}$, respectively. Conductivity is low and reflective of the low total dissolved solids in park streams. Ammonium (NH_4^+), nitrate (NO_3^-), and sulfate (SO_4^{2-}) averaged 5, 3.3, and 100 $\mu eq\ l^{-1}$, respectively; these low concentrations are indicative of high water quality and the lack of problematic land use. Bicarbonate (HCO_3^-) was quite variable, averaging 484 $\mu eq\ l^{-1}$ and ranging from 131 to 1542 $\mu eq\ l^{-1}$. Bicarbonate is a biologically important anion that reflects the buffering capacity of streams, especially against anthropogenic increases in acidity. Sulphate and bicarbonate concentrations tend to be inversely correlated in stream water, especially in low alkalinity areas such as the park. Upstream-downstream gradients in chemical constituents were not readily apparent.

4. Watershed Studies

Stream and watershed studies at Isle Royale were initiated in 1982, when NPS established the Watershed Research Program with four ecosystem study sites in Olympic National Park,

Table 8. Water chemistry results from a subset of Isle Royale streams sampled in 1981-82 (reproduced from Stottlemyer *et al.* 1998). Upstream-downstream stations are numbered with the lowest number at the head of the watershed and the highest number at the mouth of the watershed. Concentrations are in micro equivalents per liter. "Temp" is temperature in degrees Centigrade and "Cond" is conductivity in µS/cm.

Station	pH	Temp	Cond	HCO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	NH_4^+	NO_3^-	SO_4^{2-}	Cl^-
Stream Stations												
Tobin	7.8		99	935						15.0	60	33
John	7.7	17	146	590	768	213	50	4	0	3.0	103	4
John	7.7		119	476	498	145	32	2	4	0.0	33	0
Newt	7.1	6	106	459	581	246	52	33	34	1.0	55	6
Epidote	7.0	9	90	312	460	191	34	3	0	2.0	79	0
Scholtz	6.6	9	66	262	344	125	23	0	0	0.0	78	3
Whittlesey Trib 2	6.0	11	56	148	309	177	44	7	5	1.0	68	2
Whittlesey Trib 3	6.2	11	58	131	318	179	49	9	7	1.0	69	3
Whittlesey Trib 4	6.2	11	55	180	316	182	41	6	4	2.0	70	0
Little Siskiwit	6.2		94	213	391	378	57	3	3	14.0	458	18
Little Todd	6.9		115	820	430	633	100	7	0	1.0	142	16
Island Mine	7.4		132	918	569	576	117	9	0	16.0	153	9
Washington	6.9	7	115		489	370	100	10		2.0	129	52
Upstream-Downstream Stations												
Washington 1	6.7	9	100		486	354	91	10		2.0	94	22
Washington 2	7.3	19	150		789	526	87	18				
Washington 3	6.6	7	105		475	362	96	10		0.0	108	27
Washington 4	6.7	7	100		468	362	100	10				
Washington Trib 1	6.5	5	76	525	75	313	65	13		8.0	72	10
Washington Trib 2	6.8	6	148	1427	133	1398	235	16		5.0	58	10
Washington Trib 3	7.0	5	162	1542	105	1069	196	16		0.0	117	15
Greenstone 1	7.1	13	64	168	269	218	50	3	0	1.0	89	1
Greenstone 2	6.9		63	156	248	208	64	4	4	0.0	101	14
Greenstone 3	7.0	17	64	143	246	204	60	3	4	0.0	100	10
Greenstone 4	7.7	16	64	150	254	210	63	3	0	2.0	104	10
Noname 2	7.0	12	65	303	320	105	33	8	7	1.0	31	6
Noname 3	6.9	11	70	310	327	125	39	6	5	1.0	29	11
Mean	6.9	10	95	484	387	355	75	9	5	3.3	100	12
Standard Deviation	0.5	4	33	419	179	303	50	7	8	4.9	83	12
Minimum	6.0	5	55	131	75	105	23	0	0	0.0	29	0
Maximum	7.8	19	162	1542	789	1398	235	33	34	16.0	458	52



Watershed	Area (hectares)
Siskiwit River	6894
Big Siskiwit River	5075
Washington Creek	3616
Little Siskiwit River	3054
Lake Richie outlet	2768
Chickenbone Lake outlet	1885
Grace Creek	1684
Feldtmann Creek	1265
Tobin Creek	869
Lake John outlet	275
Benson Creek	216
Wallace Creek	213
Moskey Basin Creek	193

Figure 14. Major stream watersheds and their sizes.

Rocky Mountain National Park, Sequoia-Kings Canyon National Park, and the Wallace Lake watershed near Moskey Basin at Isle Royale National Park. The program was designed to address large-scale stressors such as atmospheric deposition and climate change via an understanding of watershed processes and linkages between land, water and the atmosphere (Hermann and Stottlemyer 1991). Isle Royale was selected due to its remote location, its history of limited human land use, its representation of a southern boreal forest ecotone, its relatively high atmospheric deposition and its susceptibility to climate change (Stottlemyer *et al.* 1998). Twenty years of intensive research have generated a wealth of information about how Isle Royale watersheds function and how atmospheric constituents are cycled through boreal forest, soils, snow, and surface waters. See Figure 14 for a map of ISRO stream watershed areas. Much of this work was recently compiled and summarized (Stottlemyer *et al.* 1998).

In the early years of the Watershed Research Program, the primary concern was acid deposition. Precipitation pH in the upper Great Lakes region was low in the 1970s (comparable to sites in the Adirondacks and acid-impacted parts of Scandinavia) and spanned a west-east gradient from pH=5.3 in parts of Minnesota to pH=4.3 in parts of Michigan (Glass and Loucks 1986). Isle Royale ecosystems were thought to be particularly vulnerable to acid deposition due to their relatively thin soils and Precambrian bedrock geology. Early studies by Stottlemyer, however, showed that streams could neutralize experimental acid additions over short temporal and spatial scales (Stottlemyer 1982a), such that lower reaches of streams at Isle Royale and Pictured Rocks were not generally acidic (Stottlemyer 1979). Given these results and the fact that snowfall and snow pack contaminant loads appeared to increase with elevation, headwaters of Isle Royale streams were considered more sensitive to atmospheric deposition than lower reaches. Concerns about effects of acid precipitation at Isle Royale have gradually diminished following declines in sulfur deposition and indications from Stottlemyer's work that Isle Royale surface waters were surprisingly well-buffered (Stottlemyer *et al.* 1998).

Stream water chemistry was found to be influenced only indirectly by precipitation chemistry, since precipitation was subject to the mediating effects of vegetation cover, soil characteristics, and snowmelt patterns (Stottlemyer *et al.* 1998). For instance, acid precipitation was found to be more readily neutralized by hardwood canopy cover than coniferous canopy cover (Stottlemyer 1982b). Glacial tills, distributed unevenly across Isle Royale, were generally more alkaline and able to effectively buffer against acidification (Stottlemyer 1982b). Mid-winter thaws were found to cause significant losses of the snow pack's accumulated solute load, resulting in less dramatic spring snowmelt ion peaks and more moderate depressions in stream pH and acid neutralizing capacity. Similarly, snow-insulated, unfrozen soils allowed adsorption, exchange and biological uptake of precipitation-derived ions to occur gradually throughout the winter, further moderating their influence on stream chemistry (Stottlemyer 1987, Stottlemyer and Rutkowski 1990, Stottlemyer and Toczydlowski 1991).

Research has shifted in recent years to the effects of climate change and nitrogen (N) deposition on watershed processes. Previous work showed that the Wallace Lake watershed strongly retains nitrogen inputs (Stottlemyer 1999, Stottlemyer and Toczydlowski 1999). More recent work indicates that soil mineralization of N is very efficient (approximately five times the amount arriving in precipitation annually), and positively linked to both stream N chemistry and temperature. It appears that high levels of atmospheric nitrogen inputs to Isle Royale watersheds have not yet affected stream water chemistry; however, microbial structure and function in terrestrial environments are likely already affected by excess nitrogen and future climate warming could alter export of nitrogen to streams (Stottlemyer and Herrmann 2000). The watershed carbon budget appears nearly balanced, but soil and root respiration (CO_2 efflux) are also linked to temperature (Stottlemyer and Herrmann 2000), and some have suggested that carbon and nutrient cycling in boreal forests will be quite sensitive to future warming (Pastor and Post 1988).

5. Stream Fish

Concurrent to the development of this Water Resources Management Plan, a Fishery Management Plan will be published in 2006. This plan will focus primarily on and provide management guidance for lakes and streams of the island, but will also address research and management of Lake Superior waters of the park. This Fishery Management Plan will cover specific fish and fisheries information for the streams of the park. However, investigations of stream fish populations, communities, and associated habitats have been limited. Slade and Olson (1994) collected baseline information on species presence and basic limnological characteristics in six tributaries to Lake Superior: Little Siskiwit River; Big Siskiwit River; Washington Creek; Grace Creek; Chickenbone Lake Outlet; and Tobin Creek. Thirteen fish species were captured. The USFWS has conducted surveys since 1995 to monitor brook trout populations in the Big and Little Siskiwit rivers, and the Siskiwit River which originates at Siskiwit Lake. In 2005, the USFWS began following the State of Michigan's "Streams Status and Trends Program" protocol for fish monitoring on six streams at the island, including the Big and Little Siskiwit rivers, Siskiwit River from Siskiwit Lake, Benson Creek, Grace Creek, and Washington Creek.

6. Stream Benthic Invertebrates

Ecological surveys conducted in the early 1900s (Adams 1909) likely represent the first record of aquatic invertebrate fauna on Isle Royale. The surveys included six aquatic habitat types, ranging from Lake Superior and associated beaches and rock pools to inland lakes, wetlands and streams. The investigators noted a relative lack of running water habitats on the island and focused their attention on inland lake outlet streams. Bowden (1981) presented basic hydrological and chemical data on Isle Royale streams, and addressed how benthic invertebrate assemblages varied between and among the study streams as well as seasonally. He noted within-stream longitudinal gradients in invertebrate composition, coincident with gradients in stream substrate type and water chemistry. Several taxa were most prominent at upstream sampling sites (the caddisfly *Parapsyche*, and dipterans including *Micropsectra*, *Tanytarsus*, *Simulium* and *Prosimulium*). Other taxa were more common downstream (*Baetis*, *Stenonema*, *Optioservus*, *Hydroptila*, *Conchapelopia*, *Chimarra*). Based on known species physiologies, there was no evidence that invertebrate composition was directly affected by upstream pH or alkalinity depressions. Invertebrate composition in Isle Royale streams was similar to that of streams along the north shore of Minnesota and Michigan's Keweenaw Peninsula. From May through October, the highest numbers of benthic organisms were found in July; the lowest numbers were found in October.

Invertebrate fauna collected from 31 sites along the short Siskiwit River were analyzed in detail by Johnson (1980). In total, 64 taxa were collected and identified. Substrates at most riffle sites were characterized by gravel, rubble, and lesser amounts of organic matter. Marsh site substrates were composed almost entirely of silt, muck, and pulpy peat. The 10 most abundant taxa river-wide were *Chironomidae*, *Optioservus*, Sphaeriidae, *Baetis*, *Tricorhythodes*, *Gyraulus parvus*, Oligochaeta, *Simulium*, *Cheumatopsyche*, and *Leuctra*. Spatial distribution of invertebrate taxa was given special attention. Cluster analysis and similarity quotients helped identify distinct groupings of Siskiwit River sites, which were distributed more or less longitudinally in the river (Table 9). Dominant factors affecting invertebrate composition (substrate, current, water depth, temperature, shade, chemistry, detrital food, and lake outflows) at each set of sites were

Table 9. Percentage distribution of dominant taxa for each of the community types identified for the Siskiwit River (from Johnson 1980). Only taxa constituting ≥ 2 percent of the community total are included.

Taxon	Station Groups					
	Lower section 1	Lower Section 2	Marsh Section	Middle Section	Upper Section 1	Upper Section 2
Baetis	7.2	9.2	3.8	12.1	10.3	2.0
Tricorhythodes			38.0	2.6	5.9	29.9
Leuctra	4.2	2.0			2.5	
Cheumatopsyche	7.7	6.9			2.7	
Ceraclea	4.5					
Mystacides			5.1	2.4		
Optioservus	21.6	46.8	5.2	29.0	20.0	11.4
Simulium	18.9	2.9				
Chironomidae	14.6	13.8	10.5	14.7	33.9	37.3
Hyalella azteca			3.4			
Sphaeriidae		5.5	2.9	12.1	12.1	7.7
Gyraulus parvus	4.9			3.0	3.4	
Oligochaeta		5.2	14.5	15.5		
Hirudinea	2.9		8.7			
Hydra						2.7

discussed. Plankton and other organic matter from the Siskiwit Lake outlet likely influenced benthic invertebrate composition upstream, and composition in the marsh sites was probably most influenced by substrate, current and water depth.

Appendix E provides a list of known stream invertebrate species for ISRO.

C. Inland Lakes

1. Inland Lake Ecology Background[1]

Lakes are standing water bodies originating from a variety of processes that affect their morphometry and ultimately their chemistry and biology. Lakes may be formed by tectonic events, volcanic activity, glacial activity, landslides, dissolution of limestone, river and shoreline

[1] Much of the following text is adapted from Wetzel (2001).

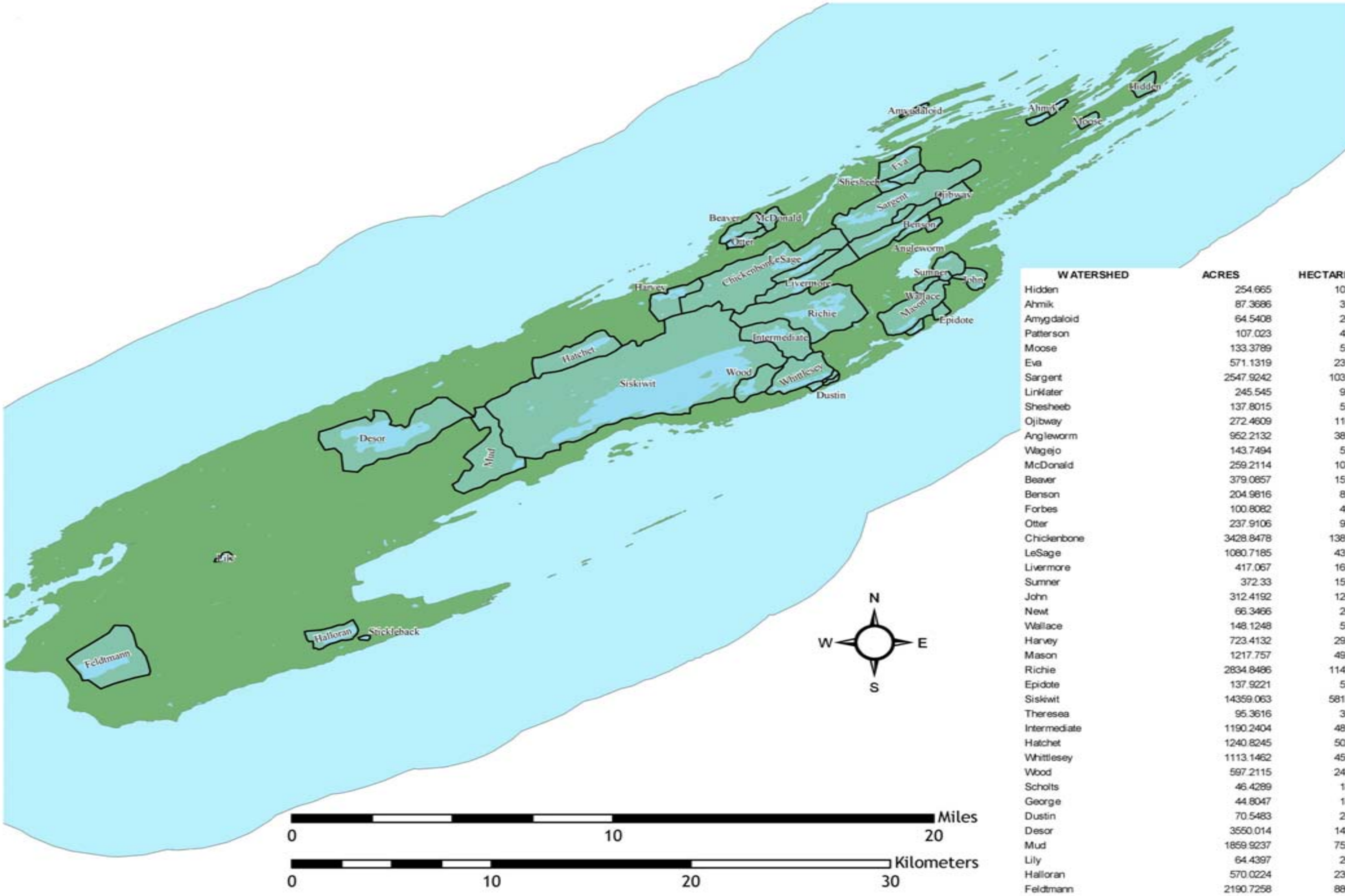
action, wind action, and damming via organic detritus accumulation, beavers, and humans. On Isle Royale, most inland lakes were formed by glacial quarrying of the island's elongated series of ridges and valleys (Kallemeyn 2000, Figure 15). Two inland lakes, Feldtman and Halloran, were created when barrier beach bars isolated embayments of postglacial lakes Minong and Nipissing. Based on present lake elevations and water level profiles from the Minong and Nipissing phases, it appears that 13 inland lakes originated during the interval between the two phases (about 4000-9000 years before present) and 12 originated during or after the Nipissing phase (about 3000 years before present) (see Kallemeyn 2000).

Lake ecosystems are frequently thought of in terms of zones. Two primary zones are the lake bottom (benthic zone) versus free open water (pelagic zone). Lakes are further subdivided into transitional zones from the lakeshore to the deepest point (Figure 16). In general, the pelagic zone describes the open water area and the littoral zone defines areas along the lake edge ranging from just above the water level, where waves and spray are influential, to below the water level where macrophytic vegetation is common. The profundal zone is characterized by poor light conditions and a lack of algae or vegetation.

Specialized organisms are adapted to life in each of these zones or habitats, and many organisms utilize several habitats over the course of a day, year, or life span. Primary producers include macrophytes and attached or planktonic algae. While macrophyte distribution is restricted by depth and substrate to the littoral zone, phytoplankton may be found throughout the photic pelagic zone, and attached algae may be found on substrates ranging from macrophyte and animal surfaces to sand, sediment, and rock. The fauna of freshwaters includes representatives of nearly all phyla. Zooplankton includes all animals suspended in water and lacking substantial locomotive powers (i.e., protozoa, rotifers, cladocerans, copepods, and some immature insect larvae). The nekton include animals capable of swimming independently of turbulence and water movement; fish and some zooplankton and adult insects are in this group. The fauna of the benthic zone commonly include insect larvae, nematodes, ostracods, mussels, oligochaetes, and certain fish species. Some organisms are even adapted to the interface between air and water, including some duckweed, and adult insects as well as certain bacteria and algae.

Like other aquatic ecosystems, lakes are open to inputs of water, energy and materials from the surrounding basin. Biogeochemical processes and landscape geomorphometry affect the composition and rate of movement of materials from terrestrial environments to lakes, greatly influencing lake metabolism. The watershed studies by Stottlemyer (Stottlemyer *et al.* 1998) have done much to describe how materials from weathering and atmospheric deposition are processed by forest canopies, soils, snow and surface water in Isle Royale watersheds. Less well-known, however, is how these processes affect inland lake ecology.

An inland lakes conceptual model developed through the Great Lakes Inventory and Monitoring Network (Route and Elias 2003) describes major ecosystem drivers, ecosystem stressors and their effects, ecosystem attributes and measures thereof (Figure 17). Natural ecosystem drivers were subdivided into watershed and climatic drivers, whereas anthropogenic drivers ranged from recreation and watershed/shoreline disturbance to atmospheric deposition and climate change. Stressors stemming from these drivers included habitat loss, contaminant loading, acid deposition, exotic species, fishing/boating, changes in temperature and precipitation, and loading of nutrients,



WATERSHED	ACRES	HECTARES
Hidden	254.665	103.0615
Ahmik	87.3686	35.3576
Amygdaloid	64.5408	26.1193
Patterson	107.023	43.3116
Moose	133.3789	53.9777
Eva	571.1319	231.1339
Sargent	2547.9242	1031.1308
Linklater	245.545	99.3707
Shesheeb	137.8015	55.7675
Ojibway	272.4609	110.2634
Angleworm	952.2132	385.3554
Wagejo	143.7494	58.1746
McDonald	259.2114	104.9014
Beaver	379.0857	153.4139
Benson	204.9816	82.9549
Forbes	100.8082	40.7965
Otter	237.9106	96.2811
Chickenbone	3428.8478	1387.6357
LeSage	1080.7185	437.3608
Livermore	417.067	168.7847
Sumner	372.33	150.6799
John	312.4192	126.4343
Newt	66.3466	26.8501
Wallace	148.1248	59.9453
Harvey	723.4132	292.7613
Mason	1217.757	492.8195
Richie	2834.8486	1147.2475
Epidote	137.9221	55.8163
Siskiwit	14359.063	5811.0332
Theresea	95.3616	38.5923
Intermediate	1190.2404	481.6837
Hatchet	1240.8245	502.1548
Whittlesey	1113.1462	450.4841
Wood	597.2115	241.6882
Scholts	46.4289	18.7895
George	44.8047	18.1322
Dustin	70.5483	28.5505
Desor	3550.014	1436.671
Mud	1859.9237	752.7008
Lily	64.4397	26.0784
Halloran	570.0224	230.6849
Feldtmann	2190.7258	886.5746
Stickleback	29.8551	12.0822

Data derived from 7.5-minute Digital Elevation Model data and
ArcView 3 Hydrologic Modeling extension

Figure 15. Lake location and watershed areas.

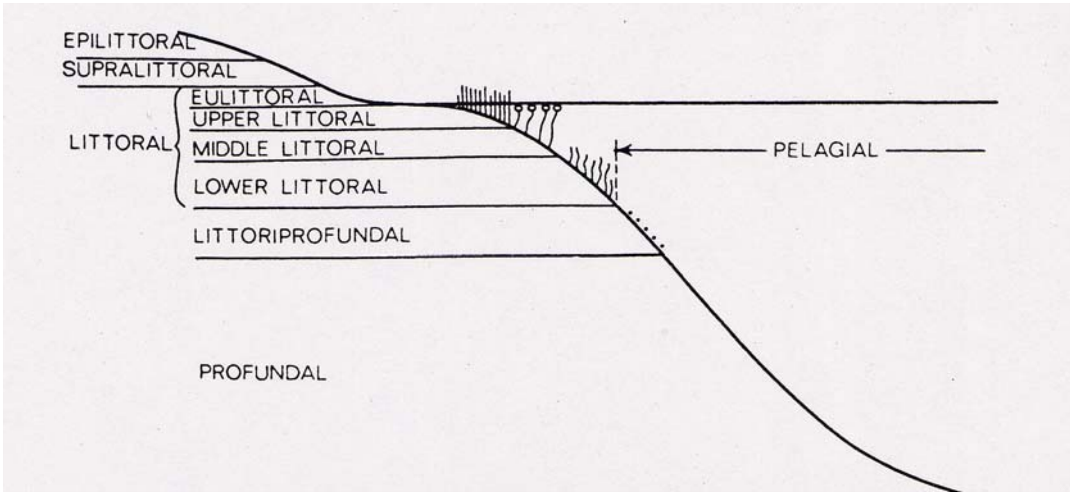


Figure 16. Zonation of lake environments showing gradients between littoral, profundal and pelagic zones (after Wetzel 2001).

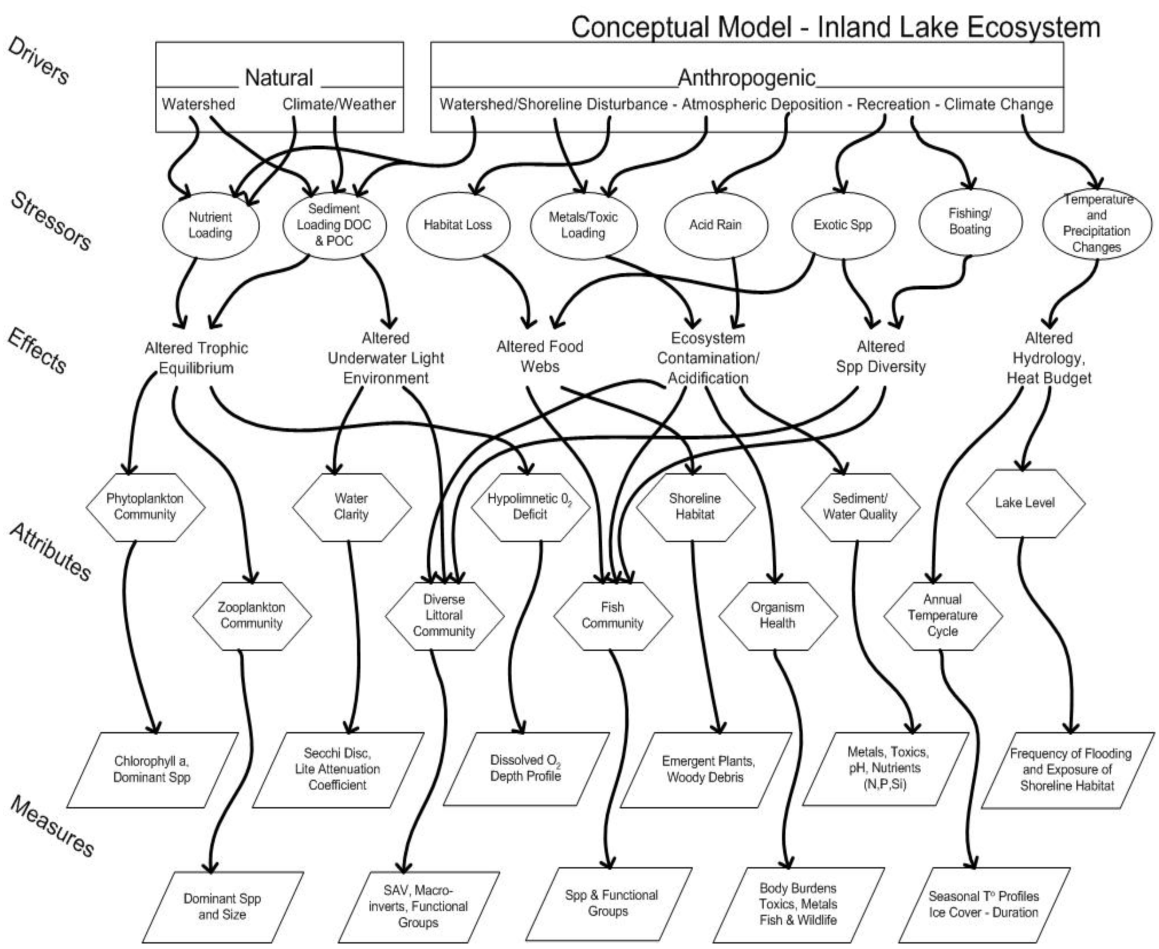


Figure 17. Inland lakes conceptual model, showing ecosystem drivers, stressors, effects, attributes and measures (Route and Elias 2003).

contaminants, and sediment and organic matter. In turn, these stressors affect lake trophic status, alter underwater light environments and food webs, cause acidification or contamination, and alter species diversity, hydrology, and lake heat budgets. Inland lake structural and functional attributes are affected in measurable ways by these stressors.

Some of the above ecosystem drivers are more influential than others in Isle Royale inland lakes. For example, because of Isle Royale's remote location and protected status, its inland lakes are mostly free from human influences related to land use change and development. As a result, anthropogenic nutrient and sediment loading is minimal, and cultural eutrophication is unlikely. Climate change and deposition of atmospheric contaminants, however, are without boundaries, and have complex effects on Isle Royale's inland lakes. Temperatures have warmed appreciably in the Great Lakes region over the last two decades, with implications for lake freeze-thaw cycles, thermal stratification, and species ranges. Additionally, long-range transport of a surprising suite of toxins to Isle Royale ecosystems has been demonstrated through studies of fish and sediments in Siskiwit Lake (Swackhamer and Hornbuckle 2003). Recreation including fishing on Isle Royale lakes is limited, and as such is unlikely to be a strong ecosystem driver. However, recreational activities do increase the likelihood of invasive species introductions.

2. Isle Royale Inland Lakes

The Long Range Aquatic Resources Management Plan for Isle Royale (Wallace 1966) reports that there are an estimated 202 lakes and ponds on the island, ranging from small shallow ponds covering a fraction of a hectare to the large and deep Siskiwit Lake. Most lakes (162) are larger than 1 acre (0.4 ha), 118 lakes are larger than 2 acres (0.8 ha), and 56 lakes exceed 5 acres (2 ha). At the time of this plan, 43 lakes were named on the current topographic map, and fishes had been reported from 39 lakes. Of the named lakes, 20 were qualitatively characterized as eutrophic, ten as dystrophic, and four as oligotrophic. Kallemeyn (2000) provided a detailed account of the morphometric, chemical. and biological features of 32 of these lakes (Tables 10 and 11). Lake surface areas are variable on Isle Royale, ranging from the 3.2-acres (1.3 ha) Epidote Lake to the 4040-acre (1,635 ha) Siskiwit Lake. Larger lakes tend to have larger watersheds (r^2=0.597), and most of the lakes are shallow and elongate. About half the inland lakes contain one or more islands. In terms of thermal regime, Isle Royale lakes fit into roughly three classes: cold polymictic (unstratified), discontinuous polymictic (sporadically stratified) or dimictic (stably stratified during summer, with mixing before and after) (Kallemeyn 2000).

3. Water Quality

Chemical and biological qualities of Isle Royale lakes were characterized most recently by Kallemeyn in his 1995-97 fisheries survey. Whitman *et al.* (2000) conducted monitoring studies on two of these lakes (Sargent and Siskiwit) in the late 1990s. Prior to these studies, the most recent water quality assessments took place in the late 1970s (six lakes, Toczydlowski *et al.* 1978) and early 1980s (18 lakes, Stottlemyer *et al*. 1998). The survey studies varied somewhat in terms of the number and identities of study lakes as well as the parameters measured. Toczydlowski's survey addressed six lakes for a limited number of basic water quality variables, whereas Stottlemeyer and Kallemeyn's surveys addressed 18 and 32 lakes, respectively, and a broader range of water quality variables. Cautious comparisons among the studies are possible where overlaps exist.

Table 10. Morphometric characteristics of 32 Isle Royale National Park inland lakes sampled during the summers of 1995-97 (from Kallemeyn 2000). Abbreviations as follows: D_L = length of shoreline/2($\sqrt{}$ area of lake) π.

Lake	Lake Elevation	Lake Area	Watershed Area	Maximum length	Maximum Breadth	Shore Development	Maximum Depth	Relative Depth
	m	ha	ha	km	km	D_L	m	%
Ahmik	192.7	10.3	35.4	0.89	0.16	2.1	3.35	0.98
Amygdaloid	187.0	10.8	26.1	1.53	0.10	2.7	8.84	2.38
Angleworm	240.5	50.4	495.6	3.51	0.20	3.0	8.40	1.05
Beaver	207.0	20.1	258.3	1.09	0.31	1.9	5.18	1.02
Benson	239.9	24.1	83.0	1.38	0.33	1.8	3.80	0.69
Chickenbone	--	92.6	1556.4	2.84	0.36	2.6	6.40	0.59
Desor	260.3	427.8	1436.7	4.45	1.91	1.8	14.02	0.60
Dustin	198.0	4.4	497.8	0.49	0.16	1.7	6.10	2.58
Epidote	189.0	1.3	55.8	0.19	0.09	1.2	3.96	3.08
Eva	187.2	17.6	231.1	0.97	0.23	1.6	6.40	1.35
Feldtman	201.2	185.8	886.6	2.66	1.02	1.4	2.74	0.18
Forbes	236.0	6.8	40.8	0.54	0.17	3.0	5.80	1.97
George	203.9	3.8	18.1	0.61	0.10	2.0	2.70	1.23
Halloran	200.0	77.4	230.7	1.82	0.42	1.4	2.70	0.27
Harvey	232.3	55.4	292.8	1.75	0.46	1.7	4.00	0.48
Hatchet	229.9	49.6	502.2	1.90	0.41	1.7	5.20	0.65
Intermediate	206.0	70.8	481.7	1.77	1.01	2.2	6.70	0.71
John	196.0	3.3	126.4	0.47	0.16	1.8	5.49	2.68
LeSage	223.4	45.0	933.0	1.66	0.48	2.4	6.40	0.85
Linklater	222.2	17.3	99.4	1.56	0.17	2.4	6.00	1.28
Livermore	213.1	30.1	168.8	1.57	0.30	2.0	5.50	0.89
Mason	186.0	22.8	492.8	1.73	0.24	2.3	8.50	1.58
McDonald	213.0	14.8	104.9	0.93	0.31	1.8	4.00	0.92
Otter	213.0	20.2	96.3	1.19	0.28	1.8	4.27	0.98
Patterson	190.0	10.1	43.3	0.76	0.19	1.8	3.60	1.00
Richie	191.4	216.2	2080.2	3.20	1.99	2.4	10.67	0.64
Sargent	212.0	143.4	1089.3	4.37	0.86	3.6	13.72	0.57
Scholts	204.0	2.3	469.3	0.52	0.08	2.1	1.52	0.89
Shesheeb	222.0	11.5	155.1	0.88	0.35	1.9	5.49	1.43
Siskiwit	201.0	1635.2	7287.1	11.06	2.30	2.2	46.00	1.01
Wagejo	228.9	6.1	58.2	0.49	0.22	1.4	2.19	0.79

Wittlesey	208.0	65.0	450.5	2.97	0.27	2.4	7.62	0.84
mean	204.3	104.8	649.5	1.93	0.49	2.1	7.10	1.13
sd	41.4	292.1	1311.0	2.01	0.57	0.5	7.69	0.70
min	1.2	1.3	18.1	0.19	0.08	1.2	1.52	0.18
max	260.3	1635.2	7287.1	11.06	2.30	3.6	46.00	3.08

Table 11. Water chemistry data from 32 Isle Royale inland lakes sampled once during the summers of 1995-1996 (from Kallemeyn 2000). Abbreviations as follows: chla = chlorophyll *a*: TP = total phosphorus; TN = total nitrogen; ANC = acid neutralizing capacity; cond = conductivity; TDS = total dissolved solids; DOC = dissolved organic carbon.

Lake	Chl a µg l^{-1}	TP µg l^{-1}	TN mg l^{-1}	NO3-N µg l^{-1}	NH4-N µg l^{-1}	Ca mg l^{-1}	Mg mg l^{-1}	Na mg l^{-1}	K mg l^{-1}	Al mg l^{-1}	SO4 mg l^{-1}	SiO2 mg l^{-1}	Cl mg l^{-1}	ANC µeq l^{-1}	Cond µmhos cm^{-1}	TDS mg l^{-1}	DOC mg l^{-1}	Color Pt-Co	pH	Secchi m
Ahmik	1.27	12	0.65	<5	27	10.4	4.38	1.92	0.32	14	2.01	4.8	0.21	943	91.5	48	13.5	53.0	7.69	2.7
Amygdaloid	0.67	10	0.35	<5	<10	8.2	3.45	1.53	0.34	15	2.52	3.1	0.37	645	64.5	34	9.7	29.3	7.65	3.5
Angleworm	1.27	7	0.20	12	6	5.8	2.13	1.32	0.51	11	3.11	4.0	0.23	414	50.7	24	6.2	14.6	7.45	5.0
Beaver	0.53	10	0.61	<5	11	8.4	4.08	2.16	0.29	14	3.22	8.0	0.26	908	93.9	45	12.2	60.0	7.66	2.0
Benson	5.46	18	0.44	8	<10	7.7	2.80	1.30	0.47	13	2.19	2.3	0.27	576	57.4	30	9.8	29.9	7.55	2.0
Chickenbone	2.00	13	0.54	16	13	9.6	3.66	2.08	0.39	10	2.94	8.5	0.57	817	79.3	42	9.9	48.6	7.82	2.4
Desor	3.80	7	0.61	13	19	11.7	3.47	1.83	0.72	10	2.55	1.6	0.87	928	88.1	47	7.3	12.7	7.87	3.5
Dustin	1.34	11	0.40	<5	7	8.7	2.09	1.17	0.24	21	2.99	2.0	0.20	560	56.8	30	7.5	36.4	7.69	2.5
Epidote	0.47	5	0.47	<5	11	11.6	2.29	0.86	0.11	71	1.48	4.4	0.14	676	68.3	36	15.3	116.3	7.37	2.5
Eva	7.68	14	0.64	12	15	10.1	4.23	2.71	0.28	17	2.10	8.6	1.43	893	91.1	48	14.7	101.8	7.78	2.1
Feldtman	0.27	13	0.49	<5	9	8.4	1.85	1.08	0.20	26	3.18	1.5	0.35	473	58.4	28	12.4	86.4	7.36	2.3
Forbes	2.27	11	0.30	ND	<10	9.4	2.69	1.43	0.46	18	1.44	3.9	0.25	646	66.5	35	8.6	36.7	7.63	2.9
George	1.00	9	0.41	<5	<10	17.5	1.56	0.96	0.15	65	2.29	3.0	0.29	1038	91.6	48	10.3	32.7	7.89	2.7
Halloran	1.07	10	0.46	19	11	7.5	0.92	0.99	0.39	22	1.76	0.9	0.75	446	50.7	24	9.8	51.9	7.43	2.7
Harvey	2.32	10	0.40	11	<10	9.6	3.82	1.87	0.81	23	2.72	1.7	0.26	778	66.0	34	8.9	29.5	8.91	3.8
Hatchet	3.62	7	0.41	<5	<10	9.9	3.44	1.75	0.54	10	2.29	10.7	0.31	764	75.5	39	11.7	58.4	7.69	2.5
Intermediate	3.35	14	0.47	<5	<10	8.2	2.32	1.08	0.76	16	2.95	2.3	0.27	510	55.3	28	10.1	46.5	7.40	3.1
John	0.67	6	0.43	<5	10	13.2	2.16	0.95	0.17	37	1.81	6.3	0.17	1062	99.5	52	13.9	87.4	7.77	3.0
LeSage	3.19	10	0.34	<5	<10	8.9	2.80	1.39	0.53	11	2.84	4.5	0.21	606	61.7	32	9.6	42.9	7.57	2.6
Linklater	6.24	11	0.38	11	<10	10.5	4.72	2.05	0.40	8	2.68	8.2	0.61	919	99.5	47	10.1	62.1	7.50	2.0
Livermore	1.48	10	0.32	5	<10	10.6	3.46	2.09	0.42	9	3.00	8.8	0.29	798	79.9	42	7.8	25.9	7.75	2.6
Mason	4.67	8	0.41	9	<10	10.4	2.27	1.24	0.54	31	3.18	5.7	1.30	522	58.6	31	15.2	94.1	7.51	2.6
McDonald	0.87	12	0.52	<5	11	8.4	4.26	2.24	0.25	14	3.33	6.7	0.29	875	88.7	41	12.1	69.4	7.68	2.1
Otter	0.93	10	0.35	11	12	8.0	3.21	1.74	0.26	11	2.83	6.3	0.25	648	69.8	33	8.3	28.0	7.60	2.3
Patterson	2.90	12	0.51	ND	<10	14.0	5.27	2.05	0.68	6	1.19	9.8	0.23	961	93.1	49	15.1	107.2	7.58	1.7
Richie	2.86	10	0.45	<5	<10	9.8	2.90	1.49	ND	36	3.24	6.4	1.03	646	68.2	36	9.6	53.9	7.53	2.8
Sargent	0.07	12	0.40	<5	<10	5.8	2.32	1.21	0.34	5	3.26	7.9	0.56	788	84.5	38	8.7	41.0	7.66	4.5
Scholts	0.00	8	0.52	12	<10	11.1	1.98	1.05	0.28	39	2.69	ND	0.21	680	68.2	36	12.5	74.7	7.66	2.5
Shesheeb	5.68	11	0.36	ND	<10	10.4	4.34	1.84	0.42	6	1.74	6.2	0.42	896	96.7	45	9.9	69.4	7.48	1.5
Siskiwit	1.07	14	0.27	27	14	8.6	2.24	1.16	0.36	5	4.49	2.7	0.37	598	65.0	34	5.0	9.7	7.90	9.0

Wagejo	7.09	17	0.35	11	<10	9.1	3.00	1.95	0.40	17	3.34	5.9	0.41	605	68.4	32	10.0	73.0	7.32	1.3
Whittlesey	2.51	7	0.25	21	<10	8.6	1.98	1.18	0.41	13	2.66	2.9	0.24	540	54.1	28	8.3	30.9	7.79	3.4
mean	2.46	11	0.43	13	13	9.7	3.00	1.55	0.40	20	2.63	5.1	0.43	724	73.8	37	10.4	53.6	7.66	2.9
sd	2.12	3	0.11	6	5	2.3	1.03	0.47	0.18	16	0.70	2.8	0.32	181	15.6	8	2.7	28.2	0.28	1.4
min	0.00	5	0.20	<5	6	5.8	0.92	0.86	0.11	5	1.19	0.9	0.14	414	50.7	24	5.0	9.7	7.32	1.3
max	7.68	18	0.65	27	27	17.5	5.27	2.71	0.81	71	4.49	10.7	1.43	1062	99.5	52	15.3	116.3	8.91	9.0

Table 12. Water chemistry results from a subset of Isle Royale lakes sampled in 1981-82 (Stottlemyer *et al.* 1998). Abbreviations as follows: Temp = temperature; Cond = conductivity.

Station	pH	Temp C	Cond µmhos cm^{-1}	HCO_3^- µeq l^{-1}	Ca^{2+} µeq l^{-1}	Mg^{2+} µeq l^{-1}	Na^+ µeq l^{-1}	K^+ µeq l^{-1}	NH_4^+ µeq l^{-1}	NO_3^- µeq l^{-1}	SO_4^{2-} µeq l^{-1}	Cl^- µeq l^{-1}
Amygdaloid	7.0		81	620	343	371	34	15	0	<0.5	104	25
Forbes	7.2	13	74	360	287	190	60	4	0	<0.5	91	7
Newt	6.6	7	97	500	547	245	37	4	3	<0.5	67	5
John	7.6		97	460	342	80	34	2	0	1.0	124	4
Epidote	7.1	15	73	280	397	162	29	3	0	<0.5	90	0
Theresa	7.5	5	32	120	180	109	20	3	3	1.0	54	7
Angleworm	7.3	15	63	240	202	148	54	4	0	<0.5	128	6
Chckenbone	6.3	9	69	580	377	289	61	5	0	7.0	98	12
Livermore	7.7		57	980	328	435	93	6	0	<0.5	88	7
Richie	7.5	15	77	340	314	214	63	6	0	<0.5	117	18
Scholtz	6.7	14	58	260	238	149	33	7	0	5.0	103	5
George	7.0	13	94	520	506	122	20	1	0	11.0	77	8
Dustin	6.8	13	59	280	256	145	30	14	0	8.0	96	6
Whittlesey	7.8	16	67	300	277	159	41	10	0	0.5	96	7
Intermediate	7.3	15	60	220	224	171	44	6	0	<0.5	132	14
Hatchet	7.2		78	700	282	411	91	6	0	<0.5	91	43
Desor	7.9		88	860	370	452	80	13	0	<0.5	90	9
Halloran	6.6		185		1614	223	140	12	14	3.0	97	121
Mean	7.2	13	78	448	394	226	54	7	1	--	97	17
Standard Deviation	0.5	4	31	238	319	117	31	4	3	--	20	28
Minimum	6.3	5	32	120	180	80	20	1	0	<0.05	54	0
Maximum	7.9	16	185	980	1614	452	140	15	14	11.0	132	121

Toczydlowski *et al.* (1978) and Kallemeyn (2000) both noted that thermal stratification was common but not universal among Isle Royale lakes. In the Toczydlowski *et al.* study, one of six lakes was unstratified at the time of sampling; in Kallemeyn's survey 11 of 32 lakes were unstratified. Unstratified lakes tended to be shallow and susceptible to wind-related mixing, and stratified lakes tended to exhibit hypolimnetic oxygen depletion (<4 $mg \cdot l^{-1}$). Whitman *et al.* (2000) observed that Siskiwit and Sargent Lakes were stratified throughout the summer months and that dissolved oxygen saturation in the hypolimnion was often well below 40 percent.

In Kallemeyn's study, conductivity ranged from 50.7 to 99.5 $\mu mhos \cdot cm^{-1}$ (Table 11) and was highly correlated with total dissolved solids (TDS) concentrations. Both conductivity and TDS were positively correlated with alkalinity and showed values similar to those in nearby lakes in Ontario and northern Michigan. Similar to Kallemeyn's findings, conductivity in Stottlemeyer's study lakes averaged 78 $\mu mhos \cdot cm^{-1}$ and was quite variable (Table 12). Alkalinity in Kallemeyn's study lakes ranged from 20.8-53.5 $mg \cdot l^{-1}$, with two thirds of lakes classifiable as soft water types. Alkalinities in Sargent and Siskiwit lakes averaged 38.85 and 29.42 mg/l, respectively. Dissolved organic carbon (DOC) concentrations varied from 5.0 $mg \cdot l^{-1}$ in Siskiwit Lake to 15.2 $mg \cdot l^{-1}$ in Mason Lake.

Total phosphorus (TP) concentrations ranged widely (4-43 $\mu g \cdot l^{-1}$) among lakes in Toczydlowski's survey, but were somewhat lower and less variable (5-18 $\mu g \cdot l^{-1}$) during Kallemeyn's more extensive study. Whitman *et al.* (2000) reported TP values of 50 $\mu g \cdot l^{-1}$ and 30 $\mu g \cdot l^{-1}$ for Sargent and Siskiwit lakes, respectively. TP in all the studies reflected lakes with low to intermediate productivity. Nitrate-N concentrations ranged from below detection to 154 $\mu g \cdot l^{-1}$ in Stottlemeyer's study, and from below detection to 27 $\mu g \cdot l^{-1}$ in Kallemeyn's more recent study. Sargent and Siskiwit lakes had average nitrate-N concentrations of 50 $\mu g \cdot l^{-1}$ and 80 $\mu g \cdot l^{-1}$ (Whitman *et al.* 2000). Total nitrogen, measured in Kallemeyn's study only, ranged from 0.25 $mg \cdot l^{-1}$ to 0.65 $mg \cdot l^{-1}$. TN:TP ratios generally exceeded 15:1, suggesting phosphorus limitation of algal growth (Kallemeyn 2000).

Chlorophyll *a* levels appear to be relatively low in Isle Royale lakes, ranging from 0.5-7.5 $\mu g \cdot l^{-1}$ (Kallemeyn 2000, Whitman *et al.* 2000). Using the Trophic State Index (an indicator of lake trophic status or productivity which incorporates measurements of Secchi depth, chlorophyll *a*, and TP into a single value), Kallemeyn considered most Isle Royale lakes to be mesotrophic, with fewer lakes considered oligotrophic and few to no lakes considered eutrophic (Kallemeyn 2000). Both Sargent and Siskiwit lakes were classified as oligotrophic. Secchi depth in Kallemeyn's study lakes was correlated significantly with color, DOC, and to a lesser extent chlorophyll *a* (Kallemeyn 2000).

Sixteen of the 18 lakes and 10 of the 12 water quality parameters surveyed by Stottlemyer in 1980-81 (Stottlemyer *et al.* 1998) were resampled by Kallemeyn in 1995-97 (Kallemeyn 2000), allowing for more careful comparisons between the two time periods (Table 13). It appears there have been few discernable changes in water quality parameters over the past two decades. Sulfate concentrations, however, were substantially lower in the more recent survey, perhaps the consequence of air quality regulations implemented in the 1970s. Sulfate concentrations declined in each of the sixteen lakes, from an average of 4.87 mg l^{-1} across lakes in the early 1980s to an average of 2.48 mg l^{-1} in the mid-1990s (Figure 18).

Table 13. Comparison of water chemistry data from 16 Isle Royale inland lakes sampled in a 1980-81 survey (from Stottlemyer *et al.* 1998) and a 1995-96 survey (Kallemeyn 2000). Summary statistics not calculated for NH_4-N or NO_3-N due to the high proportion of nondetect (ND) values.

Lake	pH		Conductivity µmhos cm^{-1}		Ca mg l^{-1}		Mg mg l^{-1}		Na mg l^{-1}		K mg l^{-1}		NH_4-N µg l^{-1}		NO_3-N µg l^{-1}		SO_4 mg l^{-1}		Cl mg l^{-1}	
	1980-81	1995-96	1980-81	1995-96	1980-81	1995-96	1980-81	1995-96	1980-81	1995-96	1980-81	1995-96	1980-81	1995-96	1980-81	1995-96	1980-81	1995-96	1980-81	1995-96
Amygdaloid	7.0	7.7	81	65	6.9	8.2	4.51	3.45	0.78	1.53	0.59	0.34	ND	<10	ND	<5	5.00	2.52	0.89	0.37
Angleworm	7.3	7.5	63	51	4.0	5.8	1.80	2.13	1.24	1.32	0.16	0.51	ND	6	ND	12	6.15	3.11	0.21	0.23
Chickenbone	6.3	7.8	69	79	7.6	9.6	3.51	3.66	1.40	2.08	0.20	0.39	ND	13	98	16	4.71	2.94	0.43	0.57
Desor	7.9	7.9	88	88	7.4	11.7	5.49	3.47	1.84	1.83	0.51	0.72	ND	19	ND	13	4.32	2.55	0.32	0.87
Dustin	6.8	7.7	59	57	5.1	8.7	1.76	2.09	0.69	1.17	0.55	0.24	ND	7	112	<5	4.61	2.99	0.21	0.2
Epidote	7.1	7.4	73	68	8.0	11.6	1.97	2.29	0.67	0.86	0.12	0.11	ND	11	ND	<5	4.32	1.48	0.00	0.14
Forbes	7.2	7.6	74	67	5.8	9.4	2.31	2.69	1.38	1.43	0.16	0.46	ND	<10	ND	ND	4.37	1.44	0.25	0.25
George	7.0	7.9	94	92	10.1	17.5	1.48	1.56	0.46	0.96	0.04	0.15	ND	<10	154	<5	3.70	2.29	0.28	0.29
Halloran	6.6	7.4	185	51	32.3	7.5	2.71	0.92	3.22	0.99	0.47	0.39	196	11	42	19	4.66	1.76	4.29	0.75
Hatchet	7.2	7.7	78	76	5.7	9.9	5.00	3.44	2.09	1.75	0.23	0.54	ND	<10	ND	<5	4.37	2.29	1.52	0.31
Intermediate	7.3	7.4	60	55	4.5	8.2	2.08	2.32	1.01	1.08	0.23	0.76	ND	<10	ND	<5	6.34	2.95	0.50	0.27
John	7.6	7.8	97	100	6.9	13.2	0.97	2.16	0.78	0.95	0.08	0.17	ND	10	14	<5	5.96	1.81	0.14	0.17
Livermore	7.7	7.8	57	80	6.6	10.6	5.29	3.46	2.14	2.09	0.23	0.42	ND	<10	ND	5	4.23	3.00	0.25	0.29
Richie	7.5	7.5	77	68	6.3	9.8	2.60	2.9	1.45	1.49	0.23	ND	ND	<10	ND	<5	5.62	3.24	0.64	1.03
Scholts	6.7	7.7	58	68	4.8	11.1	1.81	1.98	0.76	1.05	0.27	0.28	ND	<10	70	12	4.95	2.69	0.18	0.21
Whittlesey	7.8	7.8	67	54	5.6	8.6	1.93	1.98	0.94	1.18	0.39	0.41	ND	<10	7	21	4.61	2.66	0.25	0.24
mean	7.2	7.6	80	70	8.0	10.1	2.83	2.53	1.30	1.36	0.28	0.39					4.87	2.48	0.65	0.39
sd	0.4	0.2	31	15	6.7	2.7	1.46	0.80	0.72	0.40	0.17	0.19					0.76	0.59	1.04	0.27
min	6.3	7.4	57	51	4.0	5.8	0.97	0.92	0.46	0.86	0.04	0.11					3.70	1.44	0.00	0.14
max	7.9	7.9	185	100	32.3	17.5	5.49	3.66	3.22	2.09	0.59	0.76					6.34	3.24	4.29	1.03

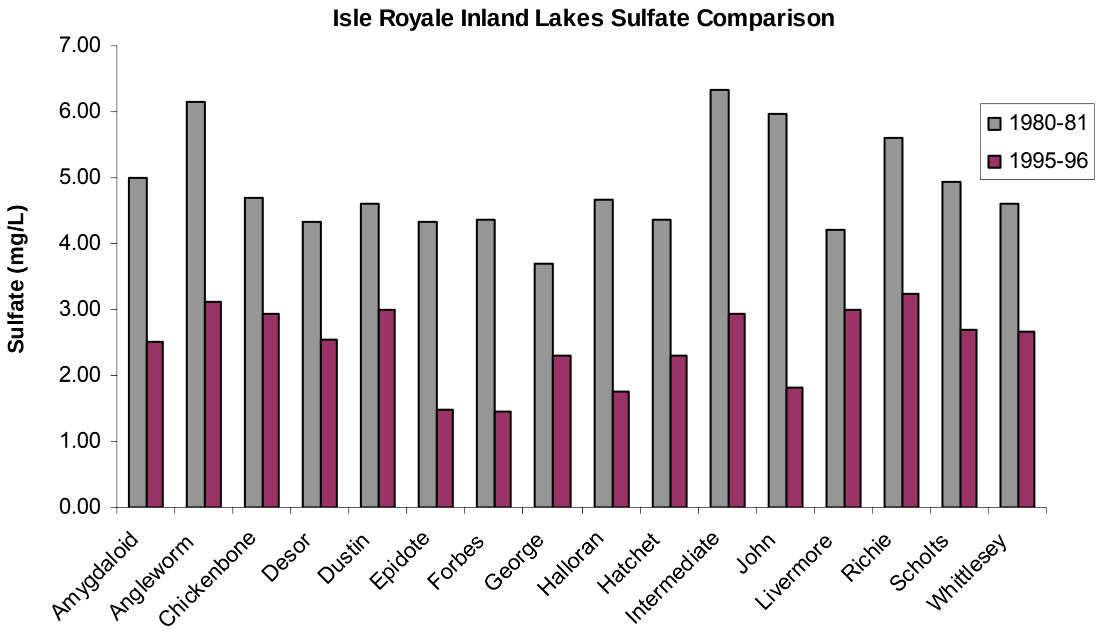


Figure 18. Comparison of sulfate concentrations in 1980-81 vs. 1995-96 for 16 Isle Royale lakes sampled during each time period. Declines in sulfate concentrations were observed for every study lake over this period. Data were derived from Stottlemyer *et al.* (1998) and Kallemeyn (2000).

4. Inland Lake Fish

Concurrent to the development of this Water Resources Management Plan for Isle Royale, a Fisheries Management Plan will be published in 2006. This plan involves participation and input from several agencies and entities familiar with the fish and fisheries of Isle Royale. It will focus primarily on and provide management guidance for lakes and streams of the island but will also address research and management of Lake Superior waters of the park. This Fishery Management Plan will cover specific fish and fisheries information in much greater detail.

The first comprehensive fish surveys of the inland lakes were conducted in 1929 as part of a University of Michigan scientific survey (Koelz 1929). Koelz surveyed 38 lakes on the island but not the Lake Superior waters around the island. Although this work was not published it was referred to as an important investigation in later survey reports by Hubbs and Lagler (1949) and Kallemeyn (2000).

Koelz's report included descriptive text of each of the surveyed lakes along with current conditions of inlet and outlet tributaries for several of the lakes. General geomorphology, bathymetry, and aquatic and terrestrial plant life were described. Depth and temperature information were taken at each lake. A total of over 3600 depth soundings were taken; the number at each lake dependent on degree of regularity of contour lines. Temperatures were taken at various depths, locations and time of day, but there appears to have been no consistency in time of day for temperature readings between lakes.

Koelz provided some incidental information on aquatic insects from fish stomach investigations and other observations, as well as descriptions of mussels or "clams" in the lakes. Descriptions of beaver activity and the effect on various lakes are also included. In describing terrestrial plant life, he occasionally refers to fires and certain tree species that escaped recent conflagrations. Koelz occasionally refers to vegetation consumption by moose; he states that "eradication by the moose of the higher aquatic plants has undoubtedly had serious consequences for the fish" and suggests that fish productivity is likely reduced in some lakes due to a decrease in food and shelter.

The most recent survey of the inland lakes was conducted from 1995-1997 by the US Geological Survey, Biological Resources Division (Kallemeyn 2000). Kallemeyn surveyed 32 of 43 named lakes at the island. This report provides a much more detailed account of physical/chemical characteristics, including lake trophic levels and biological characteristics such as mercury and selenium levels (which were not yet a known concern when Koelz conducted surveys) and age/growth analysis of fish. He also provided descriptions and references on theories of the origin of various species at Isle Royale.

Additional analysis of Kallemeyn's (2000) data by the National Park Service Midwest Regional Aquatic Ecologist resulted in four major lake types based on habitat parameters (Carlisle 2000). These four types include: 1) small shallow lakes with high dissolved organic carbon (DOC); 2) large, deep lakes with low DOC; 3) lakes with hard water and high algal biomass; and 4) soft water lakes high in total phosphorus (Figure 19). Three of the four lake types featured unique fish assemblages (Figure 20). Small, shallow lakes with low DOC tended to have assemblages dominated by the finescale dace. Fish assemblages in large, deep lakes with low DOC tended to include lake trout *(Salvelinus namaycush)*, emerald shiner *(Notropis antherinoides)*, burbot *(Lota lota)*, lake whitefish *(Coregonus clupeaformis)*, ninespine stickleback *(Pungitius pungitius occidentalis)* and spoonhead sculpin *(Cottus ricei)*. Finally, brook stickleback *(Cualea inconstans)*, northern redbelly dace *(Phoxinus eos)*, pearl dace *(Margariscus margarita)*, lake chub *(Couesius plumbeus)*, creek chub *(Semolitus atromaculatus)* and fathead minnow *(Pimephales promelas)* were generally found in the hard water, high algal biomass lakes.

5. Lake Benthic Invertebrates

Toczydlowski *et al.* (1978) sampled benthic invertebrates in both lakes and streams of Isle Royale (most sampling was conducted in stream habitats). The survey generated a list of invertebrate genera and a categorical measure of their relative abundance. Little analysis was provided; the author noted that certain taxonomic groups tended to be more common in lentic habitats (Odonata) or lotic habitats (Diptera, Trichoptera), and acknowledged that other apparent patterns may relate more to temporal variability than actual ecological phenomena.

Triplicate Eckman grab samples were used to collect benthic invertebrates from the limnetic and littoral zones of Sargent and Siskiwit Lakes during the Whitman *et al.* (2000) survey. In Sargent Lake, *Chironomus* and *Chaoborus* dominated the limnetic benthos community and the littoral zone was a taxa-rich assemblage including chironomids, *Sialis* spp., sphaeriid clams, snails, and several genera of Trichoptera and Ephemeroptera. Limnetic zone benthos in Siskiwit Lake was dominated by sphaeriid clams and the deepwater amphipod *Diporeia*. Insect taxa (particularly chironomids) dominated the littoral zone.

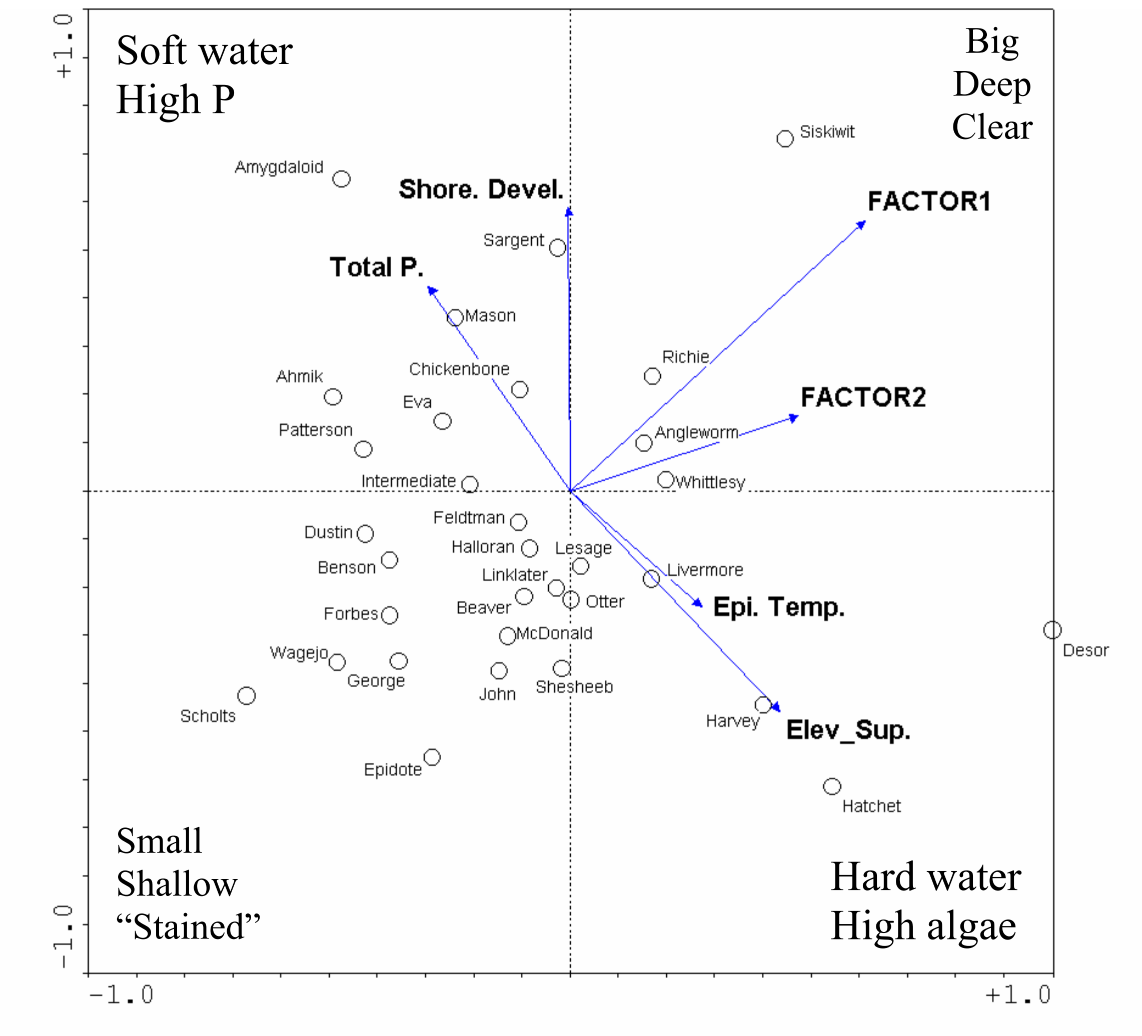


Figure 19. Canonical correspondence analysis (CCA) bi-plot of ISRO lakes, 1995-97 data (Carlisle 2000). In general, the similarity in species composition between any two sites decreases with their distance on the diagram. For example, the fish assemblage in Siskiwit was more similar to Richie than to the assemblage in Epidote. Additionally, sites that lie close to a species (Figure 20) are more likely to have that species present in its assemblage. For example, because Desor was the only lake where lake chub were found, the Desor and lake chub points are superimposed. The habitat variables most strongly associated with variation in fish assemblages are represented by 6 vectors, including shoreline development, total P, mean temperature of epilimnion, elevation above Lake Superior, and 2 multivariate "factors." Factors 1 and 2 were produced with a principle components analysis (PCA) on the habitat data to create composite variables for highly correlated variables. Factor 1 is a vector of increasing lake and watershed area, length, width, and thermocline depth, as well as decreasing DOC and color. Factor 2 is a vector of increasing cation concentrations, TDS, and ANC. The sites are positioned with respect to these habitat variables. For example, lakes in the upper right quadrant are the largest, deepest, clearest, and have the highest cation concentrations.

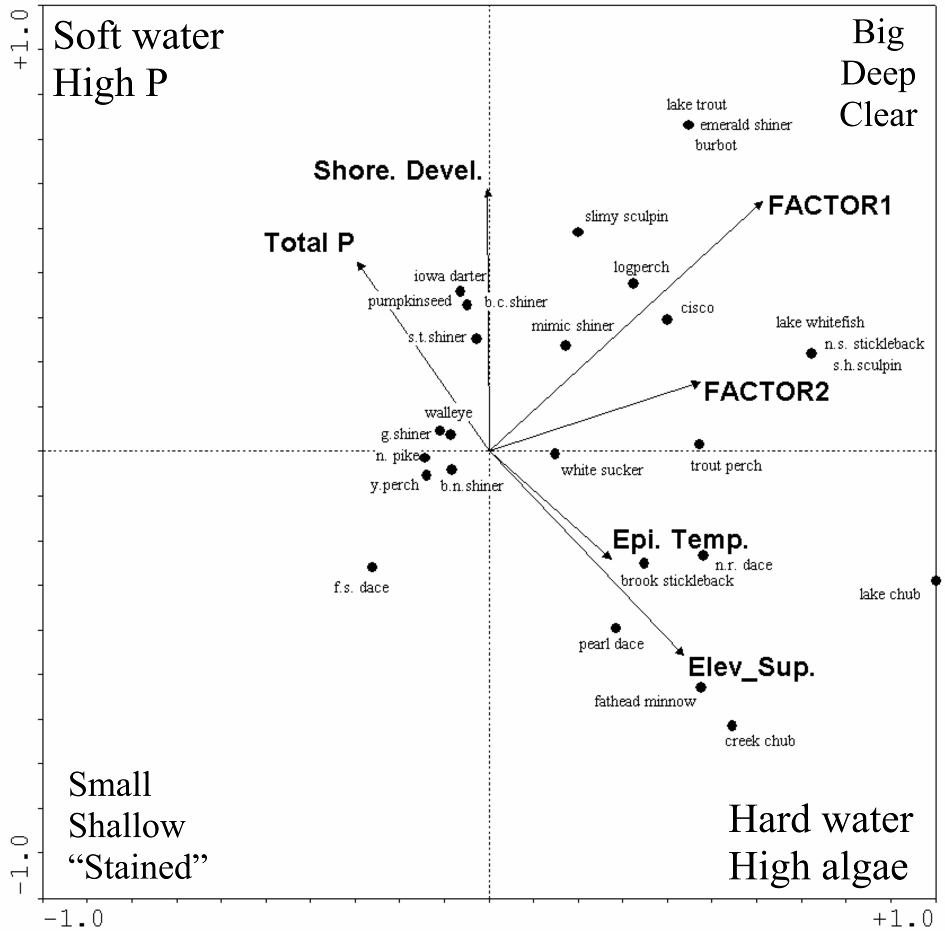


Figure 20. Canonical correspondence analysis (CCA) bi-plot of fish species and habitat variables from ISRO, 1995-97. The location of species points on the diagram are controlled by where each species was most likely to occur across the sites depicted in Figure 19. Species preferences relative to these habitat variables can also be inferred from this plot. For example, lake trout, burbot, and emerald shiners preferred large, deep, and clear lakes (Siskiwit). Species whose points are near the center of the diagram are either the most ubiquitous or are not represented well by the underlying uni-modal model. In these data, perch, pike, and blacknose shiner were certainly ubiquitous.

Adam's turn of the century survey (Adams 1909) documented mussels (specifically *Pyganodon marginata* – now *P. cataracta*) in Lake Desor. Koelz (1929) did not document any mussel species but made general references to their abundance, saying mussels were "rather scarce" in Lake Desor and "abundant" in Chickenbone. These observations were borne out decades later during a survey of mussels at Isle Royale (Nichols *et al.* 2001). Population structure, contaminant concentrations in tissues and overall status of Isle Royale's unionid mussel fauna was assessed in some inland lakes and McCargoe cove following an initial scout team survey. Unionid mussels were encountered at 11 of the 14 scout sites, and Sphaerids were found in seven (Table 14). No exotic mussels were encountered. Isle Royale streams lacked mussel populations, likely due to severe winter temperatures and lack of substrate suitable for burrowing. Mussels were also lacking in three Isle Royale lakes (Feldtmann, Hatchet and "Leech"); the reasons for their absence in these lakes are unclear but may be related to lake morphometry, chemistry, or possibly copper toxicity. Of the unionid mussels, two species of *Lampsilis* and three species of *Pyganodon* were identified. These taxa were distributed unevenly among lakes (Table 15). Unionids were found above the thermocline in deeper lakes, and were distributed in substrate-related patches in shallow lakes. *Lampsilis* spp. was more commonly found in rocky cobble areas, particularly Chickenbone and Siskiwit lakes.

In general, mussel populations appeared healthy and stable. Nichols reported high mussel densities (ranging from 2.80 per ft^2 [0.26 per m^2] in Lake Whittlesey to 92.4 per ft^2 [8.59 per m^2] in Chickenbone Lake). These densities, coupled with high lake-wide abundance estimates and multiple year classes, indicated steady recruitment and long-term adult survival. Mussel densities at Isle Royale were considerably higher than at other national parks in the area such as Pictured Rocks. No exotic mussel taxa were encountered and organic and metal contaminants were below consensus deleterious levels for all specimens measured. Nichols noted that despite low contaminant levels in individual mussels, the mass of contaminants bound in mussels on a lake-wide scale is substantial. Changes in mussel abundance or population structure will alter current patterns of contaminant transfer in these lakes.

Abundant assemblages of tall freshwater sponges were noted in several Isle Royale lakes during the recent mussel survey (Nichols *et al.* 2001). Previous information on sponge distribution at Isle Royale is limited to a report by Old (1932), which noted two species in Chickenbone Lake. A proposed survey of Isle Royale sponges would investigate their diversity, density, distribution and relationships to water chemistry and other habitat related variables.

6. Zooplankton

Larson *et al.* (2000) sampled 36 lakes for zooplankton, concurrent with the Kallemeyn (2000) fish survey. Despite substantial variation among lakes in terms of morphometry, chemistry, fish communities, and food web characteristics, zooplankton assemblages were fairly similar among lakes according to detrended correspondence analysis. Rotifers were dominant in terms of density and species richness among lakes. *Keratella cochlearis* and *Conochilus unicornis* were particularly abundant. *Bosmina longirostris* was the dominant crustacean in Isle Royale lakes and is a prominent species in many Ontario lakes. Exotic zooplankton species such as *Bythotrephes* and *Cercopagis* were not encountered in any of the Isle Royale lakes, but *Bythotrephes* is present in the park's Lake Superior waters and high densities were noted along the shores of some ISRO bays in 2005. Isle Royale inland lake zooplankton composition was distinct from that of Lake Superior, particularly in terms of dominant crustaceans, but similar to that of inland lakes in

Table 14. Bivalve distribution in selected lakes of Isle Royale National Park, 1999-2000 (Nichols *et al.* 2001). Presence at a site is denoted "x"; absence is denoted "--".

Lake	Unionids	Sphaerids[1]	Sponges[2]	Exotics[3]
Chickenbone	x	x	x	--
Desor[4]	x	--	--	--
Feldtmann[4]	--	--	--	--
Hatchet	--	--	--	--
Intermediate	x	x	x	--
"Leech"	--	--	--	--
Livermore	x	x	x	--
LeSage	x	x	x	--
McCargoe Cove	x	x	--	--
Richie	x	x	--	--
Sargent[5]	x	undetermined	undetermined	undetermined
Siskiwit[4]	x	x	--	--
Whittlesey	x	--	--	--
Wood	x	undetermined	undetermined	undetermined

[1] Sphaerid (fingernail) clam presence or absence is provided as a reference only – no further identifications were made.
[2] Refers to large sponge colonies.
[3] Exotic bivalves, in particular zebra mussels (*Dreissena polymorpha*), quagga mussels (*Dreissena bugensis*) or Asian clams (*Corbicula fluminea*).
[4] Sampled in July 2001 under a separate grant from NRPP.
[5] Visual sampling for unionid presence or absence only.

Table 15. The distribution of unionid mussel species in selected lakes of Isle Royale National Park, 2000-2001 (Nichols *et al.* 2001). Presence is denoted "x"; absence is denoted "--".

Lake	*Lampsilis luteola*	*Lampsilis radiata*	*Pyganodon cataracta*	*Pyganodon grandis*	*Pyganodon intergrades*
Chickenbone	x	x	x	x	x
Desor	--	--	x	--	--
Feldtmann	--	--	--	--	--
Hatchet	--	--	--	--	--
Intermediate	x	x	x	x	x
"Leech"	--	--	--	--	--
Livermore	--	--	x	--	--
LeSage	--	--	x	--	--
McCargoe Cove	x	x	x	x	x
Richie	--	x	x	x	x
Siskiwit	x	x	x	x	x
Whittlesey	--	--	x	x	x

Ontario and northern Michigan. Larson recommended long-term monitoring to better understand interannual variation in zooplankton assemblages and zooplankton distribution across Isle Royale lakes. He also suggested that selection of potential monitoring lakes may be based on a cluster analysis using lake chemical and morphometric parameters. Lakes could be statistically grouped according to these parameters in a multivariate analysis, and a representative subset from each group could be chosen for future monitoring.

Whitman *et al.* (2000) corroborated the above survey results with more detailed information from Sargent and Siskiwit lakes, including a characterization of zooplankton seasonal patterns and sampling efforts in both limnetic and littoral zooplankton zones. Zooplankton densities exhibited a bimodal distribution in Sargent Lake, with peaks in early and late summer; in Siskiwit Lake, patterns of zooplankton density were less distinct and inconsistent between years. Limnetic zooplankton assemblages in Sargent Lake were dominated by rotifers, particularly *Keratella* spp. and *Conochilus unicornis*, with the cladocerans *Bosmina longirostris* and *Holopedium gibberum* also common. Sargent Lake exhibited high taxonomic richness relative to other inland lakes in the survey, and had limnetic zooplankton densities ranging from approximately 50-60 individuals per liter. Siskiwit Lake limnetic zooplankton community differed taxonomically from other inland lakes and was far less dense, ranging from approximately 8-30 individuals per liter. There was no evidence of rotifer dominance. In general, the Siskiwit zooplankton community was characteristic of cold dilute lakes of the region; low densities were attributed to the lake's low primary productivity.

Unsurprisingly, taxonomic composition differed between littoral and limnetic zones in both Sargent and Siskiwit lakes (Whitman *et al.* 2000). In Sargent Lake, *Tropocyclops prasinus mexicanus* (Copepoda) and *Kellicottia longispina* (Rotifera) were more common in the littoral samples, and *C. unicornis* was less common. In Siskiwit Lake, common littoral taxa included *Diacyclops thomasi*, *Skistodiaptomus oregonensis*, *Bosmina longirostris*, *Keratella* spp., and *Kellicottia longispina*.

7. Phytoplankton

Taylor (1935) provided an early account of Isle Royale phytoplankton. Net phytoplankton samples were collected in July and August, 1930, from ten sites including nearshore and offshore waters of Lake Superior as well as Wallace and Sargent lakes. Taylor reported phytoplankton results by species, and noted their relative abundance and distribution. In general, Taylor concluded that the Lake Superior phytoplankton flora was dominated by *Dinobryon,* along with diatom taxa and *Boytrococcus,* consistent with other reports of the time. Phytoplankton of nearshore waters and inland lakes consisted of *Anabaena lemmermannii* with *Ceratium, Asterionella,* and *Tabellaria* or of *Dinobryon* and *Westella* with *Ceratium* and a wider range of diatoms. Taylor noted low densities of desmids.

In the late 1930s and early 1940s, Prescott used the same set of phytoplankton samples to construct more detailed notes on Isle Royale's desmid flora. These were published in a series of papers (Prescott 1936, 1937, 1939, 1940). Several of the 221 recorded species and varieties were new records for the state of Michigan. Isle Royale desmids were similar to those found in New England and Newfoundland, and were not unlike those found in Wisconsin. Prescott, like Taylor, noted that the abundance of desmids on Isle Royale was lower than would be expected based on collections from the surrounding mainland areas. Sampling techniques did not target desmids and may be responsible for their poor representation in the phytoplankton samples.

No further phytoplankton work was conducted until the late 1970s, when six Isle Royale lakes and one harbor site were sampled during the Toczydlowski *et al.* baseline survey (Feldtman, Intermediate, Richie, Siskiwit, Whittlesey, Wood, and Chippewa Harbor) using both one-liter samples at depth intervals and vertical net tows (Toczydlowski *et al.* 1978). Relative abundance was assessed and taxonomic lists developed. About half of the organisms found in each lake were unidentified flagellates, which complicates interpretation of the composition data. Nonetheless, some differences in phytoplankton composition were noted among lakes, particularly with respect to the relative numbers of small (<5 μm) flagellates and the presence or absence of certain diatom or blue-green algal taxa. Feldtmann Lake appears to have had the most distinct phytoplankton composition of the sampled lakes, with few diatom representatives and abundant *Gloeocapsa* (a blue-green alga) and *Scenedesmus* (a green alga). High densities of *Oscillatoria* (a blue-green alga) were noted at increasing depths in Intermediate Lake. Across lakes, flagellates were associated with lower temperatures and light levels, and were most dominant at depths of 9-13 ft (3-4 m). Subjective estimates of phytoplankton numbers and biomass suggested that Richie and Intermediate lakes had the greatest concentration of phytoplankton cells, whereas Chippewa Harbor and Siskiwit Lake had the lowest. Feldtmann Lake had abundant suspended particulate matter. A taxa list and categorical indications of relative abundance are appended to this report.

Phytoplankton were also sampled during summer months from limnetic (1997-98) and littoral (1997) sites in Sargent and Siskiwit lakes (Whitman *et al.* 2000). In Sargent Lake, limnetic chlorophyll *a* concentrations and phytoplankton abundance at 1 m depth reached their highest levels in late May and September, with lower values reported in July and August. The highest reported chlorophyll levels for both years were low (7-7.5 $\mu g \cdot l^{-1}$) and dominant taxa included *Chlorochromonas* spp. and *Sphaerocystis schroeteri*. Siskiwit Lake exhibited a pattern of increasing limnetic chlorophyll *a* and abundance through late August in 1997; as in Sargent Lake, chlorophyll peaked at approximately 7.5 $\mu g \cdot l^{-1}$. Diatom taxa, particularly *Cyclotella* spp., dominated the Siskiwit Lake flora in both 1997 and 1998. Diatoms were the predominant organisms found in littoral samples of both lakes.

D. Wetlands, Riparian Areas and Aquatic Vegetation

1. Wetland and Riparian Ecology Background

Riparian areas and wetlands occur at the interface between land and water. Collectively these areas represent only a small proportion of the landscape of ISRO. However, their hydrologic and ecological importance is very significant (Naiman *et al.* 1993). Individually and collectively, these areas provide many critical functions including water supply, maintenance of water quality, flood attenuation, essential habitats for flora and fauna, and maintenance of biodiversity.

Wetlands cover about 5.6 million km^2 of the Earth's surface, an area roughly equivalent to four times the size of Alaska (Keddy 2000). The term "wetland" describes a wide variety of environments that share certain hydrologic, soil and vegetation characteristics. Definitions for the term have been developed for both regulatory and ecological purposes. Perhaps the most recent and neutral is that developed by the Committee on Wetlands Characterization (National Research Council 1995), which states, "A wetland is an ecosystem that depends on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate. The minimum essential characteristics of a wetland are recurrent, sustained inundation or saturation at or near the surface and the presence of physical, chemical, and biological features reflective of recurrent, sustained inundation or saturation. Common diagnostic features of wetlands are hydric soils and hydrophytic vegetation. These features will be present except where specific physicochemical, biotic, or anthropogenic factors have removed them or prevented their development."

A similar definition more commonly used by the NPS is that of the U.S. Fish and Wildlife Service, which states, "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water…wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin *et al.* 1979)".

Wetlands exhibit a range of functions that are increasingly linked to ecological and societal values (National Research Council 1995). For example, they facilitate groundwater recharge and discharge, slow or alter flood flows and stabilize sediments. They perform critical functions in terms of carbon, nitrogen, and contaminant cycling. Wetlands are biologically diverse places, home to abundant and often unique aquatic plants and animals. A large percentage of U.S. threatened and endangered species are associated with wetlands. Wetlands also provide breeding, migration, and wintering grounds for wildlife, and wetland-dependent shellfish, fish, waterfowl, furbearers, and timber provide valuable harvests and recreational opportunities.

Natural riparian areas are some of the most diverse, dynamic, and complex biophysical habitats in the terrestrial environment (Naiman *et al.* 1993). The riparian area encompasses the stream channel between low and high water marks, and that portion of the terrestrial landscape above the high water mark where vegetation may be influenced by elevated water tables or flooding and by the ability of the soils to hold water (Naiman and Decamps 1997). Thus, riparian areas are ecotones between the aquatic habitat of a river and the surrounding terrestrial habitats. The riparian zone may be small in headwater streams. In mid-sized streams the riparian zone is larger, being represented by a distinct band of vegetation whose width is determined by long-term (>50 years) channel dynamics and the annual discharge regime. Riparian zones of most large streams are characterized by well-developed but physically complex floodplains with long periods of seasonal flooding, lateral channel migration, oxbow lakes in old river channels, a diverse vegetative community, and moist soils (Malanson 1993). These attributes suggest that riparian zones are key systems for regulating aquatic-terrestrial linkages and that they may be early indicators of environmental change (Decamps 1993).

Physically, riparian zones control mass movements of materials and channel morphology (Naiman and Decamps 1997). Material supplied to streams comes from erosion of stream banks, a process influenced by root strength and resilience, as well as from the uplands. Stream banks largely devoid of riparian vegetation are often highly unstable and subject to mass wasting that can widen channels by several tens of feet annually. Major bank erosion is 30 times more prevalent on nonvegetated banks exposed to currents as on vegetated banks (Beeson and Doyle 1995).

In addition, riparian zones provide woody debris. Woody debris piles dissipate energy, trap moving materials, and create habitat (Naiman and Decamps 1997). Depending upon size, position in the channel and geometry, woody debris can resist and redirect water currents, causing a mosaic of erosional and depositional patches in the riparian corridor (Montgomery *et al.* 1995).

Riparian forests exert strong controls on the microclimate of streams (Naiman and Decamps 1997). Stream water temperatures are highly correlated with riparian soil temperatures, and strong microclimatic gradients appear in air, soil, and surface temperatures, and in relative humidity.

Ecologically, riparian zones: 1) provide sources of nourishment—allochthonous inputs to rivers and herbivory; 2) control nonpoint sources of pollution, in particular, sediment and nutrients in agricultural watersheds; and 3) create a complex of shifting habitats with different spatio-temporal scales, through variations in flood duration and frequency and concomitant changes in water table depth and plant succession (Naiman and Decamps 1997).

Wetland classification has been approached in many ways, and inconsistencies in terminology across disciplines and geographic regions are common. Nonetheless, most everyone recognizes at least four types of wetlands, including swamps, marshes, bogs and fens (Keddy 2000). Swamps are dominated by woody vegetation rooted in non-peat hydric soils, whereas marshes are dominated by herbaceous, generally emergent plants rooted in non-peat hydric soils. Bogs are dominated by *Sphagnum* moss, sedges, shrubs and evergreen trees rooted in deep peat. Fens are dominated by sedges and grasses rooted in shallow peat, often with considerable water movement through the peat. Two other types, wet meadow and shallow water wetlands, are sometimes included in basic wetland classifications (Keddy 2000). Wet meadows are characterized by herbaceous plants growing in occasionally flooded soils, whereas shallow water wetlands are dominated by truly aquatic plants growing in and covered by at least 25 cm of water, such as lake littoral zones.

Another commonly used classification scheme is that of the U.S. Fish and Wildlife Service (Cowardin 1979); it is the standard. This system is hierarchical and applies to both freshwater and marine systems. The three basic classes in this system are riverine (linear wetlands generally contained within a channel of flowing water), lacustrine (larger wetland and deepwater habitats <30 percent covered by persistent vegetation), and palustrine (smaller wetlands dominated by persistent vegetation). Subclasses are defined largely by their geology, hydrology, and vegetation.

The Great Lakes Inventory and Monitoring network recently developed a regional wetlands conceptual model (Elias and Carlisle 2003), which describes wetland ecosystems in the context of drivers, stressors, and measurable attributes (Figure 21). Primary anthropogenic and natural drivers and stressors include input of toxins, sediments, and nutrients, water level fluctuations, fire suppression, exotic species introductions, draining, dredging and filling, and road crossings, in addition to climatic, successional, and natural biological disturbances. In the contiguous United States, anthropogenic drivers predominate; approximately 53 percent of wetlands have been destroyed due to human activities in the last two centuries (Mitsch and Gosselink 2000), and the Great Lakes states have suffered similar losses. Combined, natural and anthropogenic stressors influence wetland processes as well as characteristics of individual organisms, populations and communities, and landscapes.

2. Isle Royale Wetlands and Riparian Areas

Based on National Wetland Inventory (NWI) Maps of the U.S. Fish and Wildlife Service contained in the park GIS database, ISRO contains the following wetlands (Figure 22):

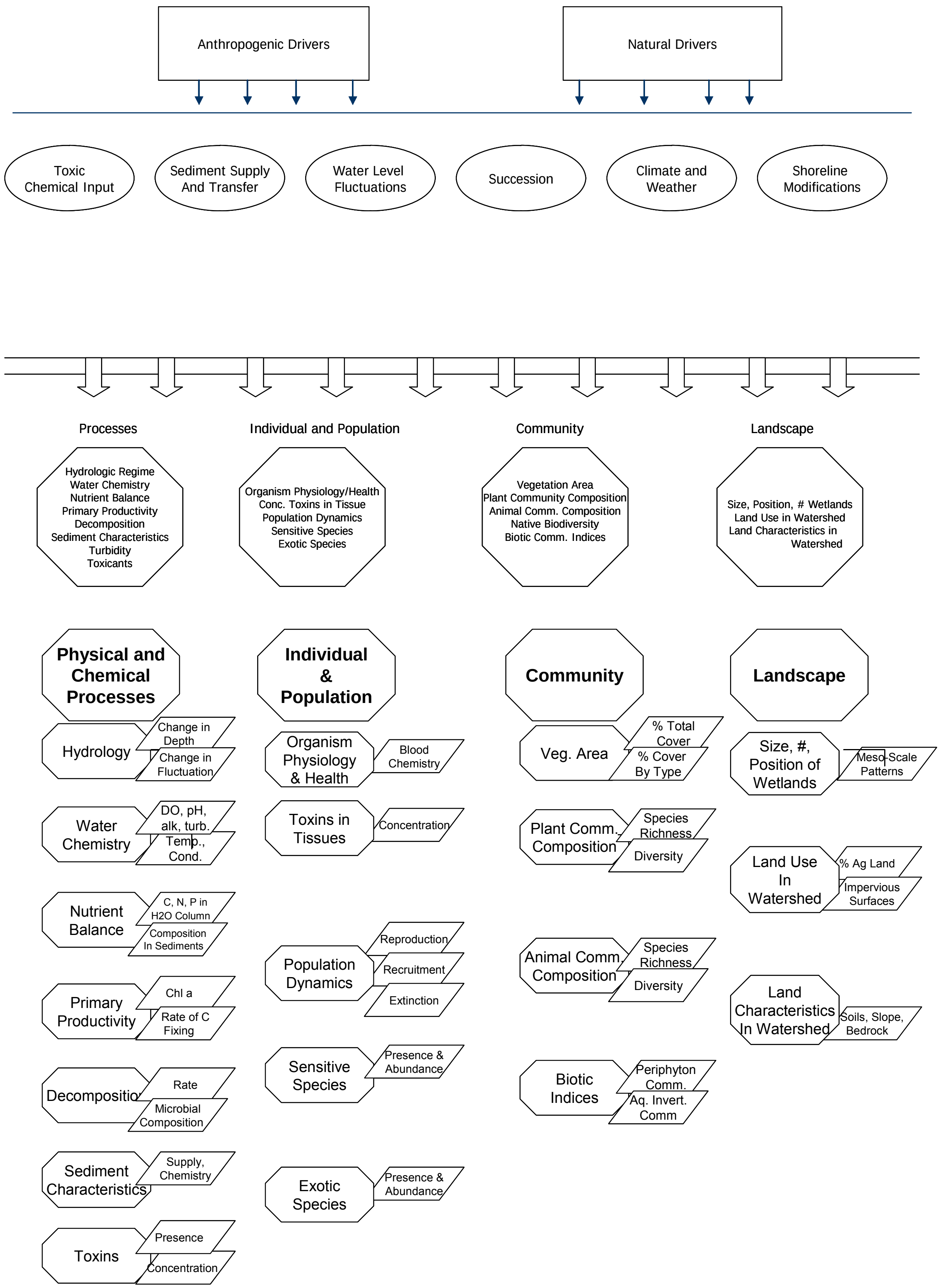
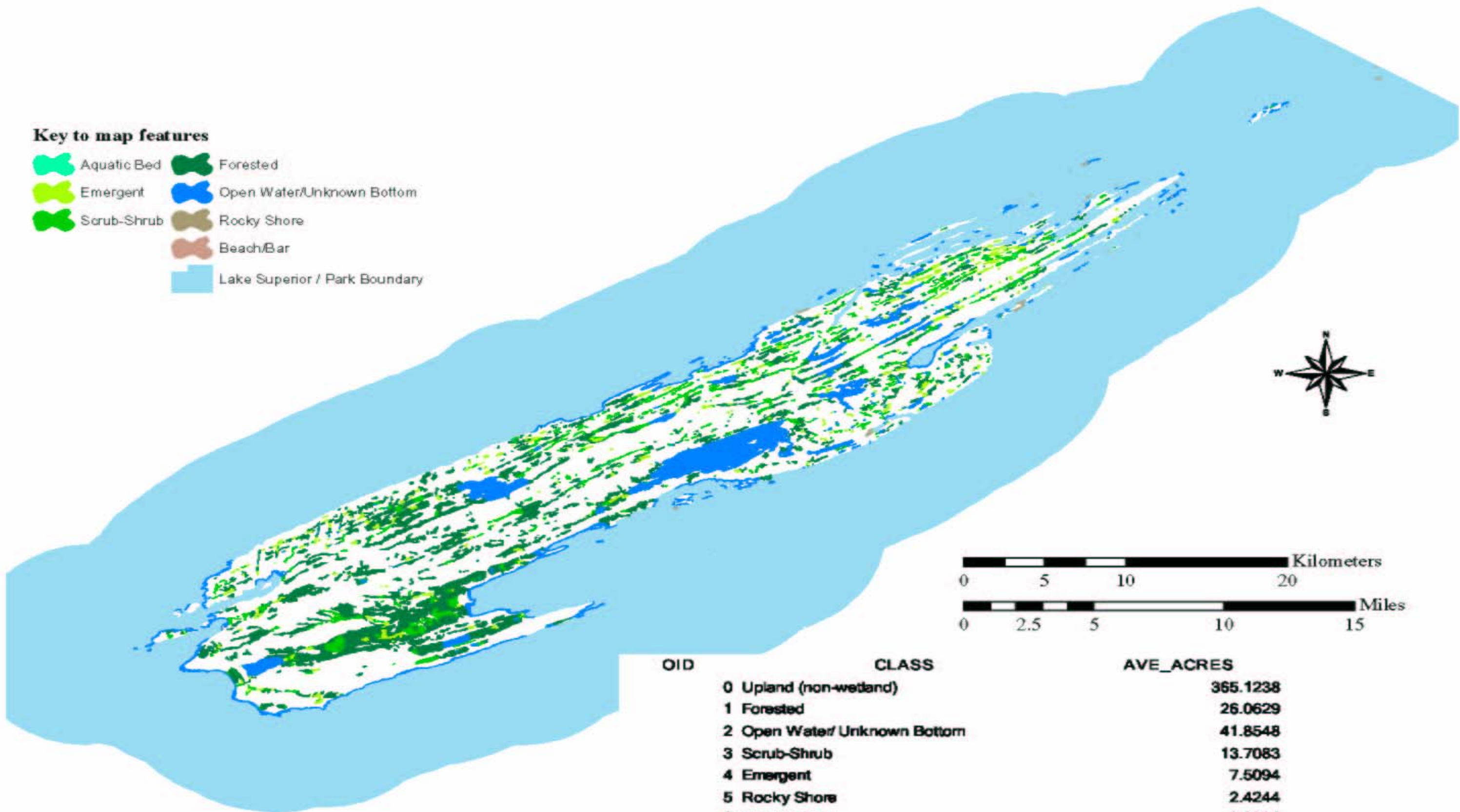


Figure 21. Wetlands conceptual model, showing ecosystem drivers, stressors, effects, attributes and measures (Elias and Carlisle 2003).



OID	CLASS	AVE_ACRES
0	Upland (non-wetland)	365.1238
1	Forested	26.0629
2	Open Water/ Unknown Bottom	41.8548
3	Scrub-Shrub	13.7083
4	Emergent	7.5094
5	Rocky Shore	2.4244
6	Aquatic Bed	3.0981
7	Beech/ Bar	2.7235

Figure 22. Wetland categories for Isle Royale from the National Wetlands Inventory of the U.S. Fish and Wildlife Service.

System	*Number*	*Acreage*
Lacustrine	**183**	**11,277**
Aquatic Bed	1	3
Open Water	146	11,188
Rocky Shore	35	84
Beach/Bar	1	3
Palustrine	**1456**	**25,094**
Forested	445	9,674
Scrub-Shrub	368	4,848
Emergent	270	2,028
Aquatic Bed	4	13
Riverine	**0**	**0**
Unknown	**15**	**424**

Subcomponents under Lacustrine and Palustrine do not sum to equal the bolded numbers; additional subcomponents are not shown. Figure 22 shows the average acreage for each wetland type based on a broader wetland classification system.

Palustrine wetlands include all nontidal wetlands dominated by trees, shrubs, persistent emergent vegetation and emergent mosses or lichens. This broad classification was developed to group the vegetated wetlands traditionally called by such names as marsh, swamp, bog, fen, and prairie. It also includes small, shallow, permanent or intermittent water bodies often called ponds. Palustrine wetlands may be situated shoreward of river channels; on river floodplains; in isolated catchments; or on slopes.

There are primarily three broad classes of Palustrine wetlands in the park: forested; scrub-shrub; and emergent. Forested wetlands are characterized by tall (> 20 feet), woody vegetation. Normally, they contain an overstory of trees, an understory of young trees or shrubs, and an herbaceous layer. Scrub-shrub wetlands include areas dominated by woody vegetation (< 20 feet), including young trees, tree shrubs, and trees and shrubs that are small or stunted because of environmental conditions. Scrub-shrub wetlands are often a successional stage leading to forested wetlands. Emergent wetlands are characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. The hydrophytic vegetation is usually perennial.

The Lacustrine system includes wetlands and deepwater habitats with all of the following: 1) situated in a topographical depression or a dammed river channel; 2) lacking trees, shrubs, persistent emergents with greater than 30 percent aerial coverage; and 3) total acres exceed 20 acres. Similar wetlands and deepwater habitats totaling less than 20 acres are also included if an active wave-formed or bedrock shoreline feature makes up all or part of a boundary or if water depth in the deepest part is greater than 6.6 feet at low water. Lacustrine wetlands in ISRO are primarily the open waters of either the littoral or limnetic zones of inland lakes and along Lake Superior.

NWI maps are useful for a general understanding of the potential aerial extent and types of wetlands that are present. These maps are based on high-altitude photography with minimal ground-truthing (typically not more than one wetland visited per quadrangle), they tend to omit smaller (< 1 acre) wetlands and wetlands with forest cover, and the scale is not adequate to detect subtle changes that may be occurring with respect to habitat boundaries or species composition changes, or delineate small wetland types, such as seeps or springs. The age of the photos could also mean that subsequent fire, drainage, beaver activity, plant growth and succession (including invasion by exotic or nuisance species) or other factors further limit the accuracy of these maps.

An additional problem with the existing NWI maps is the lack of information on plant species associations, substrates (e.g., organic vs. mineral soil), and other factors. For example, two wetlands may be classified identically on the maps as "palustrine emergent semi-permanently flooded" wetland; however, without a site visit, park staff may not know that one is a diverse habitat harboring rare species and the other is a near monoculture of cattails.

Our cursory analysis of ISRO's NWI maps shows that these maps are lacking in one obvious area -- riverine wetlands are not represented. Streams and their tributaries (both perennial and intermittent) are not delineated. Apparently, the photographic scale was inappropriate and/or the photo-interpretation was very conservative. Perhaps the presence of water in watersheds with heavy forest canopies was not obvious and wetlands were not delineated, even with the presence of a stream channel. An example from another national park unit serves to illustrate the need to verify and extend NWI maps. At New River Gorge National River, an area of the gorge (and its tributaries) with existing NWI maps was re-interpreted using NPS color aerial photography and ground-truthing (Purvis *et al.* 2002). The NWI maps show 49 wetlands representing 11 wetland types. The NPS study delineated 76 wetlands representing 21 wetland types. The dominant wetland type from the NWI maps was Unclassified (potential wetlands) followed by Palustrine. For the NPS study, dominant wetland types were the deciduous palustrine wetlands followed by riverine wetlands. Two things are striking: 1) the difference in total wetlands identified (76 vs. 49); and 2) the difference in the riverine wetlands (32.9% by NPS vs. 3.6% by NWI). The differences are probably attributable to the ground-truthing of wetland delineations. In addition, the NWI maps were dated and needed to be updated with more current aerial photography and its interpretation.

The Nature Conservancy (1999), as part of the U.S. Geological Survey – National Park Service Vegetation Mapping Program, mapped and classified the vegetation, including wetlands, at ISRO using the U.S. National Vegetation classification, the federal standard for terrestrial vegetation. Below is a list of wetland community types for ISRO based on ecological groups (boldface).

Northern Shrub/Graminoid Fens and Bogs
Boreal calcareous seepage fen
Leatherleaf bog
Leatherleaf - sweet gale shore fen
Northern poor fen
Sweet gale shrub fen
White cedar - sweet gale scrub fen

Rooted/Floating Aquatic Marshes
Midwest pondweed submerged aquatic wetland
Northern water lily aquatic wetland

Wet Meadows/Marshes
Bluejoint eastern meadow
Great Lakes shoreline bulrush – cattail marsh
Midwest mixed emergent deep marsh
Northern sedge wet meadow
Twig rush wet meadow
Water horsetail - spikerush marsh

Northern Conifer and Hardwood Forest and Shrub Swamps
Black ash – mixed hardwood swamp
Black spruce / alder rich swamp
Black spruce / Labrador tea poor swamp
Northern tamarack rich swamp
Red maple – ash – birch swamp forest
Speckled alder swamp
White cedar - (mixed conifer) / alder swamp
White cedar – black ash swamp

Great Lakes Rocky Shores
Great Lakes basalt/diabase cobble-gravel lakeshore
Great Lakes basalt/diabase cobble-gravel lakeshore, shrub zone
Great Lakes basalt (conglomerate) bedrock lakeshore

Wetlands were separable into two subgroups, the open shrub/herb dominated group and the more forested swamps. The forested swamp types showed discernable clusters in an ordination exercise. The drier forested swamps, such as the white cedar-black ash swamp and the black ash-mixed hardwood swamp were more similar to upland types than were the more saturated and peaty swamps, such as the white cedar-(mixed conifer)/alder swamp, the black spruce/labrador tea poor swamp and the northern tamarack rich swamp.

The more shrub and herbaceous dominated subgroup was analyzed separately from the swamp subgroup to further clarify patterns. The first axis orders the stands from more open water types, such as the water horsetail-spike rush marsh, through emergent marsh and meadow types, such as the Midwest mixed emergent deep marsh and the bluejoint eastern meadow, to fen and swamp peat land types, such as the boreal calcareous seepage fen and the sweet gale shrub fen. The black spruce/labrador tea poor swamp type, included for comparative purposes, clearly separates from these shrub/herb types, but is most similar to the northern sedge poor fen, the white cedar/sweet gale scrub fen, and an outlier stand of the northern sedge wet meadow type.

Riparian zone structure and function have received little attention at Isle Royale – the Wallace Lake watershed studies (Stottlemyer *et al.* 1997) may be the exception. Consequently, little is known about the riparian areas of the park.

3. Isle Royale Aquatic Macrophytes

The Isle Royale Natural Sciences Research Plan (Linn *et al.* 1966) noted a need for "accurate and detailed hydrographic maps for each lake, swamp and bog" illustrating, among other things, "the distribution, density, and kinds of emergent, floating or submerged aquatic vegetation". A recent report on Isle Royale flora notes that the status and distribution of aquatic and wetland plants remains largely unexplored (Judziewicz 1999) . A project funded through the Great Lakes Inventory and Monitoring Network in 2003-05 (Principal Investigators James Meeker, Northland College, Emmet Judziewicz, University of Wisconsin - Stevens Point, and Allan Harris, Northern Bioscience) addresses this information gap by: 1) finding historic and recent documentation of aquatic and wetland plants within Isle Royale; 2) documenting the occurrence of all aquatic and wetland plants believed to be present and ensuring good voucher specimens are kept; 3) categorizing the abundance of each aquatic and wetland plant species on Isle Royale; and 4) locating and/or mapping all significant assemblages or populations of aquatic and wetland plants. While this work will address structural aspects of Isle Royale wetland plants, functional wetland attributes and wetland fauna remain unexplored.

Previous studies offer insights about Isle Royale aquatic vegetation for a subset of lakes and streams. Toczydlowski's survey provided qualitative assessment of aquatic macrophytes for his survey lakes and streams (Toczydlowski *et al.* 1978). Several previously unreported taxa were added to existing lists for Isle Royale, including *Lemna minor, Eleocharis pauciflora, Potamogeton robbinsii,* and possibly also *P. spirillus, P. pusillus, P. stricifolius, Isoetes echinospora, Lycopus virginicus, Ranunculus purshii, and Cardamine pensylvanica.* New bryophyte taxa encountered in this Isle Royale survey were *Anomodon rostratus, Calliergonella cuspidata, Grimmia apocarpa* var. *stricta, Dicranella schreberiana,* and *Mnium cuspidatum*. Toczydlowski *et al.* (1978) conducted a more detailed percent cover study of aquatic vegetation at Wallace Lake, including maps and species lists. A cluster analysis identified five general vegetation zones with characteristic taxa (emergent shoreline, emergent littoral, beaver dam, floating mat and patchy-deep).

Other macrophyte work at Isle Royale includes two lakes sampled during the inland lakes survey (Whitman *et al.* 2000). No new taxa were recorded from either Sargent or Siskiwit Lake. In Sargent Lake, about 20 taxa were found and percent cover in the littoral zone averaged about 30 percent. Coves and small inlets were generally more diverse than the steep-sloping shorelines that characterized much of the lake. The Siskiwit Lake flora was species-poor (n=8) and sparse (<1 percent cover), likely due to rocky bottoms and steep slopes.

E. Lake Superior Nearshore Zone

1. Nearshore Ecology Background

Nearshore waters of the Great Lakes are characterized by narrow bands of shallow, warmer waters situated around the perimeter of the lakes between land masses and deeper offshore waters. The 1996 State of the Lakes Ecosystem Conference (SOLEC) focused on nearshore environments and offered definitions for these areas. Nearshore *lands* were those situated adjacent to Great Lakes and influenced by lake processes including waves, wind, ice action, currents, and temperature and lake level fluctuations. Nearshore *waters* consisted of areas with enough warm water to support a community of warm water fish and associated organisms. More technically, Edsall and Charlton (1997) state that "nearshore waters begin at the shoreline or lakeshore edge of coastal wetlands, and extend offshore to the deepest lake-bed depth contour where the thermocline typically intersects with the lake bed in late summer or early fall". In Lake Superior, this boundary typically occurs at approximately the 10 m depth contour (Bennett 1978).

Nearshore waters comprise 4.7 percent of Lake Superior by area and only 0.1 percent of Lake Superior by volume (Edsall and Charlton 1997). Despite their limited extent, nearshore environments represent an important interface between terrestrial and aquatic ecosystems. As such, processes occurring in nearshore areas influence the transport of materials, energy and even contaminants from land to water. Nearshore waters also serve as critical and productive habitat (relative to offshore waters) for diverse aquatic biota. Nearly all Great Lakes fish species require nearshore environments at some life stage – for feeding and nursery grounds, migration pathways, and even for permanent residence. Nearshore areas contain feeding, resting and rearing habitat for waterfowl, and aquatic mammals are often found in sheltered nearshore waters near coastal wetlands.

Edsall and Charlton (1997) list several potential stressors for Great Lakes nearshore waters, including power production, marine transportation and boating, shoreline modification, underwater sand and gravel mining, pollution from point and nonpoint sources, fishing and waterfowl hunting, and exotic species introductions. Of these, shipping and boating, pollution, and exotic species introductions pose the most significant threats to Isle Royale nearshore waters. Transportation-related risks to Isle Royale nearshore resources are currently being evaluated as part of a spill response plan (Rayburn 2004) and contaminants such as mercury and persistent organic pollutants (POPs) are regularly measured in fish from Lake Superior nearshore waters (see below under "Contaminants"). The issue of aquatic exotic species in Isle Royale nearshore waters is also gaining attention.

2. Nearshore Water Quality

According to the baseline water quality inventory for Isle Royale National Park (NPS 1995), water quality data from Lake Superior nearshore waters are scarce. The largest concentration of Lake Superior sampling sites at Isle Royale occurs near Amygdaloid Island at the northeastern end of the park. Water depth at the Amygdaloid Island sites exceeded the 10 m depth contour that defines the nearshore environment, but the monitoring data collected at these sites provide a general indication of Lake Superior conditions near the park.

Between June 26 and August 26, 1974, an extensive suite of water quality variables was monitored periodically at three sites near Amygdaloid Island. Water quality measurements included turbidity, conductivity, pH and concentrations of nutrients, trace metals, major anions and cations, total and fecal coliform and fecal streptococcus bacteria, and several persistent organic pollutants in bottom sediments. Most variables were measured 4-6 times each. Basic summary statistics are presented for each variable (NPS 1995).

3. Bacteria

In 1984 and 1985, researchers explored the issue of bacterial contamination in Isle Royale waters, particularly Lake Superior bays near heavy human use areas (Meldrum 1987). Samples were collected from docks at Moskey Basin, Mott Island, Todd Harbor, McCargoe Cove, Belle Isle, Malone Bay, and Chippewa Harbor. Sites in Rock Harbor near the sewage outflow and between the lodge and Raspberry Island were also included. Additional sites included three sites in the Benson Creek/Daisy Farm vicinity, sites near campgrounds on Hatchet Lake, Chickenbone Lake West and Malone Bay, and a control site outside Middle Islands Passage. Samples from all sites were collected weekly in 1984 and bi-weekly in 1985, and were analyzed for total coliform, fecal coliform and fecal streptococcus bacterial groups. Fecal coliform to fecal streptococcus (FC:FS) ratios were used to indicate bacterial sources. Isle Royale waters normally showed ratios of less than 0.7:1.0, indicative of non-human sources. However, bacteria levels were routinely high for Benson Creek samples, and high FC:FS ratios were noted occasionally at Chickenbone West, Moskey Basin and McCargo Cove. Furthermore, Rock Harbor sample sites generally had higher bacteria levels than Lake Superior control sites. The investigators recommended additional sampling at other Isle Royale sites, including new and recently removed outhouse sites. In 1987, follow-up sampling was conducted at Benson Creek/Daisy Farm sites (Isle Royale Resource Management Files). The investigator concluded that there was no evidence of human waste from pit toilets entering either Benson Creek or Lake Superior waters in the Daisy Farm vicinity.

4. Nearshore Fish Community

Concurrent to the development of this Water Resources Management Plan for Isle Royale, a Fisheries Management Plan will be published in 2006. It will focus primarily on and provide management guidance for lakes and streams of the island, but will also address research and management of Lake Superior waters of the park. This Fishery Management Plan will cover specific fish and fisheries information in much greater detail.

Many investigations of fish species have occurred in Lake Superior waters of or adjacent to ISRO. Many of these investigations provide information specific to Isle Royale fish populations. These include studies of genetic characteristics and morphometry (Moore and Bronte 2001, Burnham-Curtis and Smith 1994), age structure and growth of various species (Burnham-Curtis and Bronte 1996; Bailey 1963, 1964, 1972) and bathymetric distributions of fish (Selgeby and Hoff 1996). Undoubtedly the most studied species near the island has been the lake trout, due likely to the role this species played as a commercially important fish in the establishment of some population centers and because of its popularity with sport anglers. There have also been recent investigations to determine the status of brook trout in the Lake Superior waters of ISRO. Surveys conducted by the USFWS in Tobin Harbor and Siskiwit Bay have provided information that indicates populations of brook trout are extremely low in both areas. Due in part to this information, the State of Michigan established catch and release only regulations for brook trout in all Lake Superior waters of the park beginning in 2005. The Biological Resources Division of the USGS conducted nearshore fishery surveys in 2003 and 2004 at several locations around the island. Surveys were conducted in waters $\leq$ 15 m deep using fyke nets and Windermere traps. A final report from this survey is expected in 2006.

5. Shoreline Rock Pools

Rock pools are a common but little noticed feature of Isle Royale's Lake Superior shoreline, found in greatest abundance on the gently sloping, exposed and rocky shores of the island's northeastern end. They are variable in size and depth, but relative to Isle Royale's other waters they are small and ecologically simple. Pool waters are typically dilute and transparent. Over the past two decades, researchers have capitalized on the uniqueness and simplicity of the splash pool ecosystems. Several studies addressing populations of larval frogs, salamanders, and dragonflies have been conducted and ecological interactions within and among these populations have been explored.

Smith (1983) was the first to examine Isle Royale pools, focusing on Edwards and North Government Islands. He examined boreal chorus frog (*Pseudacris triseriata maculata*) populations, which on Isle Royale breed are thought to breed exclusively in these pools. Smith observed that the pools varied in size, persistence and proximity to Lake Superior. Small pools and those next to the lake lasted less than the time required for boreal chorus frog tadpoles to reach metamorphosis, whereas large pools near the forest edge were permanent but full of predators, such as the dragonfly *(Anax junius, Aeshna juncea)* and the blue-spotted salamander *(Ambystoma laterale)*. Consequently, boreal chorus frog densities were constrained on the one hand by pool permanence and on the other by predation risk. High densities of boreal chorus frogs were encountered only in pools at intermediate levels on the shores. In these intermediate pools, boreal chorus frog densities were constrained by competition among individuals. Smith also examined effects of body size and date at metamorphosis on boreal chorus frog survivorship to maturity, but did not find a strong relationship (Smith 1987).

More recently, Smith and Van Buskirk (1995) examined ecological performance and phenotypic plasticity in two tadpole species, spring peeper (*Pseudacris crucifer*) and striped chorus frog *(P. triseriata)*, both found in Isle Royale splash pools. Their results showed how phenotypic traits exhibited by each species could enhance their ecological performance in their respective habitats. *P. triseriata,* for example, inhabited intermediate rock pools with few to no dragonfly predators; consequently it exhibited traits that would assist in processing food rather than avoiding predators (active and conspicuous feeding, small tail muscle and tail fin). *P. crucifer,* on the other hand, inhabited larger pools near the forest edge where dragonfly predators were always present; these tadpoles had the opposite suite of characters. When Smith and Van Buskirk transplanted each species into the opposite habitats, they found that *P. triseriata* reduced its activity and increased its tail fin and tail muscle sizes in the presence of dragonfly predators.

Van Buskirk and Smith (1991) also explored *A. laterale* populations in the splash pools. They experimentally manipulated salamander densities in the pools and examined the effects on salamander survival and growth. They found that survival, growth and size distribution of the salamanders were all affected by salamander density, and hypothesized that these effects resulted from interference from conspecifics. They asserted that density dependence was likely a strong regulator of *A. laterale* populations on Isle Royale.

Van Buskirk went on to assemble a species list of Isle Royale dragonflies from rock pools as well as lakes, ponds and wetlands (Van Buskirk 1992b), and documented eight previously undocumented species on the island. Among these is *A. juncea,* which is found in Isle Royale splash pools near the southernmost extent of its generally arctic range. Van Buskirk conducted a detailed study of this dragonfly, investigating the potential for density dependence among its larvae (Van Buskirk 1992a). He found that adjacent *A. juncea* size classes interacted strongly, such that two-year-old larvae experienced higher mortality than their three-year-old counterparts following aggressive encounters between the two. Younger larvae responded behaviorally to this pressure from conspecifics. Although it compromised their feeding success, they were more secretive and sedentary, and fed more often in the daytime. Importantly, Van Buskirk (1992a) also included a diet analysis of *A. juncea* according to larval instar, which provided some insight into other rock pool fauna. Benthic prey items of *Ae. juncea* included midges (Chironomidae), ostracods (Ostracoda), water boatmen (Corixidae), and other *Aeshna*. Pelagic prey items included water fleas (Cladocera), mites (Hydracarina), water striders (Gerridae) and terrestrial invertebrates.

In a follow-up study, Van Buskirk (1993) more completely addressed density dependence among larval dragonflies (*A. juncea*) in Isle Royale rock pools. By monitoring two sets of pools (on Edwards and North Government Islands) from 1986-1992, Van Buskirk observed that competition was intense at high natural densities. Individuals in crowded pools tended to suffer developmental delays and decreased survivorship relative to individuals in more sparsely populated pools, and his experimental results from nearby rock pools showed that both feeding activity and growth rates of *A. juncea* were significantly reduced under crowded conditions. As in his earlier work with rock pool salamanders and in Smith's work with chorus frogs, Van Buskirk concluded that density-dependent dynamics are a strong factor in regulating populations of *A. juncea* in Isle Royale rock pools.

F. Contaminants

1. Mercury

Mercury is a widespread, atmospherically-transported pollutant with distribution stretching to even the most remote parts of the globe (Wiener *et al.* 2003). While mercury is a naturally occurring metal, human uses of the element (for precious metal mining, chlor-alkali plants, pulp and paper mills, fungicides and medical waste incineration) have served to redistribute it worldwide. Highly toxic, mercury can become methylated in aquatic environments and accumulate in aquatic organisms and food webs. Mercury's presence and bioaccumulation in remote Isle Royale lakes has drawn attention to the issue of long-range contaminant transport and has inspired a number of research projects since the 1970s.

Mercury in Isle Royale ecosystems was first evaluated in an historical study conducted by Kelly *et al.* (1975) using walleye from museum collections (circa 1929) and more recent sampling (1971). The authors noted high mercury concentrations (500 $ng \cdot g^{-1}$ for standard length walleye and >1000 $ng \cdot g^{-1}$ for large specimens) and no evidence of a trend over time. Kelly *et al*. asserted that since Isle Royale was isolated from direct anthropogenic mercury inputs, elevated fish mercury levels must be due to surficial geology, a hypothesis challenged in subsequent studies.

Fish from Siskiwit Lake and nearshore waters of Lake Superior were collected and analyzed for mercury by the Michigan Department of Natural Resources in 1987-89 and 1992-93 (ISRO Natural Resource Management Files). Similar sized lake trout from Siskiwit Lake showed no evidence of a change in mercury concentrations between the two sample years, and mercury levels were below the 500 $ng \cdot g^{-1}$ threshold guideline for consumption in both cases. Lake trout mercury concentrations were also similar between samplings for nearshore Lake Superior waters, although concentrations in some Lake Superior lake trout exceeded 500 $ng \cdot g^{-1}$ in both sample years.

In the late 1990's, mercury concentrations were assessed in several different fish species in 32 Isle Royale inland lakes (Kallemeyn 2000). Approximately 18% of the fish examined had mercury concentrations exceeding 500 $ng \cdot g^{-1}$. Mercury concentrations tended to increase with fish length, and higher concentrations were found in piscivores (northern pike, walleye, lake trout) than in benthivores (white sucker, lake whitefish). Legal-sized pike from five of 25 lakes had mercury concentrations above 500 $ng \cdot g^{-1}$; these concentrations were significantly correlated with lake pH. The six lakes with highest pike mercury concentrations were situated along a 4.8 km line running south from Lake Eva to Angleworm Lake. Surprisingly, the highest mercury concentrations were found in yellow perch from Lake Harvey; later diet analysis showed that larger, older perch were functioning as piscivores.

Processes influencing elevated fish mercury levels in some Isle Royale lakes have been investigated further with respect to drainage basin characteristics, invertebrate mercury concentrations and trophic structure (Gorski *et al.* 2003). Investigators examined mercury throughout the food webs of two Isle Royale lakes (Sargent and Richie) with comparable morphometry and watershed areas. Water, zooplankton, littoral zone invertebrates (including mussels), several species of fish, and sediments were collected and analyzed for total mercury (THg) and methylmercury (MeHg). While water concentrations of THg and MeHg were similar in Sargent and Richie lakes, zooplankton THg concentrations were significantly higher in Sargent Lake. Benthic invertebrates had higher average mercury concentrations in Sargent Lake than Richie, but the difference was insignificant statistically. Caddisflies tended to have lower THg than other invertebrates, and dragonflies higher. As in Kallemeyn (2000), THg concentrations in fish were related to length and age; northern pike in Sargent Lake were older and longer than in Richie and had higher THg levels. Sediment cores showed an increase in THg and an exponential increase in MeHg since 1890, further evidence that Isle Royale mercury is atmospheric in origin. Isotope analysis indicated that the Sargent Lake food web was pelagic-based, whereas the Lake Richie food web was more benthic. The authors concluded that differences in northern pike mercury concentrations between the two lakes were due to greater zooplankton mercury accumulation in the pelagic zone of Sargent Lake; reasons for this difference may include Sargent Lake's more edible algal forms and less colloidal form of dissolved organic carbon.

Gostomski (2002) summarized a fairly comprehensive series of mercury studies at Isle Royale. In one study, Cannon (1998) and Cannon and Woodruff (1999) reexamined the possibility that high mercury levels in Isle Royale fish were the result of natural geologic factors. The authors collected samples of island bedrock and soil samples from around the Minong copper mine and within the non-mined drainage basins of Sargent Lake and Lake Wagejo. No mercury was detected in island bedrock, and mercury levels in soils from the Minong mine site were lower than in soils from near Sargent Lake or Lake Wagejo. The authors concluded that atmospheric deposition was the most likely source of mercury at Isle Royale.

In a follow-up study, Cannon and Woodruff (2000) addressed the question of why soil mercury concentrations were variable across the island. They compared samples from the previous study with additional samples from Lake Richie watershed and found that mercury and organic carbon levels were highly correlated. They concluded that factors controlling carbon cycling also control the isolation of mercury in terrestrial environments, and may be related to its transport to aquatic environments. This conclusion is important in at least two ways. First, watershed carbon cycling is linked to lake DOC concentrations, which in turn are linked to both structural and functional aspects of lake ecology (for example, DOC gradients described a substantial amount of the variation in Isle Royale fish assemblages sampled during the most recent survey (Kallemeyn 2000, Carlisle 2000). Secondly, climate warming in the upper Great Lakes area will likely affect carbon cycling in Isle Royale watersheds (Stottlemyer 1999); the direct relationship between carbon and mercury concentrations implies that mercury transport and cycling will also be affected.

Mercury exposure in common loons (*Gavia immer*) of Sargent Lake and Lake Superior was examined by Kaplan and Tischler (2000). Ten percent of adult loons had feather mercury concentrations at or above 20 $\mu g \cdot g^{-1}$, a suggested threshold level for toxic effects in loons. On Lake Superior, males had significantly higher blood and feather mercury than females, suggesting diet partitioning. Adult loons from Sargent Lake and Lake Superior had similar blood and feather mercury levels, but blood and feather mercury levels of fully developed juveniles on Sargent Lake were significantly higher than those on Lake Superior. Flight feathers of fledging-aged juveniles may be the most reliable indicator of mercury exposure in specific water bodies; juvenile flight feathers develop completely on natal territories and thus reflect the mercury concentrations therein.

A separate study addressed geographical gradients in common loon feather and blood mercury content across North America (Evers *et al.* 1998), with one of the sampling areas located at Isle Royale National Park. The investigators found that mercury concentrations in adult and juvenile blood increased from west to east, with intermediate-high concentrations found in the Upper Great Lakes sites. As noted in Kaplan and Tischler (2000), mean blood and feather Hg concentrations were greater in males than in females across sites and at Isle Royale. On Isle Royale, male blood Hg concentration averaged 1.43 µg/g compared with 0.78 µg/g for females. Additionally, mercury concentrations were found to be approximately ten times greater in adults than in juveniles. On Isle Royale, juvenile blood mercury concentrations averaged 0.06 µg/g compared with 1.1 µg/g for adults. Across sites in the Upper Great Lakes the greatest mercury concentrations in blood and feathers were found in loons breeding on low-pH lakes.

Vucetich and Vucetich (2000) studied mercury concentrations in the deer mouse (*Peromyscus maniculatus*), the only mammal <150 g inhabiting Isle Royale, to test the hypothesis that Sargent Lake's watershed contains higher mercury concentrations than other areas of Isle Royale. Mice were captured from sites inside and outside of the Sargent Lake watershed and their tissues were analyzed for mercury. In general, mercury concentrations in Isle Royale deer mice were relatively low and not consistently higher inside the Sargent Lake watershed than elsewhere on Isle Royale. The authors recommended additional studies with larger sample sizes and more sample sites.

Mercury concentrations in mussel tissues analyzed during the recent mussel survey (Nichols *et al.* 2001) were generally low, even in lakes known to have high fish mercury concentrations. The highest mussel mercury concentrations were found in Lake Richie (0.221 $mg \cdot kg^{-1}$); the threshold effects concentration (TEC) for mussels is 0.200 $mg \cdot kg^{-1}$. With the exception of Intermediate Lake, mussel mercury concentrations were more than an order of magnitude below the TEC.

2. Persistent Organic Pollutants

Persistent organic pollutants (POPs) encompass a variety of chemical contaminants characterized by slow degradation times, high toxicity and a potential for long-range atmospheric transport. Almost all POPs are anthropogenic in origin and are transported to Isle Royale via the atmosphere. Some are synthetic compounds produced for industrial purposes, some are pesticides, and still others are industrial or combustion by-products. The two main categories of

POPs are polycyclic aromatic hydrocarbons (PAHs), which have some natural combustion sources, and polyhalogenated organic compounds, which include polychlorinated biphenyls (PCBs), DDT, dieldrin, aldrin, endrin, polychlorinated dibenzo-p-dioxin and dibenzofurans, chlordane, hexachlorocyclohexanes, toxaphene, hexachlorobenzene, heptachlor, mirex, polybrominated diphenyl ethers, and more. Swackhamer and Hornbuckle (2003) recently completed a comprehensive review of air pollutant impacts in Isle Royale and Voyageurs National Park.

Since the 1970s, many of these POPs have been investigated at Isle Royale, particularly in nearshore Lake Superior waters and in Siskiwit Lake. Much research has focused on contamination of fish tissue. Early work by Swain (1978) documented elevated levels of organic residues in lean lake trout (*Salvelinus namaycush*) and fat lake trout (*Salvelinus namaycush siscowet*) in Lake Superior waters near Isle Royale, and even greater levels in fish from Siskiwit Lake. Swackhamer and Hites (1988) showed that organochlorine concentrations in lake trout from Siskiwit Lake vs. Lake Superior were similar, and that they generally decreased between 1975 and 1983. The Michigan Department of Natural Resources also collected lake trout from Siskiwit Lake and nearshore Lake Superior waters, and analyzed them for a suite of contaminants (ISRO Natural Resource Management files). In Siskiwit Lake, no trends in dieldrin, hexachlorobenzene or octachlorostyrene were detected from 1987-1992. PCBs, chlordane, and toxaphene in trout tissue were below consumption standards and apparently declined between 1987 and 1992. Total DDT also declined and was below consumption standards. In Lake Superior lake trout, no trends in dieldrin, hexachlorobenzene, octachlorostyrene or heptachlor-epoxide were noted. PCBs declined from 1989 to 1992, but large fish captured in 1992 still had PCBs exceeding consumption guidelines. Chlordane and toxaphene levels in Lake Superior samples exceeded consumption guidelines in large fish in both 1989 and 1992. DDT levels also remained elevated.

A variety of studies addresses organochlorine contamination across Lake Superior and makes reference to sites near Isle Royale. Strachan and Glass (1978) summarized existing organochlorine data relating to water, sediments and fish, and noted that PCBs and DDT in fish routinely exceeded policy objectives at many sites. Eisenreich *et al.* (1979) and Eisenreich *et al.* (1980) noted a zone of high sediment PCB accumulation stretching from Thunder Bay, Ontario, to the Keweenaw Peninsula, MI. Frank *et al.* (1980) explored PCB and organochlorine insecticide contamination on a Lake Superior-wide scale, and noted zones of high DDE and PCB contamination in areas close to Isle Royale. Additionally, William Bowerman of the Institute of Environmental Toxicology at Clemson University is tracking a range of contaminant levels in herring gull eggs and in blood and feather samples from bald eagles in the Great Lakes region, including Isle Royale National Park. Results of sample analyses are not yet available.

Czuczwa *et al.* (1984) noted that polychlorinated dibenzo-*p*-dioxins and dibenzofuran (toxins produced from the incineration of chlorinated waste) were present in Siskiwit Lake sediments. Baker and Hites (2000) later used sediment cores from Siskiwit Lake to look at trends in these chemicals over time. Their data indicated that atmospheric deposition of these chemicals to Siskiwit Lake first increased in the 1930s and peaked in the 1970s. They noted that recent declines were slower than expected based on source regulations alone.

Thurman and Cromwell (2000) studied triazine herbicides and their degradation products at several Isle Royale sites. They documented atrazine presence in surface waters, with concentrations generally higher in shallow, well mixed lakes (beaver ponds and lakes Livermore, Wallace and Whittlesey) than in deeper lakes (Feldtmann, Siskiwit, and Wood lakes). Although concentrations are currently below toxicity criteria for phytoplankton and other aquatic organisms, they recommended that these chemicals be monitored every 5-10 years in order to detect future changes.

Polychlorinated napthalenes (PCNs) are a group of compounds similar to PCBs in that they are lipophilic, persistent, and prone to bioaccumulation. A recent study addressed the distribution of PCNs in fishes of Michigan waters including remote Siskiwit Lake on Isle Royale (Kurunthachalam *et al.* 2000). The investigators found that total PCN concentrations were correlated with PCB concentrations across Michigan waters. PCNs were detected in Siskiwit Lake lake trout (indicative of atmospheric transport) and fish from both Siskiwit Lake and Lake Superior contained greater proportions of highly bioaccumulative PCN congeners than fish from other sites.

PAHs are often found in high concentrations in areas with heavy boat traffic or where fuel spills occur. This is an issue of concern for Isle Royale harbors due to use of fuel-powered generators and traffic from NPS boats, concessionaire ferries and private watercraft. Carlisle (2002) evaluated ecological recovery from a 1999 spill of 1,200 gallons of diesel fuel near Washington Creek. Despite a lack of pre-spill data and a two-year time lag between the spill and the assessment, Carlisle reported that some sensitive invertebrate taxa (the winter stonefly family Capniidae and the freshwater shrimp *Gammarus lacustris*) still had much lower abundances at spill-impacted sites than at in-stream reference sites. Stream water chemistry and ecological functions such as leaf litter decomposition rate appeared to have recovered. An additional study was conducted in 2003 and 2004 (Principal Investigator Dr. Will Clements, Department of Fishery and Wildlife Biology, Colorado State University) will address potential PAH contamination in several Isle Royale harbors by investigating the types of PAHs found in sediments, the toxicity of PAHs to Isle Royale benthic invertebrates, and the effects of PAH contamination on invertebrate communities.

PAH studies have also been conducted on inland Isle Royale waters precisely because they are removed from local sources of PAHs and receive pollutants only from the atmosphere. McVeety (1986) constructed a mass balance of PAHs in Siskiwit Lake, and found that atmospheric dry deposition of PAHs constitutes the primary input to the lake, while surface volatilization is the primary loss mechanism. Overall mass transfer of PAHs was found to be dominated by resistance in the liquid phase. Sediment core data from McVeety's study indicated a peak in sediment PAHs ca. 1950, followed by gradual declines. This pattern is likely due to a shift in historical residential fuel use in the region, from coal and wood toward cleaner-burning gas and oil. Similarly, Gschwend and Hites (1981) noted that fluxes of PAHs to sediments at Isle Royale and other sites in the northeastern U.S. increased beginning about 80-100 years ago but diminished in the last several decades. They indicated that future shifts toward increased coal usage in North America would increase PAH-related impacts to both remote and urban sites. In 1998, a team of researchers from Woods Hole Oceanographic Institute collected sediment cores from Siskiwit Lake to investigate sources and fates of hydrocarbons using natural radiocarbon signatures. The ^{14}C signatures of PAHs in Siskiwit Lake sediments indicated a large shift from biomass to fossil fuel hydrocarbon sources over the past century. Their work also suggests that ^{14}C may be a viable means to trace sediment reactions between organic matter and contaminants. They hope to refine their results through additional coring at Siskiwit Lake and ultimately publish their results (Dr.

Chris M. Reddy, personal communication, Woods Hole Oceanographic Institute, creddy@whoi.edu).

Contaminant studies at Isle Royale appear to converge on at least three points. First, POP contamination of both inland and near-shore Lake Superior waters is chiefly the result of atmospheric deposition. Second, declining deposition of many POPs over the past 20-30 years has led to modest declines in the contamination of Isle Royale sediments and biota (Simcik *et al.* 2000). Finally, despite these declines many lingering contaminants can cause chronic effects at low exposures, and new POPs are being documented in increasing concentrations (Swackhamer and Hornbuckle *2003*).

G. Amphibians and Reptiles

Isle Royale National Park, with an abundance of soggy bottom land and diversity of habitats, is home to 13 species of amphibians and reptiles. In 1996, the Park began conducting annual frog surveys as part of the Michigan Department of Natural Resources' Frog and Toad Survey Program and have documented the following anurans: eastern American toad (*Bufo americanus americanus*), northern spring peeper (*Pseudacris crucifer crucifer*), boreal chorus frog (*P. triseriata maculate*), green frog (*Rana clamitans melanota*), mink frog (*R. septentrionalis*), and wood frog (*R. sylvatica*). Other amphibians documented on Isle Royale include the blue-spotted salamander (*Ambystoma laterale*), central newt (*Notophthalmus viridescens louisianensis*) and mudpuppy (*Necturus maculosus maculosus*), although the last documented occurrence of the mudpuppy was in 1905 from Benson Creek (a.k.a. Daisy Farm) and Summer Lake. Four species of reptiles reside on the island, including the black rat snake (*Elaphe obsoleta obsoleta*), northern redbelly snake (*Storeria occipitomaculata occipitomaculata*), common garter snake (*Thamnophis sirtalis sirtalis*) and the painted turtle (*Chrysemys picta*).

The boreal chorus frog and the black rat snake are listed as Michigan species of special concern. On the island, boreal chorus frogs breed from May to June on rocky shorelines in small pools exposed to storm waves from Lake Superior (Smith 1983). These frogs are most vulnerable between May and September, during their breeding season, and larval stages and would likely suffer population collapse in the event of an oil spill on the northeast end of the island (Rayburn *et al.*, 2004). Black rat snakes are semi-arboreal and spend the majority of their time away from water (Prior and Weatherhead 1998). The abundance of black rat snakes on Isle Royale is unknown and its occurrence is documented solely by a photograph (ISRO Reptile list - http://www.nps.gov/isro/NR_Profile_Internal/NR_pages/RepliteList.htm)

H. Aquatic-based Vertebrates

1. Moose

<u>General Ecology Background</u>

The largest member of the deer family (Cervidae), moose (*Alces alces*) are large even-toed mammals with hooves, long legs, heavy bodies, a long drooping nose, a "bell"' or dewlap under the chin, a hump at the shoulders, and a small tail (Rausch and Gassaway 1994). Moose inhabit northern North America and Eurasia, and their range coincides with circumpolar boreal forests. Moose are limited to cool regions because of their large bodies, inability to sweat, and the heat produced by fermentation in their gut. They are comfortable at temperatures below 15 ^{o} C, cannot tolerate temperatures that exceed 27 ^{o} C for long, and will seek shade or water for relief. Adults may stand as tall as 7.5 fit high, males range from 8.1-10.4 ft (2.5-3.2 m) in total length, females from 7.8-10.1 ft (2.4 to 3.1 m). Males weigh from 794-1323 lbs (360-600 kg) and females from 595-882 lbs (270-400 kg). Moose have thick, brown fur that ranges from light to almost black in color. Individual hairs are 15 to 25 cm long and hollow, resulting in excellent insulation. Perhaps the most distinguishing feature is the antlers. Found only on the males, these are the largest antlers (up to 6.5 ft [2m] in width) carried by any mammal, worldwide. Antlers are shed and re-grown annually. Mating takes place in September and October. Females give birth synchronously during late May and early June. Females generally produce single young, although twins are common. Males and females are sexually mature at two years of age but full growth potential isn't reached until 4 or 5 years of age. Moose eat twigs, bark, roots and the shoots of woody plants, and in the warm months, moose feed on water plants as well. In winter, they browse on conifers, such as balsam fir, and eat their needle-like leaves. They require 44 lbs (20 kg) of food per day but their stomachs, when full, can weigh up to 143 lbs (65 kg). Moose have dramatic effects on the composition of terrestrial and aquatic plant communities through the direct and indirect influence of their browsing (Bartalucci *et al.* 2000).

ISRO Moose Population

Although the exact time remains a mystery, it is generally accepted that moose colonized Isle Royale around 1905, and were well established by 1915. Their method of arrival is also unresolved. When the first wolf arrived on Isle Royale in 1948, the herd was estimated to be 800. Numbers have fluctuated since then, as a result of weather, food supply, winter ticks, and wolves. Parvovirus reduced wolf numbers from 50 to 12 in 1982. This allowed moose numbers to climb steadily to 2500, only to crash during the record-high snowfall winter of 1995-1996, which resulted in the decimation of the population to 500 during a single season. Since then, the moose population has rebounded to approximately 750-800 individuals (Peterson and Vucetich 2004).

Moose and aquatic macrophytes

With regards to aquatic systems and moose, the majority of research on Isle Royale has dealt with the effects of foraging on aquatic macrophyte production and the sodium (Na) ecology of moose.

Relationships between aquatic macrophytes and moose were first recorded by W.S. Cooper who studied on Isle Royale in 1909 and 1910 and returned in 1926 to notice moose had turned sedge mats and many bogs into mud wallows (Krefting 1974). Murie (1934) suggested that through the destruction of aquatic vegetation, moose were likely affecting other parts of lake food webs as well. Moose-macrophyte relationships were explored in greater detail during an exclosure experiment on ISRO ponds (Aho and Jordan 1979). The investigators found that moose had measurable effects on macrophyte production, evidenced by the higher macrophyte standing crops in moose exclosure areas than in control sites. The authors also hypothesized indirect effects of moose on macrophyte production, due to the increased turbidity and poorer light conditions caused by browsing and trampling. Aho (1978) reported moose browsing in the following habitats: beaver ponds, shallow lakes, slow-moving streams, and shallow sheltered inlets of Lake Superior. Through indirect technique, Belovsky and Jordan (1978) estimated that submergent vegetation comprised 75 percent of aquatic intake by moose, and emergents the remaining 25 percent. The authors assumed grazing of submergents was proportional to their occurrence on a site. They estimated the annual diet for Isle Royale moose to be 85% browse (woody plant material), 10 percent aquatic vegetation, and 5 percent forbs. In general, the majority of aquatic feeding by moose is from early to mid-summer with a marked decline by late summer (Jordan 1987).

It is postulated that aquatic vegetation consumed by moose serves primarily as a source of sodium (Na). Hutchinson (1975) suggested that Na is the only mineral likely to attract herbivores due to its far greater concentration than in adjacent terrestrial forage. In mammals, Na is required for electrolyte balance, acid-base balance, nerve impulse transmission, maintenance of membrane potentials and absorption of nutrients. Botkin *et al.* (1973) demonstrated higher Na levels in submergent macrophytes versus emergents. They also found 0.5-3 orders of magnitude more Na (dry-wt basis) in aquatic macrophytes than terrestrial plants. A net loss of Na in an aquatic system grazed by moose could occur, as the animals transport the consumed plant material from the source and deposit it in upland terrestrial systems. Na loss could also occur through outflow from substrate disturbance during aquatic grazing (Jordan *et al.* 1973). Although plausible, Faaborg (1981) showed turnover of one pond in a single growing season to be 12-fold, and annual watershed runoff of 157,000 g Na could easily replace the 800 g moose were removing from the pond.

2. Beaver

General Ecology and Background

The beaver (*Castor canadensis*) is North America's largest rodent. The beaver's scientific name is descriptive of the castor glands, located near the base of the tail. Beavers in the wild live about 10 to 12 years. They have been known to live as long as 19 years in captivity. They continue to grow throughout their lives and may reach 3 to 4 feet (0.9-1.2 m) long, including the tail. Although most adult beavers weigh 40 to 70 lbs (17-32 kg), very old, fat beavers can weigh as much as 100 lbs (45 kg). In order to survive, beavers must be assured of 2 or 3 ft (0.6-0.9 m) of water year round. Water provides a refuge from enemies. Beavers build canals to float and transport heavy objects such as branches and logs for food and construction. Food for winter use must be stored in underwater food caches. If the habitat does not have the necessary water level, beavers construct dams. A beaver may work alone or with family members to build a dam, using piled logs and trees secured with mud, masses of plants, rocks, and sticks. The den is used as a food cache, rearing area, and general home. Dens are of two types depending on water level fluctuations. Bank dens are simply dug into the stream or river bank with a mass of sticks, mud, and rocks constructed over the top of the den. Lodges are constructed of the same materials as bank dens, but are located where the water level is more stable and slower moving, like in a pond or lake. Bank dens and lodges have two things in common: they have one chamber-like room and at least one tunnel exit to deep water so it will be free of winter ice. The exit provides quick and easy access for food gathering and emergency escape from predators. The life of a beaver colony is governed largely by food supply. Beavers eat not only bark, but also aquatic plants of all kinds, roots, and grasses.

ISRO Beaver Populations

Surveys began 40 years ago, started by Phil Shelton as part of his PhD dissertation at Purdue University under Durward Allen. Since 1978, only two observers, Phil Shelton and Doug Smith, have been responsible for conducting the biennial survey, which represents the longest running dataset of its kind in the National Park Service (Smith and Shelton 2002).

Smith and Shelton (2002), explained below, have documented two population cycles since 1962:

> Beginning with 125 active colonies in 1962, colonies increased to 286 in 1974 then declined to 83 in 1980, possibly because of an all-time wolf population high of 50 wolves. Beavers are known to be an important summer-time food source for wolves (Mech 1970, Peterson 1977). By 1982 active colonies returned to their 1962 level (125 colonies) and increased to 204 in 1986, again possibly related to wolves because of a wolf population crash that was related to human introduced parvovirus (Peterson, personal communication). Since 1986 colonies have been declining probably due to habitat exhaustion as wolf density has declined since 1980 (Peterson, personal communication). Aspen, a prime beaver food once commonly used by beavers on Isle Royale (Shelton 1966), is rarely accessible to beavers except at great distance (and risk to wolf predation).

In 2002, the population had 73 beaver colonies with food caches, and 8 other sites had beaver sign (fresh cutting or mud on lodge) for a total of 81 active sites (Smith and Shelton 2002). The number of beaver colonies recorded was stable since the 2000 survey, the first time without a decline since 1992-1994. It is important to note that throughout the survey's history the majority of beaver activity documented has occurred in those areas covered by the 1936 burn. Smith and Shelton (2002) predict further population declines due to decreasing habitat quality as the forest matures.

Beavers also contribute directly to forest dynamics. Regrowth of food trees is inhibited by natural succession and beaver activities that cut the overstory deciduous trees, as well as moose browse. Beavers are then forced to travel greater distances to acquire food, extending their browse pressure while at the same time increasing the likelihood of being predated on by wolves (Shelton and Peterson 1983).

3. Loon

General Ecology and Background

During the 20th century, the southern extent of the breeding range for the common loon has retreated northward. In North America, loons historically bred from Canada southward, into portions of northern California, Iowa, Illinois, Indiana, Ohio, and Pennsylvania. In the early 1900's, writers in Michigan (Barrows, Cook) reported loons in all counties of the state containing sufficient habitat. The current breeding range in Michigan includes only the Northern Lower Peninsula and the Upper Peninsula (except for a single breeding pair remaining in Barry County, SW Michigan), and the common loon has been designated State Threatened with an estimated 300-500 breeding pairs remaining (Joe Kaplan, personal communication 2004). Isle Royale contains approximately 100 of those breeding pairs, making it the largest, single refugium in MI.

Loons, their nests, and their young have been threatened in the past by hunting pressure, entrapment in commercial fishing nets on the Great Lakes, toxic levels of contaminants such as mercury (suspected), and shoreline development and increased recreational use on northern lakes (which is on the rise in the current breeding range). Common loons are a long-lived species; thus, changes in the landscape that may affect population size could take a long time to become evident. However, annual productivity in such places as ISRO may not be enough to sustain the current population as rates are well below those observed at other monitored sites.

Loons arrive on northern lakes in early spring, often the day of ice-out, and defend a territory on which they will breed. Within the next two to three weeks, breeding pairs copulate and search for a nest site. Because loons' legs are situated at the rear of their bodies, making them adept at diving but not walking, they must place their nests at the edge of the shoreline. Nest sites are generally located on a small island (to reduce nest depredation by terrestrial predators) or in a protected bay. The female lays 1-2 (and very rarely 3) eggs in a nest that is constructed and incubated by both pair members (Joe Kaplan, personal communication 2004).

ISRO Loon Population

Isle Royale supports over 100 loon pairs (Egan 2003), a third of the state's population, and is the only documented site where common loons nest on a shoreline of the Great Lakes, with approximately forty-three territories on the shores of Lake Superior. The first informal survey of common loons was initiated in 1985, and annual monitoring began in 1990 (Gostomski and Oelfke 1994). The annual monitoring program employed the lake stratum method of survey (Robinson *et al.* 1988) and in a review of data through 1995, Gostomski (1997) concluded that the observed high productivity suggested a strong potential for future recruitment and long-term population viability. The lake stratum method was used exclusively until 1998. From 1999-2001, the lake stratum method was combined with a loon atlas (delineating all the known territories) to assess productivity. Clear differences in data between the lake stratum and atlas became apparent. The atlas system (Kaplan *et al.* 2002), developed by Biodiversity Research Institute under contract with the National Park Service, indicated a tight territory occupancy extending towards the lower limit of nesting viability and that Isle Royale's loon population is currently at or near carrying capacity. The atlas system also showed a loon population far larger than previously completed censuses, due to marked differences in survey methodology. On the surface, the apparent increase in the number of loons is encouraging, however, past lake stratum surveys, conducted late in the breeding season, likely inflated productivity because surveyors stood a greater chance of locating juveniles associated with successful nesting sites than adults associated with unsuccessful ones. For example, in 2001, under the lake stratum system, productivity measured 0.6 young/pair, within the accepted range for a stable population of 0.5-0.79 young/pair (Sutcliffe 1980), but productivity measured near the lower end of the stable range at 0.5 young/pair under the atlas system, which more accurately records nest success throughout the season (Kaplan *et al.* 2002). For comparison, in the most recent annual survey, the five-year average productivity measured well below the stable range at 0.37 young/pair (Egan 2003). Current efforts are underway to conduct a population viability analysis on the loon population to further investigate the observed low productivity.

4. Bald Eagle and Osprey

General Ecology and Background

The bald eagle (*Haliaeetus leucocephalus*) breeds or is resident in a wide band throughout most of Canada and the northern United States except for the far north. The species is locally resident in Virginia, coastal Florida and the Gulf Coast, and in Arizona, and overwinters in much of the southern United States. Bald eagles primarily forage on fish and other vertebrates associated with coastal, riverine and interior aquatic systems (www.Nearctica.com 2004).

Bald eagle breeding pairs have increased in numbers in North America since the ban on DDT and other organochlorine compounds, which caused eggshell thinning, in the 1970s. The International Joint Commission (1991) has proposed that the bald eagle serve as an indicator species for toxic effects of organochlorine compounds on piscivorous wildlife and the effects of bioaccumulation and biomagnification in the Great Lakes. Recovery of bald eagle populations in the lower 48 states prompted the U.S. Fish and Wildlife service to reclassify this species under the Endangered Species Act from endangered to threatened in 1995.

The osprey (*Pandion haliaetus*) breeds or is resident throughout the boreal forest regions of Canada and Alaska, and southward throughout most of the western United States. The species also breeds along the Atlantic and most of the Gulf Coast and is resident in southern Florida. The osprey is almost always found along water, including the shores of lakes, rivers, and the ocean, where it finds its primary source of food, fish (www.Nearctica.com 2004).

Like the bald eagle, osprey populations were decimated by pesticide residues, and have made a remarkable comeback in the past few decades. The osprey remains classified as state-threatened in Michigan.

ISRO Bald Eagle and Osprey Populations

Bald eagle and osprey populations on Isle Royale have been monitored since 1961. From 1980 until the present, aerial overflights have been used to document nesting activities. The earliest documented successful nesting attempts for bald eagle and osprey date back to 1961 and 1963, respectively. Although several active nests for both species were documented almost annually between 1961 and 1983, there were only four occasions when young fledged (Meldrum 1984a). From 1984 until the present, at least one successful nest has been documented annually, and in the last ten to fifteen years several nests for both species have been active and as many as 14 and 9 young were fledged for bald eagle and osprey, respectively (Romanski 2001).

On two occasions, 1989 and 2003, nestling eaglets had blood drawn to determine contaminant levels as part of a Great Lakes basin-wide study. The one eaglet sampled in 1989 displayed the following blood concentrations in ug/L; 170 for PCBs, 40 for DDE, 34 for DDD and 24 for DDT (Bowerman 1990). Results for the five samples drawn in 2003 have not been analyzed.

5. Colonial Water Birds

General Ecology and Background

Colonial waterbirds in the upper Great Lakes region encompass the following species; double-crested cormorant (*Phalacrocorax auritus*), ring-billed gull (*Larus delawarensis*), herring gull (*Larus argentatus*), Caspian tern (*Sterna caspia*), common tern (*Sterna hirundo*) and great blue heron (*Ardea herodias*), whose concentrated nesting in colonies or rookeries on islands and shorelines leave them vulnerable to predation and disturbance during the nesting season. These birds primarily feed on fish and other aquatic vertebrates and invertebrates. Clutch sizes for these birds range from one to four for the terns, two to three for the gulls, three to four for cormorants and three to six for the herons.

As top predators in the aquatic food chain they are vulnerable to bioaccumulation of contaminants. In the last decade or two, some species have responded with explosive growth due to changing food supplies and habitat, and are targets for animal damage control (herring and ring-billed gulls, and double-crested cormorant). However, the two tern species are on several state and provincial threatened or endangered species lists within the region (Scharf *et al.* 1993).

ISRO Colonial Waterbird Populations

Waterbird nesting colonies at Isle Royale occur almost exclusively on the peripheral islands where there is sparse vegetation and limited predation. Of the species mentioned above, historically, herring gulls have been the most abundant nesting waterbird on Isle Royale. During the 1880s and 1890s, herring gull eggs were harvested for food from colonies located in Siskiwit Bay by local residents and lighthouse keepers. Sight records indicate that ring-billed gulls were present in the late 1940s (Martin 1988). Double-crested cormorants were present in substantial numbers in conjunction with commercial and pound net fishing operations in the late 1940s; however, during the 1950s populations were decimated by pesticide contamination leaving only two colonies remaining in Lake Superior. Terns, including the black tern (*Chilidonias niger*), have been observed during migration periods (Jordan 1982).

The first formal census by Sharf (1978) documented 35 herring gull colonies, with 595 birds and 2 great blue heron rookeries with 18 birds. The NPS conducted a great blue heron count in 1984 and located seven rookeries with 26 active nests (Meldrum 1984b). Martin (1988) resurveyed the island and counted 72 herring gull colonies, seven great blue heron rookeries, two ring-billed gull colonies and one double-crested cormorant colony with eight nests. Seven years later, Gostomski (1995) documented a dramatic increase in double-crested cormorant numbers at Isle Royale, which paralleled regional populations. While the number of colonies only rose by three (two to five), the number of nests increased from 11 to 915, when compared to data from the 1988 survey. During this same survey, the number of colonies for the three other species showed little change from 1988, however, the number of herring gull nests decreased 34 percent from 2,286 to 1,501. Gostomski postulated that the decline of herring gull nests and concurrent growth of double-crested cormorant numbers may be related, and that the displacement of gulls from colonial nesting sites by cormorants required further investigation. In 1997, Cuthbert *et al.* (1998) surveyed double-crested cormorant and tern colonies throughout the Great Lakes, and their counts on Isle Royale demonstrated another increase in the double-crested cormorant population, with 1206 nests at five colonies. One year later, Cuthbert and McKearnan (1999) completed an additional survey looking at gull colonies throughout the region and tabulated 1112 nests at 52 colonies for both herring and ring-billed gulls on Isle Royale, a decrease of almost 50 percent from what Scharf *et al.* (1993) observed in 1989. Presently, there is anecdotal evidence that cormorant populations have declined significantly in the last few years at ISRO.

In addition to colonial bird nest survey work, the park is involved in a study of contaminant levels in herring gull eggs. Eggs were collected in 2002, 2003, 2005 for analysis by William Bowerman of the Institute of Environmental Toxicology, Clemson University, as part of a regional study of contaminants in colonial waterbirds. No data are available from this study so far.

In 2002 and 2003, the NPS collected herring gull eggs for contaminants analysis. At present, the park has not received the results of that analysis.

6. Otter, Mink and Muskrat

General Ecology and Background

The North American river otter's (*Lontra canadensis*) range is widespread in Canada and the midwestern/southwestern United States. Otters are semi-aquatic mammals in the weasel family, with long, streamlined bodies, thick tapered tails, and short legs. They have wide, rounded heads, small ears, and nostrils that can be closed underwater. Fur is dark brown to almost black above and a lighter color ventrally, and the throat and cheeks are usually a golden brown. The fur is dense and soft, effectively insulating these animals in water. The feet have claws and are completely webbed. Body length ranges from 2.9-4.3 ft (889-1300 mm) and tail length from 1-1.7 ft (300-507 mm). Weight ranges from 11-24 lbs (5-14 kg). Males average larger than females in all measurements (Ellis and Dewey 2003). Otters live in lakes, streams, and coastal marshes where they feed on fish, crustaceans, amphibians, reptiles, birds, and insects. Otters once lived throughout North America and were hunted by Native Americans largely for their dense fur that allowed them to keep warm. When European settlers arrived and started developing the land (cutting down forests) and using farm pesticides and fertilizers, otter habitat became threatened. By the early 1980s, eleven states reported no otter populations and thirteen other states reported scarce numbers. Reintroduction programs have led to successful recovery in much of the otter's historic range (www.Otternet.com 2002).

Mink (*Mustela vison*) are found throughout the United States and most of Canada, with the exception of the Arctic coast and some offshore islands. Mink fur is usually dark brown with white patches on the chin, chest, and throat areas. The body is long and slender with short legs and a pointy, flat face. The toes are partially webbed, showing the mink's semi-aquatic nature. Body length is usually around 2 ft (610 mm), with up to half of this length being the tail. Females, on average, are substantially smaller than males. Adult females weigh between 1.5-2.4 lbs (0.7-1.1 kg), while males range from 2-3.5 lbs (0.9-1.6 kg). Body length varies as well, with males measuring from 1.9-2.3 ft (580-700 mm) and females from 1.5-1.9 ft (460-575 mm). Mink tend to frequent forested areas that are in close proximity to water, such as streams, ponds, and lakes, with some sort of brushy or rocky cover nearby. They are mostly active at night, especially near dawn and dusk. The diet of mink during the summer consists of crayfish, small frogs, shrews, rabbits, mice, muskrats, fish, duck and other water fowl. In winter, they primarily prey on mammals. Primary threats to mink populations throughout its range include the continued existence of the fur market, destruction of habitat and environmental contaminants (Schlimme 2003).

Muskrats are found in swamps, marshes, and wetlands from northern North America to the Gulf Coast and the Mexican border. They find shelter in bank burrows and in their distinctive nests, formed by piles of vegetation placed on top of a good base (e.g. tree stump). Muskrats have large, robust bodies, with a total body length of 12.5 in. The tail is flat and scaly and is nine and a half inches in length. They have short legs and big feet; the back feet are slightly webbed for swimming. Mainly vegetarians, muskrats consume about one-third of their weight every day. Because muskrats have the ability to reproduce quickly, populations are widespread and stable (Newell 2000).

ISRO Otter, Mink and Muskrat Populations

Otter had been reported on the island around 1790 (Jordan 1982), however, in 1904 Adams (1909) commented on the absence of otter. It wasn't until 1963, when P.C. Shelton and D.E. Murray observed an individual (Jordan 1982), did otter begin to reestablish themselves on the island. R.O. Peterson (Peterson and Vucetich 2002) began tracking otter sign in 1975 as part of the annual Winter Study program and documented low populations until the early 1990s. At this point otter sign steadily increased and has remained relatively high through 2004 (Peterson and Vucetich 2003, Peterson 2004). No other ecological investigations for otter have been completed.

Occasionally seen along lakeshores, mink at the park are at a typical level for the region. Due to the lack of cattails, needed for food and lodge building, and adequate substrate for bank burrows, muskrat have never been abundant at Isle Royale (Jordan 1982). No systematic survey work for either mink or muskrat has been done to date.

I. Aquatic Invasive Species

The Great Lakes and their connecting channels and rivers form the largest surface freshwater system in the world. The water-related resources are an integral part of activities, such as recreation and tourism, valued at $15 billion annually, $6.89 billion of which is related to the fishing industry. Approximately 75,000 jobs are supported by sport fisheries, and commercial fisheries provide an additional 9,000 jobs (U.S. Fish and Wildlife Service 1995). The valuable water resources of the Great Lakes and ISRO are threatened by the infestation of harmful nonindigenous aquatic invasive species (AIS). These species alter the number and distribution of native species and the natural balance of the Great Lakes and inland lake ecosystems and have broad economic and societal impacts that extend well beyond recreational uses of ISRO's water resources.

The Great Lakes-St. Lawrence region has been subject to the invasion of AIS since the settlement of the region by Europeans. Since the 1800s, more than 160 nonindigenous aquatic organisms have invaded the region from a range of aquatic animal and plant groups, including phytoplankton, zooplankton, macrophytes, mollusks, invertebrates, fish and pathogens, among others. Approximately 55 percent of these species are native to Eurasia; 13 percent are native to the Atlantic Coast of the United States (Mills *et al.* 1993)

As human activity has increased in the Great Lakes basin, the rate of AIS introductions also has increased. More than one-third of the organisms have been introduced in the past 35 years, the surge occurring after the opening of the St. Lawrence Seaway. It is widely recognized that ballast water (liquid and entrained solids) from ocean-going commercial vessels is a primary vector for AIS introductions to the Great Lakes-St. Lawrence system. Organisms discharged with ballast water, and those left in the residual water and sediment after ballast discharge, are a threat to the integrity of the Great Lakes water resources as well as many water-dependent sectors of the economy. While introduction of new species via ballast water is of considerable concern in the Great Lakes-St. Lawrence region, the spread of established AIS populations within the system via ballast water exchange also demands attention. Concern also is mounting over the role of other commercial and recreational activities (e.g., aquaculture, recreational boating, aquarium trade, horticulture) in providing pathways for AIS introduction and spread in the Great Lakes-St. Lawrence system.

The 1993 Office Technology Assessment (OTA) Report to Congress entitled *Harmful Nonindigenous Aquatic Nuisance Species in the United States* conducted an economic impact assessment based on a comprehensive survey of invasive plants, animals and microbes found to be living beyond their natural geographical range in the United States as established, self-sustaining populations. The economic assessment included more than 4,000 species of foreign origin: 2,000 plants, 2,000 insects, 142 terrestrial invertebrates, 91 mollusks, and 70 species of fish. The economic costs resulting from these nonindigenous invasive species were estimated in the range of hundreds of millions to billions of dollars per year. Average costs reported in the OTA report were $1.1 billion per year for 79 species. The report did not detail precise estimates of the economic damage, or put a dollar value on the profound environmental damages ranging from ecological perturbations, and extinction of indigenous species to more subtle ecological impacts of ANS resulting in loss of biodiversity. However, the report did raise the issue that cost assessments tend to underestimate losses caused by those nonindigenous species that are overlooked, and that intangible, nonmarket impacts, such as ecological damages, cannot be adequately assessed (U.S. Congress OTA 1993).

A 1999 study from Cornell University counted more than 50,000 nonindigenous invasive species in the United States causing economic costs of $138 billion annually (Pimentel *et al.* 2000). Cost estimates included control, damage to property values, health costs and other factors. Reasons given for higher economic costs in this study as compared to the OTA report were based on damage assessments of more than 10 times the number of species with higher costs assessed for some of the same species. The Pimentel *et al.* report also qualified that the economic costs in the study would be several times higher than $138 billion per year if monetary values could be determined for species extinctions, losses in biodiversity, and other forms of ecological degradation and aesthetics.

More than 10 percent of the introduced species have significantly influenced the Great Lakes ecosystem, both ecologically and economically. Some of the most harmful species that have become established in the Great Lakes include the sea lamprey (*Petromyzon marinus)*, alewife (*Alosa pseudoharengus*), Eurasian ruffe *(Gymnocephalus cernuus)*, zebra mussel (*Dreissena polymorpha*), round goby (*Neogobius melanostomus*), purple loosestrife *(Lythrum salicaria)*, fishhook waterflea (*Cercopagis pengoi)* and spiny waterflea *(Bythotrephes longimanus)*. Invasion of the Asian carp into the Great Lakes is imminent, holding potential for large scale economic and ecological damage.

1. AIS Present in ISRO

A more mobile society created by technological advances in marine navigation and recreational boating, as well as increased use of ISRO itself, has made the island more accessible in recent times. This accessibility has increased the potential for exposure to and invasion from exotic and aquatic invasive species. The following species have been found on ISRO or in the nearshore waters of Lake Superior immediately surrounding the ISRO.

The sea lamprey (*Petromyzon marinus*) is an invading nonindigenous species that has had an immense impact on fish communities, fisheries, and fishery management in the St. Lawrence

River and the Great Lakes of North America. Native to the Atlantic Ocean, sea lampreys gained access to the Great Lakes via Lake Erie when the Welland Canal around Niagara Falls was completed in 1829. However, they were not noted in Lake Erie until 1921, almost a century later. Thereafter, the invasion quickened; sea lampreys were found in Lake Huron in 1932, in Lake Michigan in 1936, and in Lake Superior in 1946. Adult sea lampreys, which are shaped like eels, feed by attaching on other fish with their suctorial mouths and extracting blood and other body fluids from the fish. Each sea lamprey may kill as much as 18 kilograms of fish during the 12-20 months of its adult life. The introduction of the sea lamprey into the Great Lakes contributed to the decline of several fish species and over the years has caused hundreds of millions of dollars of damage to the sport and commercial fisheries on the Great Lakes. The sea lamprey devastated populations of whitefish and lake trout, the top sea lamprey prey in the 1940s and 1950s, thus permitting populations of less commercially valuable fish to develop. By the 1940s, the sea lamprey had depleted populations of lake trout in Lakes Huron, Michigan and eastern Lake Superior. Sea lampreys are believed to be directly responsible for the extinction of two to three endemic whitefish species in the upper Great Lakes. The fishery has rebounded recently due to better overall water quality in the Great Lakes and development of a selective chemical to control sea lamprey populations. In 1992, sea lamprey control costs were approximately $10 million a year with the benefits of the control program estimated to be slightly over one-half billion dollars.

The spiny waterflea (*Bythotrephes longimanus*) and fishhook waterflea (*Cercopagis pengoi*) are two species of the family Cercopagidae recently invading the Great Lakes from the Ponto-Caspian region. The spiny waterflea is present in Tobin Harbor and has been documented in the Lake Superior waters surrounding ISRO. During late summer, these waterfleas form large masses which look and feel like wet cotton. These masses are commonly caught on fishing lines and down-rigger cables, and may cause difficulty in retrieving lines. The fishhook water flea has the potential to be introduced to the waters of ISRO; it is currently in Lake Michigan. Both *Cercopagi*s and *Bythotrephes* can impact aquatic ecology at the base of the food web in multiple ways. They will compete directly with larval fish for zooplanktonic food sources. They can displace native zooplankton and are not desirable as a prey species by larval fish due to the difficulty that fish have ingesting and digesting these organisms. If spread into ISRO inland lakes, these zooplankton could negatively impact inland lake fish as well as other species such as native mussels. It is unknown at this point, but it is feared that these species may also disrupt the native sponge communities as well. Surveys for spiny waterflea were conducted in eight inland lakes in ISRO during July, 2005

Both *Cercopagi*s and *Bythotrephes* have long caudal processes with up to three pairs of barbs along the proximal end of the process. Both species occur in brackish and pure freshwater environments. In addition to sexual reproduction, Cercopagiids most commonly reproduce parthenogenically, which allows them to quickly establish new populations with a relatively small seed population.

The *Great Lakes Waterflea Report* (www.glerl.noaa.gov/seagrant/cercopagis/cercopagissite.htm) provides an internet-based reporting system on the distribution and seasonal population dynamics of invasive waterfleas in the Great Lakes. The reporting system was launched in 2001 by the Sea Grant Extension program at the Great Lakes Environmental Research Lab (GLERL) of the National Oceanic and Atmospheric Administration (Glassner-Shwayer GLC ANS Update *2002*).

In addition to the species described above, there is a group of non-native fish found in Lake Superior waters that are not considered invasive but do compete for the same resources as their native counterparts. Species of these non-native fish found in the waters surrounding ISRO include: the rainbow or steelhead trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), Chinook or king salmon (*Oncorhynchus tshawytscha*) and coho salmon or silver salmon (*Oncorhynchus kisutch*). These fish consume prey fish, eat native fish eggs, uproot and eat aquatic vegetation, feed on plankton, and take over optimal habitat. When combined with the stress from aggressive invaders like those listed above, native fish populations can start to decline. More detailed information about these species is included in the ISRO Fish Management Plan.

2. AIS Posing a Future Risk to ISRO

Isle Royale's specific vulnerability to new AIS lies in its attraction of private pleasure boats from infested ports, commercial touring vessels that travel throughout the Great Lakes, and commercial freighter traffic passing through park waters. The park provides visitor education on new and existing AIS, but currently has no monitoring in place to detect AIS. It relies on reports from anglers and other boaters and paddlers to determine invasion status. The lack of monitoring at the least results in a lack of awareness as to the extent of invasions. At the worst, it precludes the opportunity to take early management actions, if applicable.

The ruffe *(Gymnocephalus cernuus)*, a Eurasian fish of the perch family, was introduced to North America in the 1980s, most likely through the ballast water of a seagoing vessel. These fish have few predators, no commercial or recreational value and are possibly competing with valuable native fish. The ruffe became established in the nearshore waters of western Lake Superior and recently expanded its range along the southern shore of Lake Superior to Lake Huron, thereby posing a significant threat to the fish communities of Lakes Superior, Michigan and Huron. Based upon research and observations of ruffe populations vis-à-vis native fish population displacements in Lake Superior, it appears that ruffe will be in direct competition with yellow perch and whitefish populations. The ruffe, continuing its range expansion, was found in the summer of 2002 in Lake Michigan in the vicinity of Escanaba, Michigan. Walleye populations may be affected indirectly through a change in the food chain composition brought on by the proliferation of the ruffe. Based on moderate estimates of expected declines of yellow perch, whitefish and walleye, the annual economic loss to the U.S. sport and commercial fisheries is approximately $119 million if the ruffe were to suddenly proliferate to all lake regions (Leigh 1998). Its most significant threat to ISRO would be its impacts to the nearshore native fish communities from ecological and sport fishing standpoints.

The zebra mussel (*Dreissena polymorpha*) is not currently present near ISRO and has difficulty establishing populations in Lake Superior due to low calcium levels in the lake. The park is potentially at risk, however, because pleasure vessels routinely arrive at the island from infested ports. For example, zebra mussels have become established in a few, relatively close Lake Superior Harbors. Calcium is required by the zebra mussel for proper shell development. The zebra mussel is the most well-known recent introduction coming into the Great Lakes via ballast water from commercial ships. The species has caused economic and ecosystem impacts that are the best documented examples of the extent of AIS damages to the Great Lakes. Results of a survey completed by Ohio Sea Grant, in cooperation with the Great Lakes Panel on Aquatic Nuisance Species, estimated costs to Great Lakes facilities using surface water (electric generating plants, municipal water systems and industrial water users) to be $120.4 million during the five-year period between 1989 and 1994 (Glassner-Shwayer GLC ANS Update 1996). Ecosystem impacts are just as profound, with potential impacts on food availability and spawning areas, to name a few (Glassner-Shwayer GLC ANS Update 1998). In some aspect, all water users in the Great Lakes-St. Lawrence region are vulnerable to the negative impacts of the zebra mussel.

The Quagga mussel (*Dreissena bugensis*), was introduced into the Great Lakes in the early 1990s. Quagga mussels are now found in much of Lake Erie, Lake Ontario, the Erie Canal, the upper St. Lawrence River and parts of Lake Huron. Quaggas are biofouling mussels that look much like zebra mussels and live in many of the same habitats. Both zebra mussels and quagga mussels have striped shells. Normally, they can be differentiated by the shape of the shell. Quaggas often have paler shells with finer lines than zebra mussels, but the color patterns of both species can vary considerably. Quagga mussels attach to hard substrates in freshwater habitats and cause many of the same problems as zebra mussels. However, they the Quagga mussel is a heartier species than the zebra mussel; can survive in cold water; and live on the entire lake bottom. Zebra mussels thrive in the shallow, warmer waters of the Great Lakes and other inland lakes.

The rusty crayfish (*Orconectes rusticus*) is a crustacean that has invaded parts of Minnesota, Wisconsin, Ontario, and many other areas. Rusty crayfish are native to streams in the Ohio, Kentucky and Tennessee region, but have spread to many northern lakes and streams where they cause a variety of ecological problems. Identified in Wisconsin lakes and streams around 1960, and in a Minnesota creek in 1967, rusty crayfish were probably spread by non-resident anglers who brought them north to use as fishing bait. As rusty crayfish populations increased, they were harvested for the regional bait market and for biological supply companies. These activities probably helped spread the species further. Rusty crayfish are an aggressive species, are very prolific and can severely reduce lake and stream vegetation, depriving native fish and their prey of cover and food. They also reduce native crayfish populations.

Two more recent invaders, the round goby (*Neogobius melanostomus*) and tubenose goby (*Proterorhinus marmoratus*) were first noted in North America in the St. Clair River in 1990. After three years of being geographically limited to the St. Clair River, the round goby began to expand its range. By 1995, the round goby had spread to all five Great Lakes and in the spring of 2000 was found in the Chicago Sanitary and Ship Canal where it poses a threat to spreading to the Mississippi River basin. Both species have been documented in Duluth Harbor but have not been documented in the waters surrounding ISRO. Prior to its September 2003 discovery in Duluth Harbor, the Tubenose Goby had only been documented in Lake St. Clair and the St. Clair River. The gobies are aggressive species that prey upon bottom-feeding fishes, take over optimal habitat and are able to survive and thrive in a range of water quality conditions. Gobies compete for food and habitat with native bottom species such as sculpin (*Cottus sp.*), trout-perch (*Percopsis omiscomaycus*) and darters (*Etheostoma spp*.), all found in waters of the park. In addition, the gobies share with sculpins the ability to deeply penetrate the interstitial spaces in cobble substrates. For sculpins, this behavior makes them an effective predator of lake trout eggs. Lake trout spawn over cobble reefs and their eggs settle deeply into interstitial spaces, where they are mostly protected from storm-generated surges and from predators -- except sculpins and now gobies. The presence of a highly abundant egg predator could mean a significant setback for their lake trout rehabilitation.

The spread of invasive plant species such as the common reed (*Phragmites australis*), purple loosestrife *(Lythrum salicaria* or *Lythrum virgatum)*, and Eurasian water milfoil *(Myriophyllum spicatum)* in the Great Lakes region poses a threat to many wetland communities, especially when habitat or ecological processes are disrupted (Union of Concerned Scientists 2003). Currently, none of these species is believed to be at ISRO, though an island-wide survey has not been completed.

Because of the high quality of its water resources and the uniqueness and fragility of ISRO's aquatic ecosystems, the introduction of any of these plants or animals would have devastating consequences to the native species inhabiting the Island. The greatest threat and danger to ISRO would be the introduction and establishment of exotic species in any of the Island's numerous inland lakes.

At the April, 2002 WRMP scoping workshop, the prevention and control of AIS was identified by the workshop participants as the number one priority concern for the park. A more detailed description of the threat of AIS to the Great Lakes and ISRO including institutional arrangements for addressing these issues is included in Section V – Water Resources Planning and Management Issues and Recommendations.

V. WATER RESOURCE ISSUES AND MANAGEMENT RECOMMENDATIONS

A project scoping workshop was held on April 24, 2002 in Houghton, Michigan to bring together scientists, researchers, academicians and natural resources managers to discuss priority issues for inclusion in the ISRO WRMP. The workshop format included presentations about the importance of water resources management planning to the National Park Service and how the planning process is designed to help ISRO identify specific water resources management goals and priority needs. A presentation on the Park's natural resources provided an overview of the status of the Park's water resources and current water resources management activities.

Most of the workshop was spent in group discussion focusing on priority water resources issues and needs for ISRO. A modified nominal group process was used to facilitate discussion and gather input from the participants at the meeting. Participants at the workshop identified more than four dozen individual issues that were grouped into 14 categories.

Meeting participants were asked to review the 14 categories and to vote for their first, second, and third most important priority from the complied list of issues (Table 16). The voting results were designed to provide guidance and feedback to the Great Lakes Commission and NPS in the development of the WRMP.

Using this information from the scoping workshop, along with information gathered through the research and writing process of this WRMP, several broad areas have been identified and are summarized in this section as requiring priority attention for the NPS as it considers the ongoing management of ISRO's water resources. The summary minutes from the April 24, 2002 workshop are included in Appendix F.

A. High Priority Issues

1. Background

Table 16. Priority water resources management issues identified at the project scoping workshop.

Issue	*Total Votes*	**# 1st place votes**	**#2nd place votes**	**#3rd place votes**
Aquatic Nuisance Species prevention and control	16	10	5	1
Baseline monitoring of inland lakes	11	1	2	8
Atmospheric deposition of toxic contaminants	8	1	2	5
Prevention plan for invasive species	5	2	2	1
Wetlands information	4	3	1	0
Comprehensive monitoring programs	3	1	2	0
Bathymetric mapping	2	0	0	2
Atmospheric sampling/ monitoring	1	1	0	0
Need for ongoing monitoring	1	0	1	0
Presence and affects of mercury on ISRO ecosystem	1	0	1	0
Global warming	1	0	1	0
Pollution from boats	1	0	1	0
Recreational uses of ISRO esp. relating to motorized versus non-motorized uses	1	0	0	1
Near-shore fisheries inventory	1	0	0	1

Our knowledge of water resources at the park appears, at first glance to be rather substantial, but that knowledge only scratches the surface. Knowledge of streams is very limited; water quality assessments confined to only a few streams and water quality monitoring is essentially limited to one stream – Washington Creek. This is disconcerting considering that climate change could affect carbon and nutrient export from boreal forests to streams which in turn could affect mercury dynamics. Additionally, there have been limited investigations of stream fish and benthic communities. From the standpoint of inland lakes, a recent assessment of fish and zooplankton communities and water quality was limited in scope (32 lakes vs. a total of approximately 202). Knowledge of phytoplankton communities is also limited. The presence and persistence of organic pollutants have been documented; however, how these pollutants interfere with lake/watershed ecological processes and how these pollutants impact the health of the park's biota are unknown. An inland lake monitoring program is warranted. The water quality of nearshore waters and an understanding of an associated habitat, splash pools, are unknown. In some cases virtually nothing of substance is known about some faunal/floral groups (e.g., amphibians). Similarly, the structure and function of the park's wetlands and riparian areas have not been studied; rare, threatened or endangered plants and animals may as yet be undetected. Finally, given the imminent threat of aquatic nuisance species, it is imperative that the park be able to conduct comprehensive monitoring to detect the early presence of these species.

Because of the quantity and quality of water resources in the park; a basic lack of adequate, baseline information; and lack of a water resources management program, this water resources management plan recommends the addition of a permanent water resource professional (broadly trained in aquatic ecology), when resources become available. This professional should develop a water resources program that would concentrate on developing, prioritizing and coordinating research and management needs including the establishment of monitoring programs, development of partnerships with federal, state, local, and non-profit entities and development of program oversight documents, manuals and standard operating procedures. A water resources staff position would facilitate development of a comprehensive aquatic research and management program to guide future research and integrate sound science into future management strategies. At current staffing levels, the Natural Resources Division will continue to be limited to piecemeal research efforts that do not adequately address the data gaps and cohesive management as outlined in this plan.

2. Water Resource Inventory, Assessment and Monitoring Needs for ISRO

i. Shoreline Rock Pools

Unique among ISRO's many aquatic resources are the small rock pool habitats situated along the Lake Superior shoreline. These rock pools are exposed to extreme climatic elements of wind, waves and ice, but provide habitat for regionally rare aquatic biota. Because of their location, shoreline rock pools are vulnerable to a variety of stressors ranging from fuel and oil spills to lake level fluctuations, climate change, and species invasions. Over the past two decades, researchers have capitalized on the uniqueness and simplicity of the splash pool ecosystems. Several studies addressing populations of larval frogs, salamanders, and dragonflies have been conducted and ecological interactions within and among these populations have been explored. These studies of ISRO's rock pools have provided important ecological insights and an indication of species composition, but have been limited to a small number of barrier islands, have not comprehensively addressed rock pool biota, and have not addressed potential threats. In order to plan effective responses to likely stressors, baseline information is needed to understand the distribution and biological composition of shoreline rock pools on a park-wide basis. As an initial step, two of us (BML and JG) conducted surveys of and mapped rock pools in August, 2005. Several pools and areas with pools were identified along the chain of barrier islands form Mott Island to Blake's point. There also appears to be several suitable areas for pools along the south shore of the main island form Saginaw Point to Schooner Island. A project statement in Appendix C-1 builds upon these surveys by proposing a series of activities that would serve to identify and map rock pools park-wide, determine use of the rock pools by key taxa, evaluate species-environment relationships, assess which rock pools would be affected by potential stressors, and provide recommendations for future rock pool monitoring.

ii. Lake Superior Waters

Inventory

No known research has been conducted to inventory fish species and to describe fish population densities and community structures in the nearshore zone (depth less than 15 m) of Lake Superior. The diversity and complexity of nearshore aquatic habitats may support a higher diversity of fishes than are found in the offshore zone of the lake. The US Geological Survey conducted a multi-year inventory of nearshore fish population densities and community structures at ISRO from 2003 through 2004(see project statement in Appendix C-2). Analysis of the inventory data should reveal a variety of nearshore fish communities and their structures. For example, nearshore zones characterized by rocky, wave-swept open lake shores will harbor very different species assemblages than those found in shallow, weedy areas at the head of protected coves and harbors. Comparison of these communities will reveal different structures and comparison with those in offshore areas will likely show that many open lake species are very dependent on nearshore habitat for spawning and rearing of young. This fish inventory of the nearshore environment will enable future monitoring programs to track changes in fish populations and communities as the result of species reintroductions, species rehabilitations, changes in management approaches, and environmental and biological perturbations.

Equally unknown are other physicochemical and biological aspects of the nearshore area of ISRO. We suggest an additional inventory of the nearshore area of ISRO that would focus on water quality, habitat characteristics, benthic invertebrates and periphyton. Such an inventory would complement the nearshore fishes inventory by the US Geological Survey and together, the inventories would paint a more complete assessment of the nearshore area. Such an inventory should, at a minimum, re-visit the sampling sites used in the nearshore fishes inventory. Since the Great Lakes Inventory and Monitoring Network funded the nearshore fishes survey, it would be appropriate for ISRO to seek funding of this complementary nearshore inventory from the network.

While researching this issue, we performed a search of ISRO PMIS to review the funded project statement for the nearshore fish inventory; that project statement was not found. Subsequently, we determined that the project statement (and study plan) resided with the Great Lakes Inventory and Monitoring Network. We caution ISRO that no matter who is the funding source, if the proposed work is conducted for the park, it needs to be in PMIS as an ISRO project. This is the only way ISRO and the NPS can truly assess the park's current program and programmatic needs.

Monitoring

To date in the Great Lakes region, multiple independent systems have been created to collect, transmit, store, retrieve and provide access to physical, chemical and limnological data. These include, among others, meteorological observation networks operated by the U.S. National Weather Service and Environment Canada, as well as lake level, interconnecting waterway and St. Lawrence River water level and stream flow gauges operated by the National Ocean Service, U.S. Army Corps of Engineers, and Canadian Department of Fisheries and Oceans. Information integration efforts began on a regional level in the 1990s, built around the Great Lakes Commission-managed Great Lakes Information Network (GLIN). These efforts have provided substantial benefits to the region, with large numbers of users accessing the information.

A valuable tool for keeping tabs on a wide range of conditions in the Great Lakes is currently under development through a cooperative effort by the Great Lakes

Commission and the National Oceanic and Atmospheric Administration (NOAA). The Great Lakes Commission is working on this collaborative effort to create an integrated Great Lakes Observing System (GLOS) to provide critical real-time data for multiple users, including, among others, resource managers, researchers, homeland security interests, the commercial shipping industry and the recreational boating community. GLOS will be a regional node of NOAA's multi-year, national Integrated Ocean Observing System (IOOS) initiative. NOAA's investment in the GLOS effort will provide for full integration of many disparate observations in a cohesive, "one-stop-shopping" web locale.

The Integrated Ocean Observing System is a coordinated national and international network of observations, data management and analysis that systematically acquires and disseminates data and information on the past, present and future states of the oceans and coastal zones, including the Great Lakes. Regional associations of major stakeholders (data providers and users) are being established to develop products and services tailored to the unique needs of each region and to design, implement and operate coastal observing systems that meet these needs.

iii. Inventory and Classification of Wetlands

Digital National Wetland Inventory, developed by the USFWS, maps that reside in the park's GIS are based on substandard, 1978, 1:80,000 scale black-and-white aerial photography and plotted on 1:62,500 scale USGS topographic maps (Mike Hyslop, pers. comm.., Michigan Technological University 2005). These maps undoubtedly contain significant errors of omission and classification due to the serious limitations imposed by use of dated, very high altitude black-and-white photography and minimal ground-truthing. The age of the photos (now 25 years old) could also mean that subsequent fire, drainage, beaver activity, plant growth and succession, or other factors further limit the accuracy of these maps. Finally, the type and age of these maps could partially explain their failure to delineate riverine wetlands.

Our research has determined that the National Wetland Inventory has now mapped wetlands at the 1:24,000 scale, the national standard, for all but three of the topographic quads for ISRO (Kevin Noon, pers. comm.,NPS Water Resources Division 2005). However, the mapping is still based on 1:80,000 scale black-and-white aerial photography from 1982 -- the national standard is 1:58,000-scale color infrared photography plotted on 1:24,000 scale USGS topographic maps. These finer scale wetland maps are based on minimal ground-truthing (typically not more than one wetland visited per quadrangle), and tend to omit smaller wetlands and wetlands with forest cover, which are significant in the park. Most classification errors are probably related to lack of information on water regimes or lumping of habitat types due to small scales.

An additional problem with the NWI maps is the lack of information on plant species associations, substrates (e.g., organic vs. mineral soil), and other factors. For example, two wetlands may be classified identically on the maps as "palustrine emergent saturated wetland," however, without a site visit, park staff may not know that one is a bog habitat harboring rare species and the other is a monoculture of low-value reed canary grass.

The problems with the 1:24,000 scale NWI maps notwithstanding, these maps are the best available science on wetland inventory and classification. We strongly recommend that ISRO obtain digital versions of these finer scale NWI maps from the US Fish and Wildlife Service and upgrade its GIS.

We offer a note of caution to ISRO with regard to use of vegetation field plots to classify potential wetland vegetation according to the U.S. National Vegetation Classification System (USNVC). This classification system was recently adopted as the Federal standard guiding primarily terrestrial vegetation mapping at federal agencies. It is a hierarchical classification system defining vegetation communities by structure at broad levels then floristically at finer levels. However, the NPS standard for wetland classification (Procedural Manual #77-1: Wetland Protection) is the Cowardin *et al.* (1979) system of the U.S. Fish and Wildlife Service – a system that looks at much more (e.g., hydrology) than just vegetation in classifying wetlands. Therefore, there is a need to 'crosswalk' these two classification systems. In ISRO's case, the vegetation mapping of the park using the USNVC system is complete. Once 1:24,000 scale NWI maps are available, one can use an *ad hoc* comparison of the two systems. This crosswalk has been accomplished at a few parks. Once this crosswalk is completed, the combined product is an enhanced wetland classification, i.e. wetlands are classified by the Cowardin *et al.* (1979) system, but these wetlands now have a much more detailed understanding of vegetation composition. We encourage ISRO to conduct this crosswalk once it has obtained the latest NWI maps in digital form; contact Chris Lea, NPS Biological Resources Management Division, who has performed such crosswalks.

Additionally, the vegetation mapping using USNVC at ISRO was a field-based approach. Theoretically, that exercise would have identified wetlands (usually smaller ones) that would not normally be present on the NWI maps. Essentially, the vegetation mapping project performed a much more detailed 'ground-truthing' of wetlands that also provides the opportunity to enhance the NWI classification.

The lack of comprehensive and better quality wetland inventory maps for ISRO can have important impacts on management and protection of the park's resources. For example:

- Park staff cannot properly protect important wetland resources if they do not know their existence. For instance, recreational traffic along trails, formal or informal, may be affecting wetland resources. Any impacts cannot be fully evaluated and mitigated unless the potentially affected wet areas are identified and characterized.
- Existing threats, particularly invasion of exotic plant species, may go unnoticed. It is important to not let localized exotic plant 'hotspots' explode into massive (and perhaps irreversible) invasions.
- An enhanced inventory that locates and characterizes wetland habitats would focus other park research, resource management, and interpretation efforts.

The park also needs to have a better understanding of the hydrologic drivers in its wetland systems. Determination of subsurface connections to inland lakes and streams is critical for future management issues such as the potential for drilling wells.

iv. Inland Lakes

Various studies of ISRO's inland lakes were conducted in the late 1970s and early 1980s and then no work was conducted again until the mid-1990s – an approximately 15 year gap in data in some instances. Based upon this incomplete picture of biological and chemical parameters of ISRO inland lakes, it appears that there have been few discernible changes in water quality parameters over the past two decades. Sulfate concentrations, however, were substantially lower in the more recent survey, perhaps the consequence of air quality regulations implemented in the 1970s. Sulfate concentrations declined in each of the 16 lakes, from an average of 4.87 mg l^{-1} across lakes in the early 1980s to an average of 2.48 mg l^{-1} in the mid-1990s.

Because of Isle Royale's remote location and protected status, its inland lakes are free from human influences related to land use change and development. As a result, anthropogenic nutrient and sediment loading are minimal, and cultural eutrophication is unlikely. Climate change and deposition of atmospheric contaminants, however, are without boundaries, and have complex effects on Isle Royale's inland lakes. Temperatures have warmed appreciably in the Great Lakes region over the last two decades, with implications for lake freeze-thaw cycles, thermal stratification and species ranges. Additionally, long-range depositional transport of a surprising suite of toxins to Isle Royale ecosystems has been demonstrated through studies of fish and sediments in Siskiwit Lake. Recreation and fishing on Isle Royale lakes are limited, and unlikely to be strong ecosystem drivers, except that recreational activities increase the likelihood of invasive species introductions.

Based upon this information, there is an overarching need to establish a sustainable water quality monitoring program for the inland lakes. At present, ISRO is not well positioned, both in terms of staff and funding, to sustain a monitoring program. Fortunately, the NPS Great Lakes Inventory and Monitoring Network, of which ISRO is a member, was established to provide long-term monitoring for its members. While still in a development phase for long-term monitoring, the Network has identified the basics for an inland lake monitoring program at ISRO. That program would sample 11 lakes (Siskiwit, Richie, Feldtman, Chicken Bone, Whittlesy, Intermediate, Hatchet, Lesage, Livermore, Mason, and Wallace) every other year (Joan Elias, pers. comm.,Great Lakes Inventory and Monitoring Network 2005). The remainder of the named lakes would be monitored on a longer rotation, perhaps every 5 years. These 11 lakes were selected based on lake size, lake depth, and proximity to access trails. Current thinking on sampling parameters includes: dissolved oxygen, temperature, pH and specific conductance taken over a depth profile; lake level; total phosphorus, total nitrogen, nitrate, dissolved organic carbon, alkalinity, Secchi depth, chlorophyll *a*, chloride, sulfate, calcium, potassium, magnesium, and sodium. Additionally, the benthic diatom assemblage would be sampled every 6 years.

The above inland lake monitoring program for ISRO is a sound beginning. The lakes chosen sample the four major lake types as presented in Figure 19; three lakes represent the soft water/high phosphorus type, three represent the big, deep and clear type, three represent the hard water/high algae type, and two represent the small, shallow and stained type. There is also a spread across habitat vectors within each lake type. For example, Mason and Chickenbone lakes, in the soft water/high phosphorus type represent different points along the total phosphorus vector (Figure 19).

Inland Lake Biological Communities

Concurrent to the development of this WRMP for Isle Royale, a Fisheries Management Plan will be published in 2006. This plan involves participation and input from several agencies and entities familiar with Isle Royale fisheries. It will focus primarily on and provide management guidance for lakes and streams of the island but will also provide recommendations for management of Lake Superior waters of the park. This Fishery Management Plan will cover specific fisheries information in much greater detail than this WRMP.

There have been relatively few comparative surveys of ISRO fisheries even though commercial and sport fisheries have been documented as early as the 19th century. Surveys of inland lakes and streams of the island occurred beginning in the early 20th century, although these earliest surveys were not fisheries specific. It appears that there were several main studies conducted over the past 100 years, each separated by approximately 20 years. The period between the last two detailed surveys was about 45 years. Surveys were conducted in 1906-1909 (Ruthven); 1929 (Koelz); 1949 (Hubbs and Lagler); and 1995-1997 (Kallemeyn).

In his 2000 report, Kallemeyn indicated that in comparison with earlier surveys, relatively little change in overall species composition has occurred and that "observed changes in the fish communities included no change (14 lakes), additional species (11 lakes), and undetected species (12 lakes). In five lakes, both species gains and losses were observed." He also suggests that species gains are likely attributable to upstream migrations from other inland lakes or Lake Superior (Kallemeyn 2000).

More information on monitoring needs related to fisheries is included in the Fisheries Management Plan. However, we want to stress the need to conduct a similar fish community assessment as that performed by Kallemeyn (2000), albeit for a limited number of lakes. We recommend that the fish communities be assessed in the 11 lakes that will be sampled every other year in the water quality monitoring program for inland lakes. Perhaps this assessment could be conducted every third sampling cycle (i.e. every 6 years).

A similar line of reasoning could be used for the monitoring of the phyto- and zooplankton communities. Their sampling could occur with the same frequency as that for the fish communities; however, a more frequent sampling is preferred given the inherent intra- and interannual variability of these biological communities.

A park-wide survey of mussels, building on the work by Nicholls *et al.* (2001), is needed. Anecdotal evidence suggests that Isle Royale may be one of the last strongholds for native mussel species in the Great Lakes region. A complete survey of all inland lakes and nearshore Lake Superior waters would give park resource managers a better understanding of species diversity and abundance, which in turn would assist in identifying critical habitat areas that need protection from exotic species and pollutant discharges, such as in the case of oil spills. Also, because of the likely status as a mussel refugium, an in depth understanding species abundance and distribution may be important in future lake or basin-wide restoration efforts.

Also building on the work by Nicholls *et al.* (2001) and conducted concurrently with the above mussel survey, a survey of freshwater sponges could investigate their diversity, density, distributions and relationships to water chemistry and other habitat related variables.

v. Streams

The Great Lakes Network has as yet to develop a stream water quality monitoring program within its member parks. Given the excellent beginning to an inland lake monitoring program, we are encouraged that the Network will develop an adequate stream monitoring program for ISRO.

vi. Air Quality Monitoring

According to the Lake Superior Management Plan (2000), 82 to 95 percent of PCBs enter the lake through atmospheric deposition, 80 to 100 percent of dioxins are from atmospheric deposition, and 84 percent of mercury is from deposition. Critical pollutants include PCBs, dieldrin, chlordane, DDT, mercury, dioxins and furans. Pollutants of concern are atrazine, arsenic, cadmium, chromium, copper, cyanide, lead, selenium, zinc, hexachlorobenzene, toxaphene, and PAHs.

The Integrated Atmospheric Deposition Network (IADN) is a joint US-Canada effort to monitor loading and trends of priority toxic chemicals to the Great Lakes. A complete range of measurements is made at the Master Station at Eagle Harbor, MI (approximately 45 miles from ISRO on the Keweenaw Peninsula), which involves measurement of wet and dry deposition of semivolatile organic compounds (including PAHs, PCBs, and organochlorines and trace metals).

The Michigan Department of Environmental Quality is expanding air toxin monitoring to include an atmospheric deposition network to monitoring persistent bioaccumulative toxins and an ambient monitoring network to cover all other air toxins. The atmospheric deposition network will monitor mercury, PCBs, dioxins and furans and such monitoring will include the IADN site at Eagle Harbor.

Such monitoring should, for the most part, be sufficient for ISRO needs. However, we concur with the recommendation of Swackhammer and Hornbuckle (2003) to add mercury monitoring (wet deposition; collected weekly for total mercury) to Isle Royale in order to link mercury concentrations in fish to atmospheric processes. In addition, such information would be essential to the understanding of the mercury cycle in ISRO watersheds. However, until the mechanics of mercury dry deposition are better understood, a complete picture of mercury deposition will be lacking. Perhaps ISRO could lobby the Mercury Deposition Network (MDN) to include the park in its network. Presently, the MDN has nine sites in the Great Lakes region – one in Indiana; four in Minnesota; and four in Wisconsin.

3. Prevention and Control Plan for Invasive Species

Nonindigenous aquatic invasive species (AIS) pose a growing threat to the economy and ecosystem of the Great Lakes-St. Lawrence region. Species such as the zebra mussel, ruffe, round goby, sea lamprey, Eurasian watermilfoil and purple loosestrife, among many others, are an insidious form of biological pollution. They prey upon and displace native animals and plants, reduce biodiversity, limit water use activities and damage public and private infrastructure. Preventing new infestations and limiting the spread of existing ones is critical to protecting and enhancing ecological integrity and economic viability. A growing framework of laws, agreements and programs has been established to address the threat posed by AIS. Isle Royale National Park will benefit from the development of an 'Action Plan,' to prevent the introduction and spread of AIS to preserve the ecological integrity of the park's water resources. This plan should present a series of principles, goals and objectives to attain that vision for ISRO.

The broader issues and problems associated with AIS prevention and control have global implications that require policies and programs at various levels of government. The following summary provides an overview of the prevention and control programs targeting AIS at both the federal and state levels. For ISRO, coordination among federal, regional, state and park specific programs is critical to effectively address problems caused by the introduction and spread of aquatic invasive species.

Addressing the Threat of Aquatic Invasive Species

In drafting the federal Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA), Public Law 101-646, Congress recognized that mitigation of the adverse impacts of all aquatic nuisance species is dependent on a well-coordinated outreach, research, monitoring and prevention/control program at the Great Lakes and national level. Mechanisms for addressing these challenges included the establishment of:

- The National Aquatic Nuisance Species (ANS) Task Force, an intergovernmental organization charged with implementing NANPCA and subsequently NISA, the National Invasive Species Act, which was passed in October 1996;

- The Great Lakes Panel on Aquatic Nuisance Species. Since 1991, the Great Lakes Panel has served as a coordinative body to prevent and control the occurrence of aquatic invasive species in the Great Lakes. The Great Lakes Commission convened the Panel and serves as its secretariat per NANPCA.

With approximately 20 federal agencies working on research, use, prevention or control of desirable and harmful nonindigenous species, the need for a coordinated effort is essential. The Great Lakes Panel's regional multi-jurisdictional representation makes this entity well suited to meet the complex challenges posed by AIS invasions. A 1994 report to Congress titled *Findings, Conclusions and Recommendations of the Intentional Introductions Policy Review* further confirmed the need for regional inter-jurisdictional panels in making ecologically credible decisions.

The role and potential contributions of the Great Lakes Panel were enhanced by the provisions of the NISA. The Act responded to the increasingly national scope of the AIS problem. The zebra mussel, since its discovery in the Great Lakes in the mid-1980s, has colonized most of the Mississippi River and is gradually extending its range westward. To address this expanding threat, NISA has strengthened existing AIS prevention and control efforts and authorized the formation of new regional AIS panels. The states and provinces in the Great Lakes-St. Lawrence region have increasingly recognized the need to collaborate on a regional basis to develop and implement effective AIS prevention and control programs, most importantly the state comprehensive AIS management plans, thus qualifying the states for federal funding.

Federal Role

The enactment of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA, Public Law 101-646) and subsequently the National Invasive Species Act of 1996 (NISA, Public Law) has provided federal support for programs aimed at AIS prevention and control. NANPCA's enactment was largely due to the unintentional introduction of the zebra mussel and its subsequent economic and ecological impacts. Although the zebra mussel invasion of the Great Lakes has played a central role in prompting passage of the federal legislation, NANPCA was also established to prevent the occurrence of new AIS introductions and to limit the dispersal of nonindigenous aquatic nuisance species already in US waters (Glassner-Shwayer 2000). As enacted, the legislation has five purposes: to prevent unintentional introductions; to coordinate AIS research, control and information dissemination; to develop and carry out environmentally sound control methods; to minimize economic and ecological impacts; and to establish a research and technology program to benefit state governments.

For ISRO the pathway of introduction for AIS or "vectors" will be a consideration of utmost importance. One significant vector for the introduction and spread of AIS in the Great Lakes is through ballast water exchange from commercial vessels. Under NANPCA, the Great Lakes basin became the first geographic location where federal legislation established a regulatory regime that targeted the prevention of AIS carried in ballast water. A Great Lakes program developed to implement and enforce U.S. regulations, as required through mandatory compliance with NANPCA, was enacted in 1993. These regulations stipulate that commercial vessels bound for the Great Lakes exchange freshwater ballast with open-ocean salt water that contains organisms not likely to survive in freshwater. Enforced by the Canadian Coast Guard and Seaway authorities, the regulations require that the level of salinity in ballast water equals or exceeds 30 parts per thousand (ppt). (The salinity of normal sea water ranges from 34 to 36 ppt). Compliance with the requirements of the regulations can be met with one of the three options: 1) ballast water exchange at sea beyond the Exclusive Economic Zone of either the U.S. and Canada in a depth of at least 2,000 meters; 2) retaining the vessel's ballast water onboard during the entire voyage within the Great Lakes; or 3) implementation of an alternative environmentally sound method of ballast water management that must be first approved by the U.S. Coast Guard. Although the regulatory regime on ballast water under NANPCA addresses a portion of the problem, it does not deal with "NOBOBs", vessels entering the lakes reporting "no ballast on board." Although NOBOBs do not contain pumpable ballast in their tanks, they do carry considerable residual ballast in the form of sediment that is present even after a complete discharge operation. The organisms carried in the residual sediment may be discharged when water is added to the ballast tank and later released into the lakes from vessels with multiple destinations in the basin. It has been recognized that a large number of vessels entering the Great Lakes carry unpumpable ballast, and additional regulatory action may prove necessary to strengthen the regulatory regime established under NANPCA (Reeves 1999).

The national ANS Task Force is an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species and implementing NANPCA. The Task Force was established to coordinate governmental efforts related to nonindigenous aquatic species in the United States with those of the private sector and other North American interests. The Task Force consists of seven federal agency representatives and 10 ex-officio members. In addition to the agencies assigned as co-chairs (the US Fish and Wildlife Service and the National Oceanic and Atmospheric Administration), Task Force members include the U.S. Environmental Protection Agency, the U.S. Coast Guard, the U.S. Army Corps of Engineers, the U.S. Department of Agriculture (USDA) and U.S. Department of State. Under Section 1202 of NANPCA, the Task Force adopted the cooperative Aquatic Invasive Species (AIS) Program. The AIS Program addresses all new AIS activities that are conducted, funded, or authorized by the federal government, except those involving intentional introductions. It seeks to complement existing nonindigenous species activities rather than supplant them. The AIS Program recommends the following essential elements:

- **Prevention -** establishes a systematic risk identification, assessment and management process to identify and modify pathways by which nonindigenous aquatic nuisance species spread;

- **Detection and Monitoring -** creates a National Nonindigenous Aquatic Nuisance Species Information Center to coordinate efforts to detect the presence and monitor the distributional changes of all nonindigenous aquatic nuisance species, to identify and monitor native species and other effects, and to serve as a repository for that information;

- **Control -** the Task Force or any other potentially affected entity may recommend initiation of a nonindigenous aquatic nuisance species control program. If the Task Force determines that the species is a nuisance and control is feasible, cost-effective and environmentally sound, using a decision process outlined in the control program, a control program is eligible for approval. Support elements for setting up a control program include research, education and technical assistance.

The national AIS Program also coordinates research efforts, establishes protocols and allocates grants. Education activities relate to encouraging and facilitating efforts to inform and educate a wide range of audiences about the problems caused by nonindigenous invasive species. Technical assistance ensures the coordinated application of existing capabilities. Other related activities include coordinating the zebra mussel program, review/approval of state AIS management plans, voluntary guidelines and regulations on ballast water, and shipping initiatives to control nonindigenous species, and biological studies on the impacts of nonindigenous invasive species.

State Role

The role of state entities regarding AIS prevention and control is specifically addressed under Section 1204 of NANPCA. That legislation calls for the development and implementation of comprehensive state management plans for AIS prevention and control. Section 1204 requires that the management plan "identifies those areas or activities within the state, other than those related to public facilities, for which technical and financial assistance is needed to eliminate or reduce the environmental, public health and safety risks associated with aquatic nuisance species." The content of each state plan is to focus on the identification of feasible, cost-effective management practices and measures to be pursued by state and local programs to prevent and control AIS infestations in a manner that is environmentally sound. As part of the plan, federal activities are to be identified for prevention and control measures, including direction on how these activities should be coordinated with state and local efforts. Section 1204 also states that in the development and implementation of the management plan, the state needs to involve appropriate local, state and regional entities, as well as public and private organizations that have expertise in AIS prevention and control (U.S. Congress 1990).

The state management plans are to be submitted to the national ANS Task Force for approval. If the plan meets Task Force requirements, the plan becomes eligible for federal cost-share support. If not, the plan is returned to the state with recommended modifications. Plans may be implemented with other funds supplied by state and cooperative agencies. Further details on the state management plans can be found in Section 1204 of the act.

In 1999, the Great Lakes Commission on behalf of the Great Lakes Panel on Aquatic Nuisance Species provided a model to serve in the development and implementation of comprehensive state management plans for the Great Lakes basin states and other regions in the country. *A Model Comprehensive State Management Plan for the Prevention and Control of Nonindigenous Aquatic Nuisance Species* was structured to address different stages of ANS invasion:

- the introduction of nonindigenous species transported from water bodies from other parts of the continent or world;

- the spread of established, reproducing ANS populations to other water bodies; and

- the colonization of ANS populations within water bodies, including the harmful impacts resulting from colonization.

The three goals on which the model state management plan is based are as follows:

- prevent new introductions of nonindigenous aquatic nuisance species into the Great Lakes and inland waters of the state;

- limit the spread of established populations of nonindigenous aquatic nuisance species into uninfested waters of the state; and

- abate harmful ecological, economic, social and public health impacts resulting from infestation of nonindigenous aquatic nuisance species.

The model state management plan, through its recommended goals and associated strategic actions and tasks, has been a popular tool used to guide state agencies in the Great Lakes region and beyond in the development of state, as well as interstate, management plans for ANS prevention and control. The management plan for the State of Michigan has been approved.

Through individual actions of their state legislatures and the authority provided under state statutes, many of the Great Lakes states have adopted policies to prohibit aquatic invasive species on state lands and in state managed waters. The term "prohibited" refers to those species that are considered harmful to native aquatic species and ecosystems and harm or have the potential to cause harm to the recreational and commercial uses of the water resources of the state. Upon introduction, prohibited species are those considered most likely to survive, spread and become naturalized in jurisdictional waters. Those species designated as prohibited may not be imported, transported, purchased, possessed, propagated, sold and/or otherwise introduced/released into waters of the state (Table 17; Glassner-Shwayer GLC 1999).

Importance of AIS Prevention Planning for ISRO

The Great Lakes-St. Lawrence ecosystem has been plagued by the infestation of more than 162 nonindigenous aquatic invasive species that have become established since the settlement of North America by Europeans (Ricciardi 2001, Mills *et al.* 1993). The rate of AIS introductions has significantly increased in the last 50 years largely due to the opening of the St. Lawrence Seaway system and attendant waterborne commercial ship traffic. Other AIS introductions result from recreational and commercial activities such as aquaculture industry, aquarium trade, recreational fisheries enhancement, live bait

Table 17. Nonindigenous aquatic nuisance species listed as prohibited by State of Michigan. This information was updated in 2004 by Roger Eberhardt of the Michigan Department of Environmental Quality.
AQUATIC PLANTS
any variety, hybrid, or cultivar of purple loosestrife *(Lythrum salicaria, Lythrum virgatum, or combinations thereof)*
FISH
bighead carp-bighead amur *(Hypophthalmichthys nobiliis)*
black carp-black amur *(Mylopharyngodon piceus)*
grass carp *(Ctenopharyngodon idella)*
round goby *(Neogobius melanostomus)*
ruffe *(Gymnocephalus cernuus)*
silver carp *Hypophthalmichtttthys molitrix)*
tubenose goby *(Proterorhinus mamoratus*
INVERTEBRATES
rusty crayfish *(Orconectes rusticus)*

business and horticultural practices, among others. Irrespective of how an invasive species is introduced, experience has shown that once invasive species become established on a wide scale basis, controlling their spread is both technically difficult and expensive while eradication is nearly impossible. Therefore, prevention of AIS introductions must remain the first priority in battling aquatic invasions.

One mission of ISRO managers is to preserve the ecological integrity of every component within the park's ecosystem. For ISRO, the cold expanse of Lake Superior has done a good job of ensuring some degree of isolation from nonindigenous plants and animals, but preservation seems daunting given the onslaught of AIS already in or approaching Lake Superior. Technological advances in marine navigation and boating, and the high number of people frequenting the Island itself have made ISRO more accessible in recent times. Increased accessibility has opened the door to the threat that unwanted hitchhikers bring. Zebra mussels for instance, if established on ISRO or in the surrounding waters of Lake Superior have the potential to alter entire ecosystems in an extremely short time. In just a few short years, zebra mussels could cover nearly every living and non-living thing on the lake floor, gobble up plankton, and disrupt the food chain. Precious resources like the irreplaceable native fish community and the prolific native freshwater mussel populations within the park's inland lakes would be severely damaged or even lost if zebra mussels became established and were able to spread. Other invaders already seen at Isle Royale or knocking on the door include the sea lamprey, Asian carp, spiny waterflea, fish hook waterflea, ruffe, round goby, rusty crayfish, Eurasian milfoil, common reed, and quagga mussel. There is also a group of non-native fish we may not always consider invasive, but these fish do compete for the same resources as their native counterparts. They include the rainbow or steelhead trout, brown trout, Chinook or king salmon, coho salmon, pink salmon, splake, rainbow smelt, alewife and carp. These fish consume prey fish, eat native fish eggs, uproot and eat aquatic vegetation, feed on plankton, and take over optimal habitat. When combined with the stress from aggressive invaders like those listed above, native fish populations could decline.

The development of any plan to address the threat of aquatic invasive species must include several key components as outlined below.

Prevention

The prevention of new introductions of aquatic invasive species is widely accepted as the most effective way to manage AIS problems and is considered the first line of defense against aquatic invaders (Glassner-Shwayer 2000). Elements of a good prevention strategy include measures to minimize the risk of unintentional introductions of AIS that are or could become nuisances. Anticipating and avoiding the introduction rather than reacting once an unwanted species exists is the focus of this element and is a cornerstone of any good AIS plan.

The interruption of introduction pathways is the most effective and feasible approach for preventing the introduction and subsequent dispersal and establishment of AIS. Focusing on pathways concentrates action on the most easily disrupted element of the system. The number of pathways is much more limited that the number of suitable locations (i.e., environments) of species (Table 18).

Early Detection and Rapid Response

Intervention through early detection and rapid response is a critical strategy for preventing the establishment of new AIS populations. Early detection and rapid response efforts increase the likelihood that invasions will be addressed successfully while populations are still localized and population levels are not beyond that which can be contained and eradicated (Invasive Species Advisory Committee 2003).

Any early detection and rapid response component should be designed to address the critical period between introduction and establishment of AIS when the program focus

Table 18. High-risk pathways of unintentional AIS introduction (Glassner-Shwayer 2000).
• shipping (ballast water and sediments, anchor chains, sanitary waters, hull surfaces); • relocation of floatable oil/gas drilling rigs, dry docks, navy tenders; • recreational boating (hull surfaces, bait wells, bilge water and sediments, motors, associated tools, equipment, fishing gear); • media, containers and equipment used to transport or store live organisms (e.g., aquarium fish, plants, bait, aquaculture fish, fish stocking, research specimens, ornamental plants, pathogens); • fresh or frozen seafood transport and disposal; • human-created water connections (navigation canals, e.g., Erie and Welland canals); • interbasin water transfers (e.g., irrigation); • municipal/industrial water supply; and • natural pathways (e.g., waterfowl, tornadoes, hurricanes, other storms).

must shift rapidly from prevention to eradication and/or control. In so doing, the ultimate goal of the rapid response plan is to capitalize on the window of opportunity to stop the establishment of new harmful AIS shortly after introduction, after prevention efforts have failed. In the development and implementation of early detection and rapid response programs, environmental soundness (e.g., ecological integrity) must be maintained to avoid causing other ecological problems. It is critical that the rapid response component of the plan be established with a broad base of public and agency support to maximize opportunities for success in terms of funding and implementation. Therefore a specific goal of any viable program must be the building of consensus for the early detection and rapid response plan among stakeholders, particularly those who will play a role in plan implementation. Before a plan is introduced to the broader group of stakeholders, specific goals and objectives should be developed with consideration given to the following items:

- species specific information on AIS (e.g., taxonomy);
- habitat considerations;
- geographic and temporal issues;
- eradication/control tools available for use;
- institutional challenges; and
- legal/political issues related to plan implementation.

Eradication and Control of Established Populations

Eradication (e.g., complete elimination) of AIS is sometimes feasible, particularly if detected early in the invasion process, when the number of individual organisms would be expected to be low and the affected geographic area of the infestation would be small (Glassner-Shwayer 2000). In reality, eradication is often difficult and unlikely due to lack of early detection, insufficient monitoring and inability to respond to the invasion rapidly. Another obstacle to eradication is the tendency for environmental protection and resource management agencies to place low priority on invasive species introductions and overlook these concerns until the particular problem has escalated to the point of broad geographic distribution. Limited success stories are available on total eradication of invasive species in the country and none can be reported for the Great Lakes (Glassner-Shwayer 2000).

There are only limited tools available to respond to biological invasions through a rapid response plan designed to eradicate or aggressively control the spread of a species. These tools include physical/mechanical approaches (i.e., structural and electrical barriers, mechanical harvesters, etc.), chemical approaches (i.e., applications applied to poison a species) or biological approaches (i.e., introduction of predators, parasites, etc.).

Due to inherent limitations and problems with each of these approaches, it is critically important that planning activities involve the identification and assessment of specific existing management strategies and associated tools available for use in responding to an aquatic invasion (Table 19). Resources must also be committed to advance research and development of new approaches to expand the rapid response tool kit targeting those taxonomic groups where management experience is lacking.

Monitoring

It is recognized that there is a general lack of monitoring programs for AIS to aid in both early detection and in assessing the spread of established populations. Monitoring refers to keeping track of species, both in terms of historical distribution and abundance. Integral to good detection and monitoring efforts is ***reporting*** (an assessment and related publicity regarding the discovery of a new organism) and ***evaluation*** (an assessment of the potential impacts of new AIS).

In formulating programs to assist in detection, the focus is on species that are relatively new introductions and disruptive to the ecosystem rather than those species that are established and less environmentally disruptive. Species are generally detected in the following ways:

- **Random Event –** discoveries that occur by chance, often by the general public. Random searches through taxonomic databases and museum collections could possibly double or triple the number of species identified through this process;

- **Initial Detection –** field scientists conduct an informal survey for AIS during the normal course of scientific study because an awareness that new discoveries might occur. This awareness has increased in past decades, but is still probably less than five percent of total findings; and

- **Active** Pursuit - field scientists actively search for AIS on a random basis. This is

Table 19. Management objectives for eradication and/or control of AIS (U.S. Environmental Protection Agency 2004).
• Identify and evaluate available management options for eradication, control, containment, or impact mitigation associated with specific aquatic invasive species or taxonomic groups; • Identify and evaluate management options for containment and quarantine; • Determine which management options to implement by assessing the characteristics and requirements for using various physical/mechanical, biological, or chemical tools approved for application during a rapid response to newly discovered invasions; • Where applicable, secure pre-approval for tools needed to implement management strategies; • Secure access to the permitting process for application regarding scenarios involving high risk species and generic jurisdictional scenarios; • Encourage research and development to expand the tool kit targeting taxonomic groups where eradication and/or control measures have yet to be developed; • Ensure that all appropriate authorities participate in rapid response planning, to provide the operational and legal support needed to evaluate, select and implement management options.

- rare due to prohibitive costs. Exceptions include inspections of agricultural products and ballast water from commercial ships (Glassner-Shwayer 2000).

Monitoring efforts depend on funding availability; nevertheless, the following usually characterizes good monitoring programs. It is important to note that these monitoring programs are only as flexible as funding and vested interests allow.

- Individual taxonomic experts conduct monitoring on a case-by-case basis. This accounts for approximately 40 percent of past monitoring activities;

- Individuals in agencies conduct monitoring on a case-by-case basis with “stolen” time from other projects. This accounts for about half of AIS discoveries; and

- Agency designated to track distribution, abundance and impacts of species, conducts monitoring on a case-by-case or generic basis with allocated funding. There is active but fragmented organization between agencies in this model, which also relies on volunteer programs.

The Great Lakes Commission in its 2000 *Briefing Paper on Great Lakes Nonindigenous Invasive Species* developed recommendations to improve detection and monitoring programs for AIS (Table 20).

Table 20. Recommendations to improve AIS detection and monitoring programs (Glassner-Shwayer 2000).

- Develop regional NIS lists on a watershed basis;
- Provide incentives for taxonomic experts to detect, report or evaluate nonindigenous species;
- Establish a detection and monitoring approach that is more proactive;
- Decrease the time between detection and reporting;
- Evaluate the ecological and economic impacts and control options more quickly;
- Develop quick response teams with objective membership;
- Integrate detection as part of AIS research;
- Predict future invaders to facilitate early detection and prompt action;
- Develop regulatory support to facilitate action when eradication is still possible; and
- Establish an emergency funding source for eradication of new nonindigenous species.

Education/Outreach

The effectiveness of AIS response planning is highly dependent on education and outreach efforts applied during all phases of AIS invasions (pre-invasion, during the progression of the invasion and rapid response implementation, and post-response). Before an AIS invasion is discovered, education and outreach efforts are needed to cultivate an awareness and understanding among public and private stakeholders on the risks posed by an AIS invasion and the benefits (versus costs) of rapid response in mitigating those risks. Fundamental to this understanding is recognition of the potential ecological and economic costs of responding to invasions of nonindigenous species. An informed public that is aware of the threats posed by AIS invasions is very important in cultivating the political will needed for approval of rapid response plans. In the absence of consensus among the public stakeholders and governmental agencies, plan implementation can be weakened to the point of paralysis.

Upon approval of an AIS plan, public support needs to be maintained throughout the process of plan implementation with a focus on how early detection, rapid response and monitoring efforts are progressing in preventing the spread of the AIS invasion. Post-response education and outreach efforts should be undertaken to convey results of the AIS plan, including an evaluation regarding early detection and rapid response efforts. On an internal level within ISRO during all phases of rapid response planning, communication conducted by a primary coordinator needs to be established among team members and within the agency and across other agencies as necessary to ensure coordination and collaboration through out the entire process.

The Great Lakes Panel on Aquatic Nuisance Species fully recognizes the importance of education and outreach programming on invasive species problems plaguing the Great Lakes. The Panel revised its *Information/Education Strategy for ANS Prevention and Control* in 2001, which was previously developed in 1993 (Great Lakes Panel on Aquatic Nuisance Species 2001). A primary goal of the Great Lakes Panel's Information/Education (I/E) Strategy is to advance prevention of the introduction and dispersal of AIS within the Great Lakes by long-term efforts to raise awareness and understanding for the issue. To achieve this goal, the I/E strategy provides recommendations on how to modify behavior and measures practiced by target groups associated with invasive species problems. The I/E strategy also offers guidance on approaches to raise the profile of AIS problems in the region based on threats to ecological integrity and biodiversity of the Great Lakes. Such efforts are critical to securing the long-term political will and dedicated public resources needed to effectively addressing AIS problems in the Great Lakes.

To properly consider the importance of education and outreach programs, it will be helpful to understand one instance where lack of good education and outreach contributed to delays in implementing an effective AIS control plan. Upon discovery of the ruffe in Duluth Harbor in the early 1990s, a ruffe control plan was developed by federal and state programs to prevent the nuisance fish from spreading beyond Duluth Harbor. The proposed plan met public resistance due to the proposed use of chemical application and was not approved by state agencies at the last moment (Schmitz and Simberloff 2001). In retrospect, it could be said that a stronger outreach program was needed in the control plan to inform the public of greater risks of not taking action (thus leaving infestations uncontrolled, allowing further spread into the Great Lakes system) versus the ecological and economic costs of chemical application.

It is important to reiterate how critical it is to the success of rapid response planning to create the public will to allow for quick and effective action in the event of AIS invasions. In so doing, consideration should be given to broadening the scope of conservation ethics to include the prevention and control of invasive species, to garner public support as achieved by similar campaigns to prevent forest fires, encourage recycling and clean-up chemical pollution (Northeast Aquatic Nuisance Species Panel 2003). The first step in this endeavor is to develop societal awareness for the damaging consequences imposed by AIS invasions if left unchecked. It is the realization of the escalating ecological, economic and societal costs incurred by AIS invasions that will inevitably drive the need for rapid response and other AIS prevention and control strategies.

Appendix C-3 provides a project statement that calls for the development of an early detection and monitoring system and rapid response plan for AIS.

4. Atmospheric Deposition of Toxic Contaminants

i. Mercury Deposition and Aquatic Ecosystem Effects

Atmospheric deposition of mercury, listed as a priority pollutant by the U. S. Environmental Protection Agency, and its subsequent contamination of aquatic ecosystems has become a problem of national and global extent. Mercury deposited into lakes and streams undergoes aqueous phase chemical reactions to form toxic methylmercury, which is of greatest concern to human health. In the U.S. mercury makes more surface waters impaired for fishing than any other toxic contaminant. Currently, most states have mercury fish consumption advisories – such advisories were few to nonexistent 15-20 years ago. Although nearly all mercury in fish is methylmercury, the cycling of total mercury is of concern because an important environmental source of methylmercury is biological methylation (Grigal 2002).

Mercury is emitted into the air from anthropogenic and natural (e.g. volcanic eruptions) emission processes and from re-entrainment. [For example, 80 percent of the total anthropogenic emissions can be attributed to fossil fuel combustion (U.S. EPA 1997).] Re-entrained mercury originally came from both anthropogenic and natural emissions. Mercury is emitted in three forms -- elemental, oxidized, or particulate (U.S. EPA 1997). Once airborne, mercury in its different forms can chemically react and can be transported. Elemental mercury is not very reactive and can travel great distances. Eventually mercury is deposited, through wet or dry processes, into water bodies. All three forms of mercury can be dry deposited and the rates of deposition will vary depending on the deposition surface characteristics and meteorological conditions.

Once mercury is transformed into methylmercury via methylation, methylmercury enters the food chain and is bioaccumulated. Methylmercury accumulates at an ever-increasing rate as it moves up the food chain. Therefore, the threat of exposure is most severe to those animals at the top of the aquatic food chain and those animals and humans that feed on them. Elimination of methylmercury from fish tissue takes place very slowly, with tissue half-lives being on the order of months to years.

The chemistry of mercury is complex and its behavior difficult to predict in nature. Total mercury concentrations in the environment have not been found to be effective predictors of bioaccumulation in fish. Depending on physical, chemical and biological conditions at a site, mercury can remain largely tied up in sediments, released from particulate matter to other locations, or be taken up by aquatic biota where it may concentrate and become a threat to humans and other fish-eating animals (Ullrich *et al.* 2001). Although the precise factors controlling the accumulation of mercury in aquatic biota are not fully understood, it is clear that fish and other aquatic species are much more efficient in accumulating methylmercury than the inorganic forms that predominate in the environment. Thus, factors that influence the rate at which inorganic mercury is transformed to methylmercury also influence bioaccumulation as well.

There has been considerable confusion on the subject of methyl mercury versus total mercury. Much of the mercury in sediments can be in the inorganic form, so that total and methyl mercury measures in the same sediments can result in very different concentrations (Irwin *et al.* 1997). Another point of confusion related to total mercury versus methylmercury is the notion that most inorganic mercury is "locked up in the sediments" and no longer represents a biological hazard (Irwin *et al.* 1997). Inorganic mercury in sediments is often bound to sulfides and other compounds and generally represents less of an immediate biological hazard than organic (methylated) or other more mobile forms of mercury. However, there are mechanisms (flooding, bioturbation, release of sulfide gases, bacterial action, etc.) which tend to bring this presumably "locked up" mercury to the surface or up into the water column or even the atmosphere. Once this happens, methlylation and uptake mechanisms tend to transform these relatively harmless "locked up" forms of mercury into more hazardous and more bioavailable forms. At least part of the mercury in sediments is vertically mobile, which is a factor needing more study. Methylmercury moves from the sediments upwards into the water.

Although direct mercury deposition from the atmosphere can be important, terrestrial watersheds are the proximate source for most mercury in aquatic systems. Simply on an aerial basis, terrestrial watersheds receive more mercury from the atmosphere than do aquatic systems. Between 5 and 25 percent of atmospheric mercury deposited on upland terrestrial basins reaches associated lakes, contributing between 5 and 85 percent of the total mercury loading depending on the terrestrial-to-lake surface area ration (Grigal 2002). There is some evidence that the proportional contribution of mercury by terrestrial watersheds has increased as mercury loadings to the watersheds have increased with time (Lorey and Driscoll 1999).

The significance of the nonpoint contribution of mercury from terrestrial watersheds to aquatic systems depends on biogeochemical processes in the watershed, including deposition of atmospheric mercury, its storage in ecosystem components, its transfer among components, and its loss either as a gas or in solution. Although biogeochemical behavior of some nonpoint pollutants such as nitrogen and phosphorus is fairly well understood in terrestrial watersheds, understanding of mercury behavior is incomplete. From our perspective, research into the biogeochemical processing of mercury at ISRO could be fruitful. Indeed, Swackhammer and Hornbuckle (2003) encourage research at ISRO to better understand the processes of mercury cycling and bioaccumulation through linkages between atmospheric deposition, watershed processing, methylation, and transfer up the food web.

What are the sources and pathways of total mercury derived from atmospheric deposition to the lakes and streams (especially those that are inflows to lakes) in ISRO's forested watersheds from a biogeochemistry perspective? Research in the Northeast in small forested catchments is beginning to provide some answers to this question (http://vmc.snr.uvm.edu/CurrentIssues/CImercury.htm; http://wwwbrr.cr.usgs.gov/projects/SW_corrosion/sleepers/). Results to date suggest that up to 90 percent of atmospheric mercury is retained in the forest, mostly on the forest floor. It is accumulated and released from forests to streams during major hydrologic events. Stream water quality monitoring is currently looking at concentrations of mercury, dissolved organic carbon and several trace metals in soil and stream solutions, comparing the behavior of mercury with DOC and trace metals in these media, and using the results to identify factors that might affect the transport of dissolved mercury in an upland catchment. For example, both dissolved and particulate mercury were positively correlated with stream discharge in the Sleepers River in Vermont suggesting that most stream transport of mercury occurs during high-flow periods (Figure 23). Episodic export of particulate mercury during the highest flows appears to be the dominant mechanism of mercury movement. In addition, strong correlations were found between dissolved and particulate mercury and dissolved and particulate organic carbon fractions (Figure 24). Mercury export occurs principally in discrete episodes of high flow accompanied by large releases of particulate organic carbon. There are two possible explanations for these mercury-organic carbon correlations: 1) mercury in stream water represents a small fraction of incoming mercury in rain or snowmelt that avoids removal by the soil because it associates with a mobile organic carbon fraction or 2) mercury and organic carbon are flushed from a common source- the soil organic horizon by infiltrating meltwater or rising ground water. Although methylmercury *per se* is diluted with increasing flow during snowmelt in Sweden (Bishop *et al.* 1995), these episodic fluxes of total mercury may be the dominant source of mercury that is ultimately methylated and assimilated in the food web in downstream waters.

This close relationship between mercury and dissolved organic carbon is well documented (Joslin 1994). This relationship is considered to have strong explanatory power for the transport of mercury from terrestrial to aquatic systems (Driscoll *et al.* 1995). In spite of similarities across the Northern Hemisphere, such as similar slopes of about 0.2 ng mercury per 1 mg dissolved organic carbon, there are regional and local differences in the mercury-dissolved organic carbon relationship (Grigal 2002). This would be one of many research avenues to explore at ISRO.

Additionally, we recommend that ISRO encourage future research in ecotoxicology. Mercury is among the most extensively studied of all the environmental pollutants, but the information on the distribution in various environmental or body compartments exceed information on effects at the organism, population and ecosystem level. There remain substantial gaps in our understanding of the effects of mercury on different kinds of organisms, on different trophic levels, and on ecosystem function itself. Ecological effects can be measured by some impacts on microorganisms, plants, and animals that make up the decomposer, producer, and consumer trophic levels of ecosystems. The endpoints in individuals exposed to mercury can include changes in behavior, physiology, reproduction, or longevity, as well as acute effects such as morbidity and mortality. Endpoints among species can include changes in survivorship and population structure, population declines or local extinction. Ecological endpoints include changes among species interactions, usually reflected in food webs, as well as in the cycling of matter or the patterns of energy use and production.

From the standpoint of monitoring, we highly recommend that the mercury in surface waters, both elemental and methylmercury, be added as a measurement parameter to the inland lake water quality monitoring program for ISRO being developed by the Great

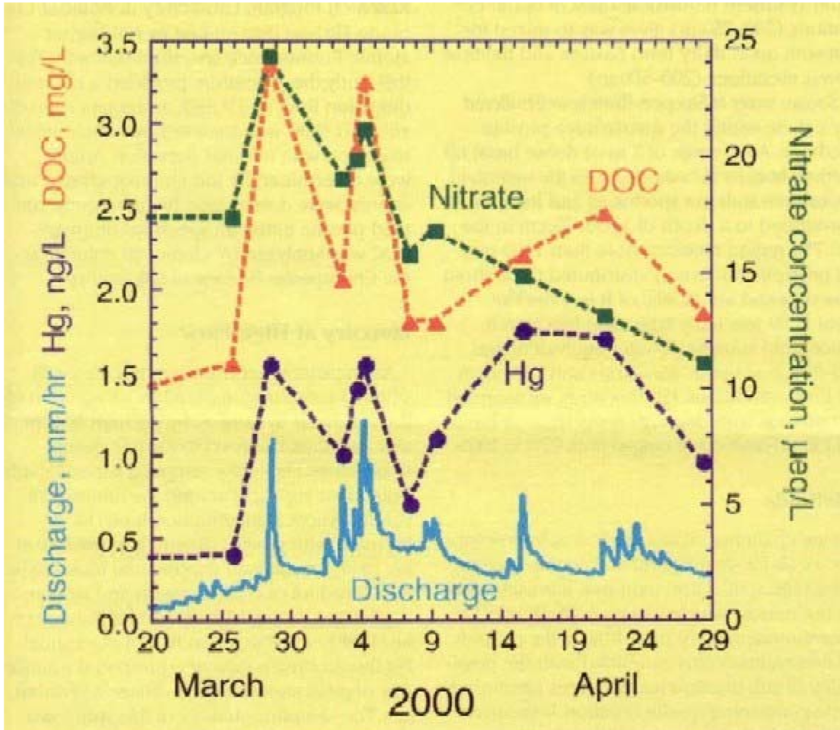


Figure 23. Relationship of mercury (Hg), dissolved organic carbon (DOC), and nitrate with discharge during the snowmelt period in the Sleepers River, Vermont (http://wwwbrr.cr.usgs.gov/projects/SW_corrosion/sleepers/).

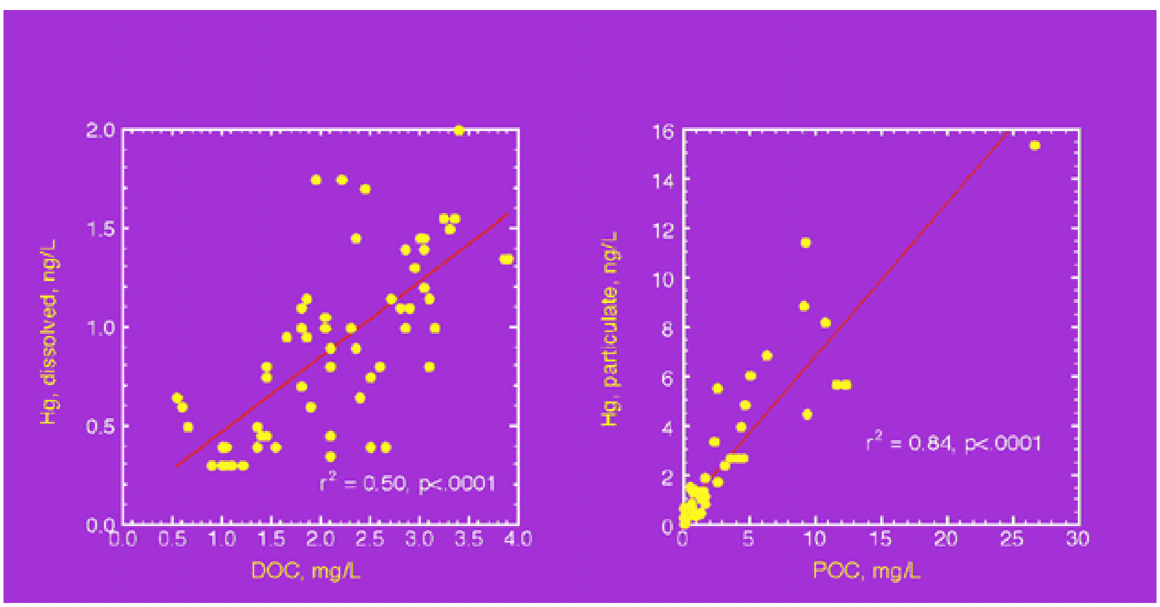


Figure 24. Relationships of the dissolved and particulate factions of mercury (Hg) and organic carbon [D(dissolved)OC and P(particulate)OC] in the SleepersRiver, Vermont (http://wwwbrr.cr.usgs.gov/projects/SW_corrosion/sleepers/).

Lakes Inventory and Monitoring Network. Ideally, mercury and methylmercury should be sampled via profiles throughout the water column, but this may be cost prohibitive. We also recommend sediment depth mercury profiles at a frequency of every 4-6 years. We concur with Swackhammer and Hornbuckle (2003) that a trend monitoring program for contaminants of concern in fish is needed. This would include mercury as well as a select set of organic contaminants of concern, i.e., PCBs, PCDD/PCDF, PBCEs, PFOs, and chlorinated pesticides. The Michigan Department of Natural Resources analyzes lake trout from Lake Superior waters and Siskiwit Lake for a wide range of contaminants, including mercury. However, this program should be expanded to the core lakes in the proposed inland lakes water quality monitoring program because of differences among lakes in bioavailability of methylmercury and food webs (Gorski *et al.* 2003).

B. Medium Priority Issues

1. Pollution from Boats / Effects of Polycyclic Aromatic Hydrocarbons (PAHs)

There are no roads in Isle Royal National Park. Except for a small concentrated area on Mott Island in the park administration center, there are no wheeled vehicles (motorized or unmotorized including bicycles) allowed in the park. Excluding recreational hiking activity and foot patrols and land movement by park personnel and rangers, all transportation of park personnel, visitors, equipment, supplies, fuel, construction materials, etc. is done via boat traffic in motorized boats in and around park waters. There is a small amount of sea plane traffic which lands and takes off in local waters of the park. Table 21 shows total island visitors and boat traffic into ISRO. Over the past 15 years, the average number of private boaters visiting the park was 1332 per year. Visits by boater tended to stay in park waters after arriving, with the average number of over night stays by boaters at 13,478 per year.

A 2004 boat inventory of ISRO equipment lists 36 motorized craft in use by park personnel. The largest vessel listed is the Ranger III, a 165-foot ferry running between Houghton, MI and the park on weekly trips during the park open season. The Ranger III is the largest ship in service in the NPS. Also included in the inventory is a 110-foot crane barge, an 81-foot fuel barge, a tug boat and a 70-foot maintenance vessel. The vast majority of the vessels listed are 16- to 31-foot motorized work and patrol boats. These range in size from 25 horse-power outboard engines to a 31 foot vessel powered by a Twin-Cat 3208 engine. These vessels are used on a daily bases throughout the park. As of this writing no data could be found on the total number of water miles that these vessels log on a per year bases within the park boundaries (NPS 2005).

Several harbors in the park receive heavy traffic from NPS maintenance and administrative activities, five large concessionaire ferries, and private boat traffic. Motor boating use is unregulated on the Lake Superior waters within the park. Docking facilities are located in protected harbors where there is less mixing of the water compared to the open waters of Lake Superior. Although the inland lakes are within

Table 21: Isle Royale National Park boating use 1989-2003 (NPS 2004).

Year	Total Island Visitation	Private Boats	Private Boaters	Private Boater Overnights
1989	15,824	1,493	5,091	17,554
1990	16,258	1,516	5,452	18,026
1991	16,468	1,692	5,782	17,933
1992	16,751	1,580	5,368	16,519
1993	16,625	1,680	5,625	17,635
1994	18,725	1,928	6,408	18,820
1995	18,488	1,592	5,539	16,547
1996	17,122	1,442	4,859	14,988
1997	15,409	1,263	4,206	12,829
1998	16,709	1,335	4,467	12,775
1999	16,809	1,166	3,833	10,472
2000	15,602	1,021	3,335	9,700
2001	15,306	840	2,748	9,123
2002*	14,692	563	1,819	4,357
2003	14,551	875	2,881	4,899
15 Year Average	**16,356**	**1,332**	**4,494**	**13,478**

*Permitting computer in Grand Marias, MN crashed, and a significant number of boating permits were lost.

designated wilderness and thus motor boating is prohibited there, atmospheric deposition of exhaust compounds from motor boat activity in and around the park is a concern, given the atmospheric deposition of other contaminants in park inland lakes (Clements 2002). No baseline information exists for the extent of motorboat fuel contaminants in the park, despite extensive motorboat use. The park's recently completed General Management Plan (GMP) acknowledged public concerns regarding pollution from motorboat use and proposed a baseline assessment of park waters. Because some fuel-based contaminants accumulate in aquatic sediments, persist for years, and are highly toxic, there is likelihood that some ISRO harbors are contaminated and suffering ecological harm.

Nearly all personal watercraft (PWC) utilize conventional two-stroke engines. As much as 30 percent of the fuel used by these engines is discharged unburned into water (California EPA 1999). At common fuel consumption rates, an average 2-hour ride may discharge 3 gallons of the gas-oil mixture into the water. As a result, the use of PWCs has resulted in measurable water quality degradation in the nation’s lakes and reservoirs (VanMouwerik and Hagemann 1999).

The two-stroke engine intakes a mixture of air, gasoline, and oil into the combustion chamber, while exhaust gases are expelled from the combustion chamber. Since the intake and exhaust processes are occurring at the same time, it is unavoidable that some of the unburned fuel mixture will escape with the exhaust. This expulsion of unburned fuel is the reason for the elevated levels of hydrocarbon emissions from conventional two-stroke engines. Hydrocarbon emission levels for conventional two-stroke outboard motors, range from approximately 100 grams/kw-hr to more than 300 grams/kw-hr (VanMouwerik and Hagemann 1999). Based on average use, a typical conventional two-stroke outboard will expel as much as 30 percent of the incoming fuel mixture, unburned, via the exhaust.

The following fuel components are discharged to receiving water: benzene, toluene, ethyl benzene, xylene (collectively called BTEX), and methyl tertiary butyl ether (MTBE). Polycyclic aromatic hydrocarbons (PAHs) are discharged to water in small amounts as part of the unburned fuel and in much larger amounts as part of the exhaust from engine combustion. Because of its chemical characteristics, BTEX readily transfers from the water to air, whereas MTBE and PAHs do not. MTBE and PAHs have been found in lakes and reservoirs with PWC usage, sometimes at levels in excess of human health and ecologic risk standards (VanMouwerik and Hagemann 1999).

Polycyclic aromatic hydrocarbons are ubiquitous contaminants of freshwater and marine ecosystems (see reviews by Neff 1979, Johnson *et al.* 1985, Eisler 1987). The primary sources of PAHs to aquatic ecosystems are industrial discharges, urban runoff, deposition of airborne particulates, and petrochemical spills. Because of their persistence (Eisler 1987), acute toxicity (Swartz *et al.* 1990), potential to bioaccumulate, and widespread distribution (Payne *et al.* 1988, Marcus *et al.* 1988), concerns over fate and effects of PAHs have increased in recent years. In addition, certain classes of PAHs, especially the 5- and 6-ring compounds, are among the most carcinogenic compounds known to exist (Malins *et al.* 1987, Metcalfe *et al.* 1988). In aquatic environments, PAHs are partitioned between water, sediments, interstitial water, and organisms (Eisler 1987). However, the greatest proportion of these contaminants is associated with sediments (Varanasi *et al.* 1985, Marcus *et al.* 1988). Levels of PAHs in sediments and interstitial water are often several orders of magnitude greater than concentrations in overlying water (Neff 1979; Eisler 1987).

High levels of PAHs have been associated with marinas and other areas receiving heavy motorboat activity (Smith *et al.* 1985, Voudrias and Smith 1986, Marcus *et al.* 1988). Motor exhausts, accidental fuel spills, and routine maintenance near marinas result in pulsed releases of PAHs to sediments. For example, surveys of marine sediments at sites frequented by motorboats in the Great Barrier Reef reported that concentrations of total PAHs exceeded 1300 μg/kg. Background concentrations at nearby reference sites were generally less than 1.0 μg/kg. Eisler (1987) noted that the highest concentrations of PAHs measured in Cayuga Lake (New York) were associated with marinas. Finally, Marcus *et al.* (1988) reported significantly elevated levels of PAHs in sediments collected near marinas in South Carolina. Results showed that the level of motorboat activity and sediment particle size influenced concentrations of total PAHs in sediments.

Although sediments are a major repository for PAHs in aquatic systems, they are not the ultimate sink for these contaminants (Reynoldson 1987). Owing to various physical, chemical, and biological processes, PAHs in sediments may be rapidly mobilized and made available to aquatic organisms. Carcinogenic PAHs have been identified in stomach contents of bottom-feeding fish, indicating the likelihood of dietary uptake of these compounds (Maccubbin *et al.* 1985, Malins *et al.* 1987). Because of their close association with sediments and importance in aquatic food chains, benthic invertebrates play an important role in the transfer of PAHs to higher trophic levels (Clements *et al.* 1994). Since levels of PAHs in sediments and associated benthic invertebrates are generally much greater than in overlying water, it follows that accumulation from food and sediments may be substantial.

Cox and Clements (2004) evaluated the impacts of PAHs on aquatic communities in ISRO through an integrated analysis of sediments, benthic community structure, and sediment toxicity. The strength of an integrated analysis is the weight of evidence approach and its ability to distinguish direct toxicological effects from natural variation in habitat characteristics. Twelve sites were selected along a gradient of motorboat activity. Cox and Clements are still in the analysis stage and the following was provided by Will Clements (personal communication, Colorado State University, 2005). They found that PAH concentrations in sediments at marinas were at threshold levels established in the scientific literature that affect macroinvertebrate communities. Marinas always separated out from reference sites based on PAH concentrations in sediments. Also, PAH concentrations were much reduced beyond the marinas; however, because the objective of the study was to determine if PAHs were present, no gradient analysis of PAH concentrations in sediments were performed. Sediment toxicity tests (using the amphipod *Hyalla*) demonstrated acute toxicity at two of the three marinas – more than twice the mortality at marinas compared to reference sites. The response of the benthic community was fairly subtle in response to PAH concentrations, but multivariate statistical analyses always separated reference sites from test sites. The amphipod *Diporiea*, specifically used in sediment toxicity test in the Great Lakes region, showed the most consistent macroinvertebrate response at marinas – a reduction.

In an effort to further evaluate the impact of PAH's on the ISRO ecosystem, park managers should encourage additional research that will identify the gradient in PAH concentrations in sediment as one proceeds away from marinas, i.e. to define the area of impact. Research should also be encouraged that would determine if any correlation exists between the number (and/or kinds) of boats at marinas versus sediment concentrations of PAHs. Furthermore, research into the concentration of PAHs in organisms should be performed and related to any ecotoxicological effects – *Hexagenia*, a mayfly, may be a good test organism in this case (W. Clement, Colorado State University, personal communication, 2005). Management response to PAHs contamination can only be based on the assembly of an adequate information base.

As this additional research is funded and proceeds, ISRO management should consider the development of a long-term program to monitor PAH concentrations in sediments.

2. Aquatic-based Effects of Climate Change

Freshwaters are naturally rich in biological diversity but many of the fauna associated with freshwater ecosystems are under the threat of extinction because of human activities (Meyer *et al.* 1999). A changing climate may intensify these threats in many ways, such as the spread of exotic species, changes in numbers and types of species because of warmer temperatures, and changes in precipitation and changes in human activities and living patterns due to a warming climate. These anthropogenic changes might include such things as structural changes for flood control or building additional water supply reservoirs, etc. While important to the region as a whole, these human induced changes may be less significant for ISRO. The expected changes to ISRO will relate more to how a changing climate affects the hydrology of the island and the subsequent impacts that may occur as a result of those changes.

i. Potential Impacts on Fluvial Ecosystems

Apart from extreme rainfall events, summer rainfall in the Great Lakes region is expected to decline in the future due to climate change, especially in the southern and western portions of the basin. Drier conditions will translate into lower summer stream flow and reduced and lower quality stream habitat. Expected aquatic impacts associated with summer drought conditions will be warmer water temperatures, depleted dissolved oxygen levels, higher concentrations of contaminants as water volumes decline, and reduced transport of nutrients and organic matter and disruption of normal food webs (Union of Concerned Scientists 2003).

In small streams, where flow comes primarily from surface runoff, as many as 50 percent will stop flowing if annual runoff decreases by 10 percent or more. Another consequence of periodic drought may be the occurrence of a strong acid pulse to streams and small lakes in the watershed due to an increase in sulfates that are mobilized during post-drought rains. Streams and small lakes in the Great Lakes region most susceptible to acid-related impacts are those on the Canadian shield of Ontario, along the higher gradients reaches of streams in New York and in northern Michigan, Minnesota and Wisconsin. This may include the streams and lakes on ISRO. Table 22 shows the potential impacts of climate change on stream ecosystems in more detail.

ii. Potential Impacts on Lacustrine Ecosystems

In smaller lakes, primary production is controlled by a combination of temperature, light and nutrients. Increases in algal growth caused by excessive nutrients can lead to eutrophication causing noxious algal blooms and degraded water quality. On the other hand, drops in primary production in lakes can ultimately reduce fish production. Research indicates that the expected longer ice-free periods in the Great Lakes region and higher future surface water temperatures will spur greater algal growth (Union of Concerned Scientists 2003). Changes in the species composition of algae and in seasonal

Table 22. Potential impacts of climate change on stream ecosystems (from Union of Concerned Scientists 2003).

Climate-Driven Change	**Likely Impacts on Physical and Chemical Properties**	**Likely Impacts on Ecosystem Properties**	**Intensifying or Confounding Factors**
Earlier ice-out and snow melt	• Peak flows occur earlier. • Ephemeral streams dry earlier in the season. • Backwater pools experience anoxia earlier.	The timing of fish and insect life cycles could be disrupted.	Snowmelt occurs earlier and faster in urban areas and where coniferous forest harvest has occurred.
Lower summer water levels	• More headwater streams dry; more perennial streams become intermittent. • Concentrations of dissolved organic carbon decrease thereby reducing ultraviolet-B attenuation. • Groundwater recharge is reduced.	• Habitat decreases in extent. • Hydrologic connections to the riparian zone are reduced. • Groundwater recharge is reduced. • Species with resting life stages or rapid colonizers dominate communities.	Impervious surfaces and impervious soils exacerbate stream drying due to reduction in infiltration and groundwater recharge.
More precipitation in winter and spring and increased water levels	• Spring floods reach greater heights. • Surface runoff increases. • Nutrient and sediment retention decrease. • Groundwater recharge potential increases.	• Floodplain habitat for fish and invertebrates grows. • Hydrologic connections with wetlands increase.	Precipitation occurring when soils are frozen results in higher runoff and increases flood height.

Warmer temperatures	Stream and groundwater temperatures increase.	• The rates of decomposition and respiration increase. • Insects emerge earlier. • Primary and secondary production per unit of biomass increases when nutrients are not limited; however, total production could decrease if aquatic habitat shrinks under drought conditions.	• Impervious surfaces and both natural and human-made retention basins increase water temperatures. • Woody riparian vegetation can buffer stream temperatures. • In areas with porous soils and active groundwater connections, temperature extremes are smaller.
More frequent heavy rainfall events	• Larger floods occur more frequently. • Erosion and pollutant inputs from upland sources increase. • Runoff increases relative to infiltration.	• Fish and invertebrate production decreases. • Fish and insect life histories and food webs are disrupted by changes in the intensity, duration, and frequency of flooding.	• Impervious surfaces increase runoff and stream flow. • Channelized streams increase peak flow.
Elevated atmospheric CO_2		Possible changes in leaf litter quality could impact aquatic food webs.	

patterns of blooms are also likely consequences of climate change. Earlier ice-out (thaw of lake ice) and spring runoff will shift the timing of the spring algal blooms. Earlier and longer periods of summer stratification will tend to shift dominance in the algal community during the growing season from diatoms to inedible blue-green algae (Table 23; Union of Concerned Scientists 2003).

iii. Impacts on Biodiversity and Food Webs

In general, a warming climate, combined with land-use changes and other anthropogenic influences, and the introduction of aquatic invasive species will pose a great threat to biodiversity in the coming century (Union of Concerned Scientists 2003). Again, the expected impacts to ISRO may be softened as long as human-induced changes to the island are kept to a minimum. Native plants and animals will differ widely in their responses to a warming climate, and subsequent impacts to aquatic ecosystems caused by increases to stream temperature and alterations to hydrology. Some species will respond by adapting to warmer temperatures, expanding their ranges northward or reducing their ranges to areas where temperatures and flow patterns remain stable and suitable. Insects and plants that have resistant or mobile life history stages (larvae, cysts, seeds) will survive better than other organisms during periods of reduced water levels and flows.

Table 23. Expected effects of climate change on lakes and subsequent impacts on algal productivity (Union of Concerned Scientists 2003).

Climate Driven Change	Impacts on Production	Most Sensitive Lake Type
Increases in both ice-free period and maximum summer water temperature	Increase in production	Moderate in surface area, depth and nutrient concentration
Increase in duration of summer stratification and loss of fall top-to-bottom mixing period	Decrease in production caused by decrease in nutrient regeneration rates	Deep and oligotrophic, nutrient poor (e.g., Lake Ontario Lake Superior)
Drought-induced decrease in lake water volume	Initial increase in production, followed by progressive decrease at the lake level declines	Small and shallow
Drought-induced decrease in annual input of nutrients (phosphorus) and dissolved organic carbon	Decrease in production resulting from nutrient limitation	Small and oligotrophic

Fish species at higher risk may be those that have small geographic ranges, require steady water flows or specific and narrow habitat requirements, reproduce at older ages or require specific foods (Union of Concerned Scientists 2003). Another potential impact on stream food webs comes directly from increasing atmospheric levels of CO_2. Studies indicate that plant leaves grown under elevated CO_2 levels have lower food value. If these changes in leaf chemistry turn out to be significant, they could slow microbial decomposition of plant material that falls into streams, reducing growth and survival of some insects that feed on these leaves. Such impacts would be magnified up the food chain (Union of Concerned Scientists 2003).

iv. Potential Impacts on Wetland Ecosystems

Wetlands along the Great Lakes occur as three distinct types: fringing coastal marshes that are directly impacted by lake levels and wave action, riverine wetlands that are partially influenced by both lake and river and protected lagoons or barrier beach systems that are hydrologically connected to the lake only via groundwater. Inland wetlands are even more diverse and range from entirely rain-driven systems such as bogs and fens, to riparian wetlands fed by contributions from both surface and groundwater. Bogs and fens cover extensive areas in the northern Great Lakes region and contain a wide-range of acid loving plants. All wetland types are sensitive to hydrologic alterations that are likely to accompany climate change (Union of Concerned Scientists 2003). The largest expected impacts to wetlands will be to rainfall-dependent types, since wetlands that are largely recharged by groundwater are more resistant to climate related changes. Projected decreases in summer rainfall in the southern and western portions of the Great Lakes region will also cause drying of prairie potholes and similar depressional wetlands.

Wetlands serve as the main interface for moving nutrients and sediments from land to water. Decreased runoff from the land in summer months will decrease the deposition of material from uplands into wetlands. The materials that do not enter wetlands will be retained longer on the land and high water pulses from storm events will wash these materials directly into streams and lakes.

Carbon stored in wetland soils may also be lost to the atmosphere in a warming climate. Northern peatlands such as those found in northern Michigan, Minnesota and Ontario normally form when cold temperatures and waterlogged soils limit the rate of decomposition of carbon-rich plant matter. Warmer temperatures are likely to increase the rate of organic matter decomposition and accelerate carbon release to the atmosphere in the form of CO_2. Carbon release from wetlands in the form of methane, which is 25 times more potent than CO_2, will also increase as a result of warmer temperatures and higher water levels (Union of Concerned Scientists 2003).

Reduced stream flow in summer will decrease the amount of dissolved organic carbon washed from the land into wetlands and other surface waters. Less dissolved organic carbon results in clearer water which allows higher doses of ultraviolet-B radiation to penetrate further into the water column. Organisms such as frogs living in shallow waters will be at greater risk because ultraviolet-B radiation penetration is generally restricted to the top 2 to 8 inches of surface water. In deeper waters, organisms can find refuge from the harmful radiation.

Earlier spring or summer drying of ephemeral wetlands will threaten the reproductive success of certain species such as the wood frog (*Rana sylvatica*) and many salamanders in the Great Lakes region. Wetland losses and degradation also threaten to drive certain songbirds such as the Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*) to local extinction in some parts of the Great Lakes region. This songbird's habitat is restricted to a small subset of marshes that have suitable vegetation in any given year as a result of fluctuating water levels. Changes in water levels caused by increases in spring rains or summer drying might render remaining marshes unusable by this bird.

Most aquatic birds in the Great Lakes region depend upon seasonal flooding and gradual drops in water levels. Changes in the timing and severity of floods will affect the availability of safe breeding sites for birds and amphibians as well. Finally, the availability of seasonal mudflats for migratory shorebirds and endangered beach-nesting species such as the piping plover will be affected by the drying and loss of wetlands.

Table 24 summarizes the expected impacts of climate change on wetland ecosystems.

Although there are significant uncertainties associated with projections in climate change there is enough evidence to suggest that the threat of global climate change to the Great Lakes region and to Isle Royale, in particular, is significant enough to alert park management and to recommend further research on the potential effects of climate change on the park's water resources. Such research already exists in the form of an unfunded project statement that exists as Project Number 73188 in PMIS. This project statement (Appendix C-4) addresses how increasing temperatures will increase dissolve organic carbon (DOC) and dissolved organic nitrogen (DON) export to lakes, and could

Table 24. Potential impacts of climate change on wetland ecosystems (Union of Concerned Scientists 2003).

Climate-Driven Change	Likely Impacts on Physical Properties	Likely Impacts on Ecosystems	Intensifying or Confounding Variables
Earlier ice-out and snow melt	Wet periods are shorter, especially in ephemeral wetlands.	• Fast developing insect and amphibian species are favored as are species with resting stages. • The timing of amphibian and insect life cycles could be disrupted.	• Snowmelt occurs earlier and faster in urban areas and where coniferous forest harvest has occurred.
Lower summer water levels	• Isolation and fragmentation within wetland complexes increase. • Fens store less carbon. • Reductions in dissolved organic carbon result in less attenuation of ultraviolet-B radiation.	• Habitat and migration corridors are reduced as are hydrologic connections to riparian zones and groundwater recharge. • Emergent vegetation and shrubs dominate plant communities. • Amphibian and fish reproduction fails more often in dry years. • Organisms with poor dispersal abilities become extinct.	• Agricultural and urban development exacerbate fragmentation effects.
Warmer temperatures	• Evaporative losses increase. • Fens and bogs store less carbon.	• The rates of decomposition and respiration increase. • Insects emerge earlier. • Primary and secondary production per unit of biomass increase when nutrients are not limited. • Species at the southern extent of the range become extinct.	• Impervious surfaces increase water temperatures. • More competition from invasive species may accelerate extinctions.
More frequent heavy rainfall events	Wetlands increase in extent.	• Habitat area increases. • Ground-nesting birds may be lost during flood events.	• Wetland losses from development reduce flood storage capacity.
Elevated atmospheric CO_2		Possible changes in leaf litter quality could impact aquatic food webs.	

alter concentrations sufficiently to reduce production efficiency at the base of the aquatic food web.

We do not recommend any long-term monitoring program that would specifically address the impacts from climate change. This is primarily because the long-term lake monitoring program, as presently envisioned by the Great Lakes Inventory and Monitoring Network, incorporates monitoring parameters that would be indicative of climate change. Those parameters would allow an assessment of both direct and indirect effects on ISRO's aquatic systems. For instance, an increase in air temperature due to global warming will translate into warmer water temperatures for lakes and most streams and rivers, thereby altering fundamental ecological processes. A warming of water temperatures by 4^{o} C in current ecosystems would represent a northward latitudinal shift in thermal regimes of about 422 miles (680 km), and this would have serious consequences for aquatic ecosystems (Sweeney *et al*. 1992). Warmer water holds less dissolved oxygen, so water quality will be reduced for organisms that have a high oxygen demand. The warming of lakes will increase the potential for production of nuisance algae. As these algae die and fall into deeper waters, bacteria and other benthic organisms consume them and deplete oxygen in the lower depths. This depletion of oxygen means that by late summer these deep waters may become marginal habitats for many invertebrates and fish. As surface waters become warmer, the ratio of mercury methylation to demethylation should increase (Ramlal *et al.* 1993), causing greater contamination of aquatic fauna (Bodaly *et al.* 1993).

Moore *et al.* (1997) noted that increased water temperatures enhance the toxicity of metals in aquatic ecosystems and that increased lengths of biological activity could lead to increased accumulation of toxics in organisms. Ironically, increased bioaccumulation could decrease the concentration of toxics in the water column, improving local water quality. Similarly, higher temperatures may lead to increased transfer of chemicals from the water column to sediments.

One of the most direct effects will be reduced lake levels, although areas that become wetter could have higher lake levels. Permanent lowering of lake levels will expose more shoreline, possibly harming productive littoral zones and associated wetlands. Many lake-fringing wetlands may become isolated, reducing habitat for fish that require wetlands for spawning and nursery habitat.

In north temperate regions, DOC concentrations are projected to decrease because of reduced runoff from drier catchments, resulting in increases in water clarity, thermocline depth, productivity, and UV-B penetration. Schindler (1997) estimated that this latter effect could lead to a greater exposure of aquatic animals to ultraviolet radiation than would result from reductions in the stratospheric ozone layer. Extended droughts in the boreal regions have been shown to result in acidification of streams due to oxidation of organic sulfur pools in soils (Schindler 1997).

Aside from its importance as a nutrient, DOC absorbs the light energy passing through the lake's water column. A reduction in the delivery of DOC to lakes allows light to

penetrate more deeply, thereby heating the lake to greater depths. If incoming stream flow is reduced, warmer, less-oxygenated water may extend to deeper levels in lakes. This reduces the cool-water habitat refuge of deep water that many fish require.
The deeper penetration of UV because of DOC declines would presumably allow greater conversion of methyl mercury to elemental mercury, the form susceptible to loss to the atmosphere. Once in the atmosphere, mercury is susceptible to long-range transport and biomagnification in distant food chains (Schindler 1997).

3. Bathymetric Mapping

Bathymetry is the science of measuring and mapping the depths of a water body (oceans, seas, lakes) to show the topography of their basins. Bathymetric maps are two-dimensional representations of the 3-dimensional shape of these basins and provide the perspective and geospatial reference needed to understand the field relationships between sample locations and habitat types, depth of the water column, or proximity to major underwater features.

Detailed bathymetric data are the most basic and oldest form of information needed about a body of water. In fact, some of the earliest organized scientific surveys of the Great Lakes, conducted by the U.S. Army Corps of Engineers in the 1840's for nautical charting purposes, were established to obtain soundings.

Bathymetric information is specifically needed and important for habitat mapping. As a recent example of the importance of bathymetry in the Great Lakes, high resolution charts completed by NOAA's Great Lakes Environmental Research Laboratory, allowed better definition of the boundaries of the Six Fathom Bank Lake Trout Refuge in Lake Huron. This is important because some fisheries are depth dependent and one key statistic of interest to many fisheries scientists is the total bottom area between two depth contours, which can only be obtained from detailed processed bathymetric information. Bathymetric information is also necessary for circulation and coastal forecasting models and it is the only way to visualize underwater topography for educational purposes (U.S. Department of Commerce 2004).

Good bathymetric charts are in demand by sport and commercial fishing interests, museums, schools, and citizen groups. Engineering firms often benefit from bathymetric information for siting of pipes and cables. Almost any study of the Great Lakes has some use or need for good bathymetric information.

Much geological and geophysical data were collected in the Great Lakes during the last 150 years and there are extensive holdings of sounding data in both the U.S. and Canadian government archives. Good quality data have been collected since about 1903, when the standard physical data in use for bathymetric surveying were first established. Historic bathymetric data were collected mainly by the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration (NOAA) - National Ocean Service (NOS), and the Canadian Hydrographic Service. It is estimated that total Great Lakes data holdings between the U.S. and Canada include several million soundings.

Updating and improving bathymetric data has received priority attention for all of the coastal areas of the United States except for the Great Lakes. Beginning in the late 1980s an effort began under the National Ocean Service (NOS) of NOAA to improve the bathymetric data for the coastal areas considered part of the exclusive economic zone (EEZ).

The exclusive economic zone is "the area adjacent to a coastal state which encompasses all waters between: (a) the seaward boundary of that state, (b) a line on which each point is 200 nautical miles (370.40 km) from the baseline from which the territorial sea of the coastal state is measured (except when other international boundaries need to be accommodated), and (c) the maritime boundaries agreed between that state and the neighboring states (United Nations FAO Glossary)." In simpler terms, it is a zone under national jurisdiction (up to 200-nautical miles wide) within which the coastal State has the right to explore and exploit, and the responsibility to conserve and manage, living and non-living resources (United Nations Atlas 2004).

The Great Lakes are not considered part of the EEZ because there are no international waters in the Great Lakes as defined under the 1982 United Nations Convention of the Law of the Sea which established the EEZ. All waters in the Great Lakes are either U.S. waters or Canadian waters (D. Knight, pers. comm., Great Lakes Commission 2004).

Until the 1990s, sounding data for the Great Lakes had not been fully utilized for bathymetry purposes and were therefore unavailable to the potential user communities in both the United States and Canada (D. Reid, pers. comm., National Oceanic and Atmospheric Administration, GLERL 2004).

In the early 1990s a cooperative effort involving federal agencies and research entities was begun to develop highly detailed bathymetric maps of the Great Lakes. The groups involved in this effort include: NOAA's Great Lakes Environmental Research Laboratory, Ann Arbor, MI, NOAA's National Geophysical Data Center (NGDC), Boulder, Colorado, the Canadian Hydrographic Service, Ottawa, Canada, the Cooperative Institute for Limnology and Ecosystems Research, University of Michigan, Ann Arbor, MI and the Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder.

The cooperative effort described above is proceeding based upon the availability of resources. This effort relies on existing data obtained through the last full topographic survey of Lake Superior in the early 1970s. Surveys of smaller areas occur on a regular basis by the U.S. Army Corps of Engineers in order to maintain the shipping channels and the navigable waters of the United States.

Using available data, there is a two-step process toward completing a detailed bathymetric map. The first phase involves the development of hand drawn contour maps. The second phase involves the digitizing of these maps. For U.S. waters of Lake Superior, a small portion of the western end of the Lake from Duluth-Superior Harbor to the far western end of Isle Royale and south to the base of the Keewenaw Peninsula has been contoured and digitized. The U.S. waters south and east of ISRO have been contoured but not digitized. No contouring or digitization has occurred for the Canadian waters of Lake Superior (Reid 2004).

Bathymetry maps will be important for both the inland lakes and the park waters of Lake Superior for the purpose of aquatic biota habitat mapping. It is recommended that ISRO consider taking the following activities and steps to improve its bathymetric data:

- Encourage NOAA and the Army Corps of Engineers to facilitate the completion of bathymetric charts (both contouring and digitizing) for all of Lake Superior;
- Work with the State of Michigan and USGS to initiate a bathymetric mapping program for the inland lakes; and
- Establish a cooperative agreement with NOAA's Great Lakes Environmental Research Laboratory and the NGDC in Boulder to complete the bathymetric charts for the surrounding waters of ISRO.

C. Further Recommendations

1. Partnerships

Isle Royale National Park is charged with protecting a vast set of natural, wilderness, marine, and cultural resources in an extensive freshwater archipelago for use and enjoyment of the public. As with other national parks and other government agencies in general, the park faces many of the same financial complexities resulting from expanding responsibilities and decreasing funding sources. Like other National Parks, ISRO must deal with issues involving maintenance backlogs, deficient funding for demands of basic operations and a current inability to invest fully in priority resource areas. Isle Royale's situation is unique when compared to other National Parks. It is the only park in the system to fully shut down during the winter due to access limitations in severe weather months. The relatively short tourist season limits the park's revenues from visitor's user fees, concessionaire fees, and permits. The harsh winter maritime climate takes its toll on building structures, docks, and other facilities. Winter closure necessitates an intense six month work period when all in-park work activities must be accomplished safely within strict regulatory standards. The seasonal closing also presents difficulties in recruiting and retaining skilled personnel (NPS 2002c).

According to the ISRO Business Plan, Fiscal Year 2001, funding for the park has remained flat in real dollar terms since 1980. Park costs have increased due to new regulatory requirements such as the Oil Pollution Act of 1990, changes in information technology, and personnel cost and compensation. A financial and operations analysis reveals an operational funding short fall of $1.8 million and 26 full-time equivalents (FTE's) in 2001. The largest shortfall is in the resource protection area which would require an additional $484,000 (a 137 percent increase) to reach operational standards (NPS 2002c).

Increasing funding sources through higher user fees and reimbursable funds may not be a feasible alternative for the Park. Its remote location requires higher transportation costs to access the Park, compared to other National Parks. Along with a $4 per day user fee currently charged to all visitors, and a premium-priced visitor lodge and high meal expenses at Rock Harbor, park officials run the risk of making the park unaffordable and inaccessible to the average visitor by imposing higher fees. To meet this financial challenge, the Park must seek to diversify its funding sources and develop new operating techniques and innovative strategies in partnership with other organizations and resource sources.

Preliminary steps have been taken by the Park in this direction. In fiscal year 2001 non-appropriated funds equaled a quarter of total funding. The park also gained $220,000 in volunteer services equal to approximately 7 percent of its appropriated budget (NPS 2002c). The park should be encouraged to increase funding sources through partnerships with external partners and improve access for park volunteers through cooperation with schools, universities, and research facilities. Park staff should also be encouraged to pursue research grants from outside funding sources which would address park issues and research needs. Because the park is a naturally pristine ecosystem in a relatively undisturbed setting, more efforts could be directed at encouraging greater research activity and long-term monitoring of Park natural and water resources. Universities and other science-based organizations could expand involvement and funding in programs such as the Isle Royale Institute. This program provides educational courses to groups and coordinates research efforts through Michigan Technological University and the University of Minnesota, Duluth.

According to the 2001 Business Plan, the park had no dedicated staff to develop, monitor and manage partnership efforts outside of the National Park system. Volunteers were coordinated part-time by the Cultural Resource Manager, research efforts part–time by the Natural Resources Manager, and fund raising efforts part-time by the Chief Ranger.

The Great Lakes Basin area and its regional organizations and initiatives could offer additional funding sources and in-kind services to Isle Royale National Park (and other National Parks within the basin) especially in the areas of water resource management and environmental education for the public. An important step has recently been taken by the current administration to encourage broader cooperation in the Great Lakes Basin and may open possibilities for Isle Royale National Park expansion in other joint efforts within the region.

In May, 2004 President Bush signed an Executive Order creating the Great Lakes Interagency Task Force (USEPA 2004). The Task Force, under the lead of the U.S. Environmental Protection Agency (EPA), brings together 10 Agency and Cabinet officers to provide strategic direction on federal Great Lakes policy, priorities and programs. The executive order attempts to coordinate various Great Lakes program responsibilities currently shared among EPA, the Army Corps of Engineers, the Fish and Wildlife Service, the National Oceanic and Atmospheric Administration and other agencies. The ten agencies together administer more than 140 different federal programs that help fund and implement environmental restoration and management activities in the Great Lakes basin. The Executive Order calls for the development of outcome-based goals such as cleaner water, sustainable fisheries, and system biodiversity and calls on the Task Force to ensure federal efforts target measurable results. Creation of the Task Force continues the commitment made by the Bush Administration with the signing of the Great Lakes Legacy Act of 2002.

See Appendix B "Partnership Sources" for a detailed list with contact information of agencies, organizations, and programs that exist that could possible collaborate with the National Park service.

2. Great Lakes Network Inventory and Monitoring Program

The Great Lakes Inventory and Monitoring Network (GLKN) was established in 2002 as part of the NPS Natural Resource Challenge. One of 32 such networks nationwide, GLKN is intended to help meet several long-term NPS goals: 1) ensure that baseline inventories of basic natural resources are underway for all network parks, 2) establish effective long-term monitoring programs to monitor ecosystem status and trends, 3) provide geographic information systems and other tools to assist with park management decisions, 4) integrate natural resource inventory and monitoring programs with park planning, operation and maintenance, visitor protection, and interpretation activities, 5) cooperate with other federal and state agencies to share resources, achieve common goals, and avoid unnecessary duplication of effort and expense (paraphrased from http://www1.nature.nps.gov/protectingrestoring/IM/inventoryandmonitoring.htm).

GLKN is comprised of nine NPS units within the states of Minnesota, Wisconsin, Michigan, and Indiana. General oversight of the network is provided by a Board of Directors consisting of four park superintendents, the Midwest Regional Inventory and Monitoring Coordinator, and the GLKN coordinator. A Network Technical Committee, comprised of the natural resource managers from each park, provides detailed strategic recommendations about natural resource priorities, sampling and data management protocols, and GLKN personnel and budget requirements. The Technical Committee also assists in the selection of monitoring indicators or "vital signs", and reviews annual reports and work plans (Great Lakes Inventory and Monitoring Network 2002).

Each network is required to follow a 3-phase approach in developing their monitoring plan, and each phase culminates in a formal report. The Phase I Report describes the organizational aspects of the network (formation of the Board of Directors, Network Technical Committee, science advisory groups, etc.) and the progress made in summarizing existing data, defining monitoring goals, and developing conceptual models. The Phase II Report updates the materials in the Phase I Report and also articulates which vital signs will be monitored based on the results of one or more vital signs scoping workshops. The Phase III Report serves to formalize network monitoring plans and implementation strategies. The GLKN has completed its Phase I Report (Route and Elias 2003) and will be submitting its Phase II Report in September 2004.

Water-related actions for Phase I

GLKN initiated a variety of activities to summarize aquatic resource information. First, state and federal water quality standards and regulations were compiled. Baseline water quality conditions in each park were assessed based on these standards (Ledder 2003). Second, existing aquatic and fisheries research was synthesized and evaluated for monitoring implications and gaps in knowledge (Lafrancois and Glase 2005). Finally, GLKN data specialists were deployed throughout the network to retrieve monitoring datasets from each park, catalog them, and create standardized metadata. Natural Resources Research Institute (NRRI) was contracted in 2003 to conduct a critical analysis of these data sets and to subsequently recommend future monitoring strategies.

In addition to these information summary efforts, GLKN has developed conceptual models for six important ecosystems and processes (Route and Elias 2003). Four of these are water-related: 1) Great Lakes, 2) inland lakes, 3) large rivers, and 4) wetlands. These conceptual models provide an overview of ecosystem processes and identify important drivers and stressors, ecological attributes, and specific ecological measures.

Several GLKN information summary activities are not specific to water resources but include some water resource components. These include: 1) compiling a bibliography of natural resource literature references for the network parks (available through NatureBib), 2) acquiring verified lists of vascular plants, mammals, birds, fish, amphibians and reptiles (available through NPSpecies), and 3) constructing an information transfer system to make natural resource data from NPS and other agencies and organizations readily accessible via the web (contracted to Michigan State University, Institute of Water Research, 2003).

Water-related actions for Phase II

Vital Signs Development
GLKN staff, the Network Technical Committee, and several science advisors assembled a list of potential aquatic vital signs, and each park ranked them according to management significance. GLKN subsequently organized an aquatic vital signs workshop (held February 2004), at which a group of NPS and non-NPS aquatic scientists discussed the candidate vital signs and ranked them according to ecological significance and measurability/sensitivity. Results of the vital signs workshop suggest that future GLKN monitoring activities will focus on water quality parameters (core and advanced suites), hydrologic parameters (lake levels, stream flow), land cover parameters, aquatic plants and invertebrates, fish, and diatoms.

Design and Implementation
The GLKN monitoring plan will fully address issues of monitoring endpoints, sampling design and methods. Park-specific monitoring needs will be considered in the plan; however, available funds will be spread throughout the nine parks and will not likely address all the monitoring needs of each park. Funds for water quality monitoring will include $123,000 per year from the Water Resources Division of NPS. Since most

network parks are water-based, GLKN also expects to contribute some of its general funds to water-related monitoring.

Recommendations

The core monitoring plan presented by GLKN will address certain monitoring needs and certain aquatic habitats for ISRO. Remaining needs and habitats should be identified, and research and monitoring projects developed to address them. An ISRO-specific water quality monitoring plan, expanding on the monitoring services provided by GLKN and addressing inventory and monitoring needs described in the issue statements above may be desirable. Plans for biological monitoring related to aquatic nuisance species will be essential and may not be covered by GLKN.

The GLKN monitoring plan is expected to be somewhat flexible. Ongoing exchanges between park staff and GLKN staff will help ensure that GLKN monitoring activities continue to target key resources and water quality variables.

GLKN will maintain an extensive water quality database which will be readily accessible to ISRO staff. This database should be mined regularly by resource specialists from ISRO, GLKN and the Midwest Regional Office and used to generate research hypotheses and develop project statements.

3. Evaluation of Ground Water as a Future Water Supply

Currently, the park uses surface water from Lake Superior for its water supplies in developed areas. While these water and wastewater systems are adequate to meet park needs, they are costly and require constant maintenance and monitoring while the park is open. Periodically, the question arises regarding the possibility of establishing ground water wells for water supply, at least for some of the developed areas. Test wells installed in 1981 near Windigo for evaluating this option showed that the basaltic lava underlying Windigo does not contain sufficient water at depths less than 175 ft, and that a change in bedrock lithology in the area would be expected only at depths exceeding 175 ft (Granneman and Twenter 1982). However, there would be no assurance that water from beyond that depth, if available, would be of good quality. For example, in some places on the Keweenaw Peninsula, water from similar rock at these greater depths is salty. Glacial deposits near Washington Creek showed the possibility of an adequate water supply, but required much more extensive tests prior to drawing any conclusion (Granemann and Twenter 1982).

If the park were to consider well development in the future, several important considerations with respect to water supply and potential impacts on water resources would need to be addressed. Besides the evaluation of long-term costs to install a new system and abandon or partially abandon an existing one, basic hydrogeologic investigations (studies of subsurface hydrologic and geologic conditions) would be needed at each potential well location). These investigations collect data about the type and thickness of geologic materials, the occurrence of ground water, how it flows in pore spaces and/or fractures, and the quality of the ground water. In addition, the park would need to estimate the quantity of water necessary to sustain present and future visitor/employee use on a daily basis. That information would help evaluate an individual well's production and viability. In addition, determinations on what type(s) of treatment would be necessary to make well water potable should address the indirect impacts of those treatments (i.e., more intensive use of chemicals, salinity levels in the well water, etc.). The park is encouraged to seek NPS-Water Resources Division technical assistance for planning and implementation of any hydrogeologic investigations.

The effects of ground water withdrawals depend on the location of wells, local hydrogeologic conditions, the amount and rate of withdrawals, and whether or not the water is returned to the aquifer after use. Furthermore, to determine any possible long-term hydrologic impacts to surface water resources, such as wetlands, streams, and inland lakes, data on water table and well water levels would need to be collected during well production; this data could be used in numerical models that simulate the local hydrogeologic flow system. The park is also encouraged to seek NPS-Water Resources Division technical assistance in any determinations of the potential impacts of water withdrawals to aquatic ecosystems.

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VII. APPENDICES

Appendix A. Laws, Executive Orders, Agreements and Treaties Important to Isle Royale National Park

A-1. Federal Laws

National Park Service Organic Act
Through this act, passed in 1916, the United States Congress established the National Park Service and mandated that it "shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of future generations." Congress, recognizing that the enjoyment by future generations of the national parks can be ensured only if the superb quality of park resources and values is left unimpaired, has provided that when there is a conflict between conserving resources and values and providing for enjoyment of them, conservation is to be predominant. This is how courts have consistently interpreted the Organic Act.

The General Authorities Act of 1970 reinforced this act -- all parklands are united by a common preservation purpose, regardless of title or designation. Hence, federal law protects all water resources in the national park system equally, and it is the fundamental duty of the National Park Service to protect those resources unless otherwise indicated by Congress.

Redwoods National Park Act
In 1978 an act expanding Redwood National Park further amended the general authorities of the National Park Service to mandate that all national park system units be managed and protected "in light of the high public value and integrity of the national park system." Furthermore, no activities should be undertaken "in derogation of the values and purposes for which these various areas have been established", except where specifically authorized by law or as may have been or shall be directly and specifically provided for by Congress. Thus, by amending the general Authorities Act of 1970, this act reasserted system-wide the high standard of protection prescribed by Congress in the Organic Act.

National Parks Omnibus Management Act
Recognizing the ever increasing societal pressures being placed upon America's unique natural and cultural resources contained in the national park system, this act, passed in 1998, attempts to improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the national park system by:

- assuring that management of units of the national park system is enhanced by the availability and utilization of a broad program of the highest quality science and information;

authorizing the establishment of cooperative agreements with colleges and universities and the establishment of cooperative ecosystem study units to conduct multi-disciplinary research and develop integrated information products on the resources of the national park system;
- undertaking a program of inventory and monitoring of national park system resources to establish baseline information and to provide information on the long-term trends in the condition of national park system resources; and
- taking such measures as are necessary to assure the full and proper utilization of the results of scientific study for park management decisions.

In each case in which an action undertaken by the National Park Service may cause a significant adverse effect on a park resource, the administrative record shall reflect the manner in which unit resource studies have been considered. The trend in the condition of resources of the national park system shall be a significant factor in the annual performance.

<u>Wilderness Act</u>
The Wilderness Act, Public Law 88-577, was approved September 3, 1964. It directed the Secretary of the Interior, within 10 years, to review every roadless area of 5,000 or more acres and every roadless island (regardless of size) within the National Wildlife Refuge and National Park Systems and to recommend to the President the suitability of each such area or island for inclusion in the National Wilderness Preservation System (which the Act established). Final decisions regarding this designation are to be made by the U.S. Congress. The Secretary of Agriculture was directed to study and recommend suitable areas in the National Forest System.

A wilderness, in contrast with those areas where man and his own works dominate the landscape, is … an area where the earth and its community of life are untrammeled by man… an area of undeveloped federal land retaining its primeval character and influence… which is protected and managed so as to preserve its natural conditions in such a way that:

- wilderness areas appear to have been affected only or primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; and
- wilderness areas provide outstanding opportunities for solitude or a primitive and unconfined type of recreation.

Wilderness areas under the definition of the Act should contain at least 5,000 acres of land or are at least of sufficient size as to make practicable their preservation and use in an unimpaired condition.

The Act also provides criteria for determining suitability for wilderness designation and establishes restrictions on activities that can be undertaken on a designated area. It authorizes the acceptance of gifts, bequests and contributions of land to further the purposes of the Act and requires an annual report at the opening of each session of Congress on the status of the wilderness system.

There are no permanent roads within any wilderness area, except as provided by law. Except as needed for administrative purposes, there are to be no temporary roads or use of motorized vehicles or motorized equipment, no landing of aircraft, no other form of mechanical transport, and no structure or installation within any wilderness area.

The management of areas as wilderness could constrain water resource management activities, such as ease of access to surface and groundwater monitoring stations and the need for structures for purposes of impact mitigation from human activities or water resources reclamation.

Isle Royale National Park was designated part of the National Wilderness Preservation System on October 20, 1976 and remains today as an example of primitive America. Over 99 percent of the land in Isle Royale is designated wilderness.

Endangered Species Act

When the Endangered Species Act was passed in 1973, it provided a statement of America's concern about the decline of many wildlife species in North America and around the world. The purpose of the Act is to "conserve the ecosystems upon which endangered and threatened species depend" and to conserve and recover listed species. Under the Act, species may be listed as either "endangered" or "threatened". Endangered is defined as any specie that is in danger of extinction throughout all or a significant portion of its range. Threatened means a species is likely to become endangered within the foreseeable future.

The law is administered by the Interior Department's U.S. Fish and Wildlife Service and the Commerce Department's National Marine Fisheries Service. The FWS has the primary responsibility for terrestrial and freshwater organisms while the National Marine Fisheries Service's responsibilities are mainly for marine species such as salmon and whales.

The Endangered Species Act requires the National Park Service to identify and promote the conservation of all federally listed endangered, threatened, or candidate species within any park unit boundary. This act requires all entities using federal funding to consult with the Secretary of Interior on activities that potentially impact endangered flora and fauna. It requires all federal agencies to protect endangered and threatened species as well as designated critical habitats. While not required by legislation, it is the policy of the National Park Service to also identify state and locally listed species of concern and support the preservation and restoration of those species and their habitats.

Coastal Zone Management Act

The Coastal Zone Management Act, passed in 1972, enables coastal states, including Great Lakes states, to develop a coastal management program to improve protection of sensitive shoreline resources, identify coastal areas appropriate for development, designate areas hazardous to development and improve public access to the coastline.

Michigan was among the first states to have its coastal program approved in 1978. The program, administered by the Michigan Department of Environmental Quality, includes local pass-through grants, administration of coastal sections of Michigan's Natural Resource and Environmental

Protection Act of 1994, and review of federal agency activities for consistency with Michigan's approved program.

National Environmental Policy Act (NEPA)

Congress passed the National Environmental Policy Act (NEPA) in 1969. Environmental compliance in the National Park Service encompasses the mandates of NEPA and all other federal environmental laws that require evaluation, documentation and disclosure, and public involvement, including the Endangered Species Act, Clean Water Act, Executive Orders on Floodplains and Wetlands, and others.

All natural resource management and scientific activities are subject to environmental analysis under NEPA through the development of environmental assessments and environmental impact statements. Parks are encouraged to participate as cooperating agencies in the environmental compliance process to the fullest extent possible when National Park Service resources may be affected, and as set forth in Council on Environmental Quality (CEQ) regulations. Participation by the National Park Service in the environmental compliance processes of other agencies and jurisdictions is an important management tool. It can provide the National Park Service with information that will allow the Service to respond to possible external threats to a park well before they occur. Section 102 of NEPA sets forth a procedural means for compliance. The CEQ regulations further define the requirements for compliance with NEPA.

An environmental assessment is not included as part of this water resources management plan because this plan provides a general direction for the water resources program for ISRO. Compliance with NEPA will be undertaken for specific actions resulting from this plan, where appropriate, when it becomes apparent that individual actions or groups of actions will be implemented.

Clean Air Act (and amendments)

The Clean Air Act, passed in 1970, regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources. Reductions in criteria pollutants have been required for areas that are in non-attainment of promulgated standards. Attainment areas are subject to prevention of significant deterioration (PSD) regulations that limit the amount of additional air pollution a source can contribute. Several areas, including many national parks, have been designated as "Class I" areas which require more stringent PSD regulations, primarily to preserve or restore visibility. In addition, the Clean Air Act gives federal land managers the responsibility of protecting "air quality related values", including vegetation, water bodies, soils and wildlife.

The 1990 amendments to this act were intended primarily to fill the gaps in the earlier regulations, such as acid rain, ground level ozone, stratospheric ozone depletion and air toxics. Acid rain was addressed by aggressive reduction requirements for precursor compounds, including an emissions trading program for SO_2. Stratospheric ozone depletion was addressed by a phase out of CFCs and other ozone depleting chemicals. The amendments identify a list of 188 hazardous air pollutants. This list includes PCBs; dioxins and furans; metals, such as mercury compounds, lead compounds and cadmium compounds; pesticides, such as chlordane and toxaphene; and others. The U.S. Environmental Protection Agency (EPA) must study these chemicals, identify their sources, determine if emissions standards are warranted, and promulgate appropriate regulations. Criteria pollutants are addressed through more aggressive non-attainment regulations as well as more stringent enforcement measures.

The Clean Air Act directs the USEPA to monitor, assess, and report on the deposition of toxic air pollutants to the "Great Waters," which include the Great Lakes. Activities include establishing a deposition monitoring network, investigating sources of pollution, improving monitoring methods, evaluating adverse effects, and sampling for the pollutants in aquatic plants and wildlife.

Federal Water Pollution Control Act (Clean Water Act)

The Federal Water Pollution Control Act was passed by Congress in 1972. It is more commonly known as the Clean Water Act, and has been amended several times since it was first promulgated (e.g. 1977, 1987 and 1990). This law's purpose is to restore and maintain the chemical, physical and biological integrity of the nation's waters, including the waters of the national park system. To achieve this, the act called for a major grant program to assist in the construction of municipal sewage treatment facilities, and a program of effluent limitations designed to limit the amount of pollutants that could be discharged. Effluent limitations are the basis for permits issued for all point source discharges, known as the National Pollutant Discharge Elimination System (NPDES).

As part of the Act, the U.S. Congress recognized the primary role of the states in managing and regulating the nation's water quality. Section 313 requires that all federal agencies comply with the requirements of state law for water quality management, regardless of other jurisdictional status or land ownership. States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water quality standards. Standards are based on the designated uses of a water body or segment of water, the water quality criteria necessary to protect that use or uses, and an anti-degradation provision to protect the existing water quality. Different water bodies may have different standards in order to meet the designated uses of the water body. For instance, water bodies designated as cold water fisheries (e.g., protected for trout) will have more restrictive standards for dissolve oxygen and temperature (Sayles 2004).

A state's anti-degradation policy is a three-tiered approach to maintaining and protecting various levels of water quality. Minimally, the existing uses of a water segment and the quality level necessary to protect the uses must be maintained. The second level provides protection of existing water quality in segments where quality exceeds the fishable/swimmable goals of the Clean Water Act. The third level provides protection of the state's highest quality waters where ordinary use classifications may not suffice; these are classified as Outstanding National Resources Waters (ONRW). In Michigan, the Department of Environmental Quality (DEQ) designates Outstanding State Resource Waters (OSRW). The only waters that are OSRW's are those that have been designated as wild rivers under the Michigan Scenic Rivers Act, Wilderness Rivers under Part 305 of Michigan Act 451, or those within select national parks or lakeshores such as ISRO.

When high quality water bodies are designated OSRW's by the DEQ, controls shall then be applied on pollutant sources to the OSRW or tributaries so that the water quality is not lowered in the OSRW. A short-term, temporary (e.g., weeks or months) lowering of water quality in the OSRW may be permitted by the department on a case-by-case basis. All waters of ISRO are OSRW under the act.

Section 303 of the Clean Water Act requires the promulgation of water quality standards by the states. Additionally, each state is required to review its water quality standards at least once every 3 years. This section also requires the listing of those waters where effluent limitations are not stringent enough to implement any water quality standard [so called 303(d) list]. When a lake or stream does not meet the water quality standards a study must be completed to determine the amount of a pollutant that can be put into a water body from point sources and nonpoint sources and still meet the prescribed water quality standard. As part of this process, each state must establish, for each of the waters included on the 303 (d) lists, total maximum daily loads, known as TMDLs, for applicable pollutants. The TMDL is a tool to determine how much pollutant load a lake or stream can assimilate. The establishment of a TMDL for the waters of ISRO would be relevant only if the waters were not meeting water quality standards.

Section 401 requires that any applicant for a federal license or permit to conduct an activity which will result in a discharge into waters of the U.S. shall provide the federal agency, from which a permit is sought, a certificate from the state water pollution control agency stating that any such discharge will comply with applicable water quality standards. Federal permits that require Water Quality Certification from the State of Michigan include 404 permits from the U.S. Army Corps of Engineers for the discharge of dredged or fill material.

Section 404 of the Clean Water Act further requires that a permit be issued for discharge of dredged or fill materials in waters of the U.S., including wetlands. The U.S. Army Corps of Engineers administers the Section 404 permit program with oversight and veto powers held by the U.S. Environmental Protection Agency.

It was the 1987 amendment to the Clean Water Act that finally established a stringent nonpoint source control mandate. Subsequent amendments further developed this mandate by requiring that states develop regulatory controls over nonpoint sources of pollution and over storm water runoff from industrial, municipal, and construction activities. Many of the NPS’s construction activities are regulated by the Clean Water Act under the storm water permitting requirements.

<u>Rivers and Harbors Appropriations Act (as amended)</u>

This act passed in 1899, gave the U.S. Army Corps of Engineers jurisdiction and authority over the protection of navigable waters. Navigable waters of the U.S. are those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. U.S. Army Corps of Engineers permits are required under Section 10 of the act for structures and/or work in or affecting navigable waters of the U.S.

The U.S. Army Corps of Engineers began regulation of wetlands under this act, and then received a much broader grant of jurisdictional authority under the Clean Water Act. Because of the broader geographic reach of “waters of the U.S.” jurisdiction under the Clean Water Act, Rivers and Harbors Act jurisdiction will usually not be of significance to wetlands regulation in current cases. There are, however, several situations in which Rivers and Harbors Act jurisdiction alone will be available: when an exemption from Section 404 coverage applies, and when activities as opposed to waters are covered by the Rivers and Harbors Act and not the Clean Water Act. For instance, the mooring of houseboats in a bay may require a permit under the Rivers and Harbors Act, but would not under the Clean Water Act.

Nonindigenous Aquatic Nuisance Prevention and Control Act (reauthorized through the National Invasive Species Act (NISA))

The Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990 began the process of establishing a national program regarding the prevention, research, monitoring and control of invasive species in U.S. waters. NANPCA provides an institutional framework that promotes and coordinates aquatic nuisance species (ANS) research, develops and applies prevention and control technologies, establishes national ANS priorities, educates and informs citizens and coordinates public programs. NANPCA also called for a policy review of the impacts of intentional introductions of exotic species (such as for aquaculture or biological pest control), a zebra mussel demonstration project, and state aquatic nuisance management planning. The law created a regional entity, the Great Lakes Panel on ANS, to help coordinate federal, state, local and private-sector efforts to prevent and control exotic species within the Great Lakes basin. Other provisions addressed the brown tree snake, quarantine protocols for research on exotic species, and risk assessment. Under NANPCA, the Great Lakes became the first area to address ANS introductions through ballast water through the direction to the U.S. Coast Guard to promulgate regulations to reduce the number of new alien species introductions into the Great Lakes via commercial vessels.

In 1996, NANPCA was reauthorized through NISA. NISA expanded the scope of the ballast management program beyond the Great Lakes to encompass the nation's waters. NISA also broadened the legislation from its focus on zebra mussels to ANS in general. Other components of NISA included ballast technology demonstrations, ecological and ballast discharge surveys to assess the risks and impacts of invasions, and the establishment of regional coordination panels for other regions of the country.

Noxious Weed Act

This act, passed in 1974, provides for the control and management of non-indigenous weeds that injure or have the potential to injure the interests of agriculture, commerce, land and water resources, wildlife or the public health. In passing this Act, Congress found that noxious weeds interfere with the growth of useful and native plants, clog waterways, interfere with navigation, cause disease and are generally detrimental to agriculture, commerce, public health and land and water resources.

The act empowers the Secretary of Agriculture to seize, quarantine, treat, destroy, or dispose of any product or article infested by a noxious weed as an emergency measure to prevent dissemination. The Secretary may also temporarily quarantine any state, territory, or district or any portion thereof, and may prohibit the interstate movement of any products from the quarantined area.

The act calls for the Secretary of Agriculture to cooperate with other governmental agencies, farmers, associations and similar organizations to carry out measures to eradicate or control the spread of any noxious weed. The act also requires other federal agencies to develop a management program to control the spread of undesirable plants on federal lands under the agency's jurisdiction, establish and adequately fund the program, implement cooperative agreements with state agencies to coordinate the management of undesirable plants on federal lands and establish integrated management systems to control particular undesirable plants identified under any cooperative agreement. A federal agency is not required to carry out a management program on federal lands unless similar programs are being implemented on state or private lands in the same area.

The act directs the Secretaries of Agriculture and the Interior to coordinate programs for the control, research and education efforts associated with noxious weeds. The Secretaries together may identify regional control priorities and disseminate technical information to interested state, local and private entities.

If an environmental assessment or environmental impact statement is required under NEPA to implement plant control agreements, federal agencies must complete those assessments or statements within one year after the requirement is known.

In the Great Lakes region, the Noxious Weed Act has been used to provide protection against the spread of nonindigenous aquatic weeds.

Fish and Wildlife Coordination Act

This act, passed in 1965, requires federal agencies to consult with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service and with parallel state agencies whenever water resource development plans result in alteration of a body of water. The Secretary of the Interior is authorized to assist and cooperate with federal agencies to "provide that wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs."

Safe Drinking Water Act (and amendments)

The Safe Drinking Water Act, first promulgated in 1974, directs the U.S. Environmental Protection Agency to publish and enforce regulations on maximum allowable contaminant levels in drinking water. The act requires the Environmental Protection Agency to issue regulations establishing national primary drinking water standards. Primary enforcement responsibilities lie with the states. The act also protects underground sources of drinking water with primary enforcement responsibilities again resting with the states. Federal agencies having jurisdiction over public water systems must comply with all requirements to the same extent as any non-governmental entity.

The act was amended in 1986 and 1996. The 1996 amendments to the Safe Drinking Water Act initiated a new era of cost-effective protection of drinking water quality, state flexibility, and citizen involvement. Source water assessment and protection programs provided under these amendments, offer tools and opportunities to build a prevention barrier to drinking water contamination Source water protection means preventing contamination and reducing the need for treatment of drinking water supplies. Source water protection also means taking positive steps to manage potential sources of contaminants and contingency planning for the future by determining alternative sources of drinking water.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
This act commonly referred to as Superfund, was enacted in 1980. It creates a federal Superfund to clean up uncontrolled or abandoned hazardous waste sites as well as accidents, spills and other emergency releases of pollutants. The act contains an extensive list of hazardous substances that are subject to release reporting regulations. The National Response Center must be notified immediately by the person in charge of a vessel or facility when there is a release of any environmental media of a designated hazardous substance exceeding the predefined reportable quantity within any 24-hr period. The reporting quantities are determined on the basis of aquatic toxicity, reactivity, chronic toxicity, and carcinogenicity, with possible adjustments based upon biodegradation, hydrolysis, and photolysis.

Resource Conservation and Recovery Act
This act, enacted in 1976, establishes a regulatory structure for handling, storage, treatment, and disposal of solid and hazardous wastes. Many products and materials are regulated under this act including commercial chemical products, manufactured chemical intermediates, contaminated soil, water, or other debris resulting from the cleanup of a spill into water or on dry land, and containers and inner liners of the containers used to hold waste or residue.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
Congress originally passed this act in 1947 as a consumer protection statute focused on the registration and labeling of pesticides. It now also regulates the sale, distribution, use, and cancellation of pesticides within the United States. Under this act, the U.S. Environmental Protection Agency has the authority to study the consequences of pesticide use and to require users to register when purchasing pesticides.

Oil Pollution Act (OPA)
Significant oil spill events in the late 1980's prompted Congress to enact the Oil Pollution Act (OPA) of 1990, which was designed to expand the scope of public and private planning and response activities associated with the discharges of oil and hazardous substances. OPA amended Section 311 of the Clean Water Act (CWA) to enhance federal authority to prepare for and respond to oil spills, increase penalties for spills, expand the federal response organization, and augment preparedness and response activities. Specifically, OPA extends the liability of Responsible Parties (RPs) to include damage to natural resources, damage to property, loss of revenues, profits, or earning capacity, and costs during or after removal activities.

For owners/operators of oil storage facilities, the most significant change in the CWA is Section 311(j)(5) which requires the preparation of facility-specific response plans for responding, to the maximum extent practicable, to a "worst-case-discharge" of oil and to the substantial threat of such a discharge to the surrounding environment. This requirement applies to all off shore and onshore facilities from which a discharge could reasonably be expected to cause "substantial harm" to the environment. Section 311(j) (5) (C) of the CWA sets forth certain minimum requirements for the development of Facility Response Plans including:

- Be consistent with the requirements of the National Oil and Hazardous Substances National Contingency Plan and applicable Area Contingency Plans;
- Identify the qualified individual having full authority to implement removal actions and require immediate communications between that individual and the appropriate federal official and the persons providing removal personnel and equipment;
- Identify and ensure by contract or other approved means the availability of private resources and equipment necessary to remove, to the maximum extent practicable, a worst-case-discharge (include those resulting from a fire or explosion), and to mitigate a substantial threat of such a discharge;
- Describe the training, equipment testing, periodic unannounced drills, and response actions of persons at the facility to be carried out under the FRP to ensure the safety of the facility and to mitigate or prevent a discharge or substantial threat of a discharge;
- Be updated on a periodic basis; and
- Be resubmitted for approval for each significant change.

A-2. Great Lakes Specific Laws and Statutes

Great Lakes Critical Programs Act

This act, passed in 1990, amends part of the Federal Water Pollution Control Act (Clean Water Act) by putting into place requirements for the U.S. EPA's Great Lakes National Program Office to implement Great Lakes programs such as the Great Lakes Water Quality Agreement of 1978 (see description below).

In passing this Act, the Congress finds that the Great Lakes are a valuable national resource, continuously serving the people of the United States and other nations as an important source of food, fresh water, recreation, beauty and enjoyment.

The Act directs the government of the United States to seek to attain the goals embodied in the Great Lakes Water Quality Agreement of 1978 (as amended in 1987) and any other Great Lakes agreements and amendments, with particular emphasis on goals related to the reduction of toxic pollutants. The Act directs the U.S. Environmental Protection Agency (EPA) to be the lead agency to meet the goals of the Great Lakes Water Quality Agreement, working cooperatively with other federal agencies, states and local authorities.

The Critical Programs Act also established EPA's Great Lakes National Program Office (GLNPO) within the Agency. It had previously been established by the Administrator of EPA. GLNPO is thus required to carry out other important provisions of the Critical Programs Act. These include:

- Establishment of a Great Lakes system-wide surveillance network to monitor the water quality of the Great Lakes.
- Coordination of actions of the Agency (EPA) with other federal agencies, states and local authorities related to achieving the objectives of the Water Quality Agreement.
- Development of water quality guidance for the Great Lakes system for the purpose of developing water quality standards.

- Establishment of a schedule for the completion of remedial action plans (RAPs) for the 26 U.S. Areas of Concern (AOCs).
- Working with the government of Canada on a schedule for completion of the 5 binational AOCs and the 11 Canadian AOCs.
- Establishment of a Lake wide Management Plan (LaMP) for Lake Michigan and a process for development of LaMPs for the other Great Lakes.
- Development of a 5-year plan and program for the reduction of nutrients into the Great Lakes.
- Development of a demonstration program for contaminated sediment remediation.
- Development of a management plan for every confined disposal facility (CDF) for contaminated sediments, in consultation with the Secretary of the Army for Civil Works.

<u>Great Lakes Water Quality Initiative (GLI)</u>
The Great Lakes states agreed in 1989 to work with the Environmental Protection Agency (EPA) to develop uniform pollution limits to protect the lakes and implement the Clean Water Act (CWA). The goal was to set limits on a coordinated basis that would prevent further buildup of toxic pollutants in fish and wildlife. In the Great Lakes Critical Programs Act of 1990 (P.L.101-596, which amended the CWA), Congress endorsed the process of establishing coordinated pollutant limits and specified a number of deadlines for the process.

In March, 1995 EPA issued final water quality guidance for the Great Lakes system, known as the GLI (see http://www.epa.gov/ost/GLI/). The guidance is required under section 118 of the CWA and was first proposed in 1993. Although classified as guidance, it is a regulation which is one of the most complex ever issued by EPA. The primary purpose of the guidance is to provide a consistent level of protection for people and wildlife which may be exposed to toxic pollutants from the lakes.

The guidance establishes water quality criteria for 29 pollutants, with a particular focus on persistent bioaccumulative toxics (that is, those that occur in higher concentration in aquatic biota than in open waters). The criteria are intended to protect human health, aquatic life, and wildlife and include the first-ever EPA wildlife criteria to protect birds and mammals from long-term exposure to mercury, DDT, PCBs, and dioxin. The guidance also includes implementation procedures, methodologies to develop criteria for additional pollutants, and anti-degradation provisions (procedures to ensure that once water quality goals are attained, additional pollution will not be allowed to lessen or degrade water quality).

The Great Lakes states are required to revise their water quality management programs and water quality standards consistent with the guidance. State water quality standards are the basis for establishing discharge limits in permits issued to industries and municipalities, making it likely that dischargers throughout the basin will be subject to more stringent control requirements in the future.

<u>Water Resources Development Act (WRDA) of 1986 (Section 1109) (as amended)</u>
Section 1109 of WRDA 1986 prohibits any new or increased diversion of water by any state, federal agency or private entity from any portion of the Great Lakes within the United States or from any Great Lakes tributary within the United States for use outside of the Great Lakes basin

without the approval of each of the governors of the Great Lakes states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin. Section 1109 also prohibits any federal agency from undertaking any study or expending any federal funds to contract for any study involving the transfer of Great Lakes water for any purpose for use outside the Great Lakes basin or the feasibility of diverting water from any portion of the Great Lakes basin within the United States for use outside the Great Lakes basin. This prohibition does not apply to any study or data collection effort performed by the U.S. Army Corps of Engineers or other federal agency under the direction of the International Joint Commission in accordance with the Boundary Waters Treaty of 1909. Section 504 of WRDA 2000 amended Section 1109 by adding a prohibition against exporting Great Lakes water for use outside of the basin. WRDA 2000 also encourages the Great Lakes states in consultation with the Canadian provinces of Ontario and Quebec to develop and implement a mechanism to provide for a common conservation standard embodying the principles of sound water conservation and resource improvement to aid decision making for Great Lakes water withdrawal and use projects.

Water Resources Development Act (WRDA) of 1999 (Sections 455 and 456)
Section 455 of WRDA 1999 establishes the John Glenn Great Lakes Basin Program. The Program has three components:

> Section 455 (a) instructs the Secretary of the Army through the U.S. Army Corps of Engineers to develop a Great Lakes strategic plan for Corps of Engineers programs and proposed projects in the Great Lakes basin. It also provides for a comprehensive study of the Great Lakes region to ensure future use, management and protection of water resources and related resources of the Great Lakes basin.
>
> Section 455 (b) instructs the Corps of Engineers to request from each relevant federal agency, data and information relevant to the Great Lakes biohydrologic system and to provide an inventory of such information in the possession of each agency. Information to be collected includes:
>
> > groundwater and surface water hydrology;
> > natural and altered tributary dynamics;
> > biological aspects of the Great Lakes system influenced by and influencing water quantity and water movement;
> > meteorological projections and the impacts of weather conditions on Great Lakes water levels; and
> > other Great Lakes biohydrological system data relevant to sustainable water use and management.
>
> The Corps is further instructed to consult with the Great Lakes states, Canadian provinces, Indian tribes and U.S. and Canadian federal agencies in the conduct of this study. After this consultation, the Corps is required to submit a report to the Congress, the International Joint Commission and the Great Lakes states, recommending ways to improve the biohydrologic information base so as to support environmentally sound decisions regarding diversions and consumptive uses of Great Lakes water.

Section 455 (c) instructs the Corps of Engineers in cooperation with the Great Lakes states, to conduct a study and prepare a report detailing the economic benefits of recreational boating in the Great Lakes basin, particularly at harbors benefiting from operation and maintenance projects of the Corps.

Section 456 calls for a Great Lakes Navigational System review. In consultation with the St. Lawrence Seaway Development Corporation, the Secretary of the Army is required to review the Great Lakes Connecting Channel and Harbors report of 1985 to determine the feasibility of undertaking any modifications of the report recommendations to improve commercial navigation on the Great Lakes, including a review of locks, dams, harbors, ports, channels and other related features.

Great Lakes Legacy Act

The Great Lakes Legacy Act, signed into law in 2002, authorizes $270 million over five years to remediate contaminated sediments in Great Lakes Areas of Concern. The Act provides $50 million annually to monitor, evaluate or remediate contaminated sediments, or prevent new contamination. The Act also authorizes $3 million annually for research on innovative technologies for remediating contaminated sediments; and $1 million annually for public outreach and education. The Act requires a 35 percent nonfederal cost share for remediation projects. (Additional information is available from U.S. EPA's Great Lakes National Program Office at www.epa.gov/glnpo/sediment/legacy/.)

Great Lakes Fish and Wildlife Restoration Act

Great Lakes Fish and Wildlife Restoration Act, enacted in 1990, establishes goals for the U.S. Fish and Wildlife Service programs in the Great Lakes and requires the Service to undertake a number of activities specifically related to fishery resources. These include:

- conduct a study by October 1, 1994, of the status of, and the assessment, management, and restoration needs of, the fishery resources of the basin;
- invite the Secretary of the Army, the affected State directors, Indian tribes, the Great Lakes Fishery Commission, Canadian government entities, and others to enter into an MOU regarding the scope and focus of the study and the responsibilities of those choosing to participate;
- establish a Great Lakes Coordination Office to coordinate all Service activities in the basin;
- establish a Lower Lakes Fishery Resources Office to carry out Service operational activities related to fishery resources in the lower Great Lakes;
- establish one or more "Upper Great Lakes Fishery Resource Office(s)" to carry out Service Operational activities related to fishery resources in the upper Great Lakes; and
- within one year of enactment and annually thereafter, submit reports to Congress discussing the progress and results of the study, recommending implementation activities, and describing activities taken to accomplish the goals established in the Act.

The legislative history includes: H.R. 4299; House Report 101-748; pages H8489-92 of the October 1, 1990, Congressional Record; and page S16618 from the October 24, 1990, Congressional Record.

Great Lakes Fish and Wildlife Restoration Act of 1998, Public Law 105-265, October 19, 1998, reauthorizes the 1990 law. It recognizes the 32 recommendations in the 1995 Great Lakes Fishery Resources Restoration Study and moves the law from study to action. The law:

- shifts emphasis from study of species and habitat restoration needs to implementation of restoration projects emphasizing the 32 study recommendations;
- authorizes $3.5 million for each fiscal year through 2004 for activities of the U.S. Fish and Wildlife Service's Great Lakes Coordination and Fishery Resources Offices;
- establishes a Committee to recommend projects for funding to the Director of the Fish and Wildlife Service;
- authorizes $4.5 million for each fiscal year through 2004 to fund restoration projects recommended by the Committee. Projects require a 25 percent non-federal match.

The law recognizes the successful partnerships in the Great Lakes region and provides the process for achieving on-the-ground restoration activities to benefit fish, wildlife and plants in the Great Lakes.

A-3. Executive Orders

<u>Executive Order 13340 – Great Lakes Restoration</u>
On May 18, President Bush issued an Executive Order (EO 13340) that established a Cabinet-level task force charged with coordinating Great Lakes restoration. The Task Force, and a Working Group composed of the heads of federal regional offices will focus on cleaner water, sustainable fisheries and developing measurable results.
www.epa.gov/greatlakes/taskforce/index.html

<u>Executive Order 13112 – Invasive Species</u>
Signed in 1999, this E.O. complements and builds upon existing federal authority to aid in the prevention and control of invasive species. This executive order established the National Invasive Species Council. The Executive Order also required that a Council of Departments dealing with invasive species be created. Currently there are 12 departments and agencies on the Council.

<u>Executive Order for Floodplain Management (E.O. 11988)</u>
The objective of E. O. 11988 (Floodplain Management) is "… to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative." For non-repetitive actions, the E.O. states that all proposed facilities must be located outside the limits of the 100-year floodplain. If there were no practicable alternative to construction within the floodplain, adverse impacts would be minimized during the design of the project. NPS guidance pertaining to this E.O. can be found in Director's Order #77-2, Floodplain Management. It is NPS policy to recognize and manage for the preservation

of floodplain values, minimize potentially hazardous conditions associated with flooding, and adhere to all federally mandated laws and regulations related to the management of activities in flood-prone areas. Particularly, it is the policy of the National Park Service to:

- restore and preserve natural floodplain values;
- avoid to the extent possible, the long- and short-term environmental impacts associated with the occupancy and modification of floodplains, and avoid direct and indirect support of floodplain development wherever there is a practicable alternative;
- minimize risk to life and property by design or modification of actions in floodplains, utilizing non-structural methods when possible, where its is not otherwise practical to place structures and human activities outside of the floodplain; and,
- require structures and facilities located in a floodplain to have a design consistent with the intent of the Standards and Criteria of the National Flood Insurance Program (44 CFR 60)

Executive Order for Wetlands Protection (E.O. 11990)
Executive Order 11990, entitled "Protection of Wetlands", requires all federal agencies to "minimize the destruction, loss or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands." Unless no practical alternatives exist, federal agencies must avoid activities in wetlands that have the potential for adversely affecting the integrity of the ecosystem. NPS guidance for compliance with E.O. 11990 can be found in Director's Order #77-1 and Procedural Manual #77-1, "Wetlands Protection." Particularly, it is the policy of the NPS to:

- avoid to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands;
- preserve and enhance the natural and beneficial values of wetlands;
- avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative;
- adopt a goal of no net loss of wetlands and strive to achieve a longer-term goal of net gain of wetlands service wide;
- conduct or obtain park wide wetland inventories to help assure proper planning with respect to management and protection of wetland resources;
- use "Classification of Wetlands and Deepwater Habitats of the United States " (Cowardin *et al.* 1979) as the standard for defining, classifying and inventorying wetlands;
- employ a sequence of first avoiding adverse wetland impacts to the extent practicable; second, minimizing impacts that could not be avoided; and lastly, compensating for remaining unavoidable adverse wetland impacts at a minimum 1:1 ratio via restoration of degraded wetlands;
- prepare a Statement of Findings to document compliance with Director's Order #77-1 when the preferred alternative addressed in an environmental assessment or environmental impact statement will result in adverse impacts on wetlands; and restore natural wetland characteristics or functions that have been degraded or lost due to previous or ongoing human activities, to the extent appropriate and practicable.

National Park Service Management Policies and Guidelines

The National Park Service Management Policies (2001) provide broad policy guidance for the management of units of the national park system. Topics include park planning, land protection, natural and cultural resource management, wilderness preservation and management, interpretation and education, special uses of the parks, park facilities design, and concessions management.

With respect to water resources, it is the policy of the National Park Service to determine the quality of park surface and ground water resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside of parks. In particular the National Park Service will work with appropriate governmental bodies to obtain the highest possible standards available under the Clean Water Act for protection of park waters; take all necessary actions to maintain or restore the quality of surface and ground waters within the parks consistent with the Clean Water Act and all applicable laws and regulations; and, enter into agreements with other agencies and governing bodies, as appropriate, to secure their cooperation in maintaining or restoring the quality of park water resources.

The National Park Service will also manage watersheds as complete hydrologic systems, and will minimize human disturbance to the natural upland processes that deliver water, sediment and woody debris to streams. The National Park Service will manage streams to protect stream processes that create habitat features such as floodplains, riparian systems, woody debris accumulations, terraces, gravel bars, riffles and pools.

The National Park Service will achieve the protection of watershed and stream features primarily by avoiding impacts to watershed and riparian vegetation and by allowing natural fluvial processes to proceed unimpeded. When conflicts between infrastructure (such as bridges) and stream processes are unavoidable, park managers will first consider relocating or redesigning facilities, rather than manipulating streams. Where stream manipulation is unavoidable, managers will use techniques that are visually non-obtrusive and that protect natural processes to the greatest extent practicable.

Additionally, natural shoreline processes (such as erosion, deposition, dune formation, and shoreline migration) will be allowed to continue without interference. Where human activities or structures have altered the nature or rate of natural shoreline processes, the National Park Service will investigate alternatives for mitigating the effects of such activities or structures. The National Park Service will comply with the provisions of Executive Order 11988 and state coastal zone management plans prepared under the Coastal Zone Management Act.

Recommended procedures for implementing service-wide policy are described in the National Park Service guideline series. The guidelines most directly pertaining to actions affecting water resources include:

Director's Order #2: Park Planning;
Director's Order #12: Conservation Planning, Environmental Impact Analysis, and Decision-making;
Director's Order #77-1: Wetland Protection;

Director’s Order #77-2: Floodplain Management;
Director’s Order #83: Public Health;
NPS-75: Natural Resource Inventory and Monitoring; and
NPS-77: Natural Resources Management

A-4. State of Michigan Statutes

In 1994 the State of Michigan enacted the Natural Resources and Environmental Protection Act (Act 451) to codify, revise, consolidate and classify laws relating to the environment and natural resources of the state. Below are descriptions and limited annotations of parts of this act that pertain to water resources, directly or indirectly, and that are of importance to ISRO.

Part 31 – Water Resources Protection

This part establishes water quality standards, establishes the State’s antidegradation policy, defines and establishes Outstanding State Resource waters, toxic substance water quality-based effluent limits for point source discharges, requirements related to the implementation of the National Pollutant Discharge Elimination System, and standards for land application and recycling of biosolids originating from domestic and sanitary sewage treatment systems.

Part 33 – Contamination of Waters
Part 81 – General Nonpoint Source Pollution Control
Part 87 – Groundwater and Freshwater Protection
Part 88 – Water Pollution and Environmental Protection Act

This part provides for grants to local government and non-profit entities to implement best management practices in approved watershed management plans, and for contracts under the Clean Water Fund to implement the environmental quality monitoring program for Michigan’s surface waters, water pollution control projects, storm water treatment projects and well head protection projects.

Part 91 – Soil Erosion and Sedimentation Control
Part 95 – Watercraft Pollution Control
Part 301 – Inland Lakes and Streams
Part 303 – Wetlands Protection
Part 305 – Natural Rivers
Part 307 – Inland Lake Levels
Part 309 – Inland Lake Improvements
Part 311 – Local River Management
Part 313 – Surplus Waters
Part 315 – Dam Safety
Part 321 – Great Lakes Compact Authorization
Part 322 – Great Lakes Basin Compact
Part 323 – Shore lands Protection and Management
Part 325 – Great Lakes Submerged Lands
Part 326 – Great Lakes Submerged Logs Recovery
Part 327 – Great Lakes Preservation
Part 329 – Great Lakes Protection
Part 333 – Coastal Beach Erosion

Part 337 – Flood, Drainage and Beach Erosion Control
Part 351 – Wilderness and Natural Areas
Part 355 – Biological Diversity Conservation
Part 358 – Adopt-A-Shoreline Program
Part 359 – Adopt-A-River Program
Part 451 – Fishing From Inland Waters
Part 453 – Fishing With Hook and Line
Part 455 – Frogs
Part 457 – Mussels
Part 477 – Fish Restoration and Management Projects
Part 487 – Sport fishing

A complete description of each of these parts is available at http://www.michiganlegislature.org/law/getobject.asp?objName=Act-451-of-1994.

A-5. Treaties between Native American Tribes and the United States

Treaty rights are exercised today in Wisconsin, Michigan and Minnesota in various ways. In some instances tribes exercise their rights under federal court orders. This is the case in Wisconsin for territories ceded to the United States under treaties in 1837 and 1842, in Michigan for territories ceded in 1842 and in Minnesota for territories ceded in 1837.

In entering into these treaties, the tribes kept the right to hunt fish and gather on lands they sold to the United States government in order to provide access to the foods and resources important to the lives of the tribal peoples.

The Keweenaw Bay Indian Community Treaty of 1842 ceded to the United States, a large portion of Lake Superior that lies off the shores of Michigan's western Upper Peninsula. In addition, the Keweenaw Bay reservation is located on the shores of Lake Superior and encompasses a portion of the lake.

Fishing in Michigan's Lake Superior waters is governed by comprehensive tribal regulations. These regulations establish harvest quotas, set fishing seasons, establish permit requirements and impose biological monitoring. The regulations are enforced by wardens of the tribes and of the Great Lakes Indian Fish and Wildlife Commission (GLIFWC). The tribes with affirmed fishing rights in Michigan's Lake Superior waters include: the Bay Mills Band, Sault Ste. Marie Tribe of Chippewa, the Grand Traverse Band of Ottawa and Chippewa, the Little River Band of Ottawa and the Little Traverse Bay Bands of Ottawa.

In Wisconsin, the Red Cliff and Bad River Bands exercise treaty fishing rights in Lake Superior under 10 year agreements with the State of Wisconsin.

In Minnesota, the Fond du Lac and Milles Lacs Bands exercise treaty fishing rights in Lake Superior under retained treaty rights in Minnesota's 1837 Treaty ceded territory.

A-6. International Agreements, Treaties, Conventions and Compacts

Boundary Waters Treaty of 1909 and related initiatives and orders

The 1909 Boundary Waters Treaty between the United States and Canada established the International Joint Commission (IJC), a bi-national agency consisting of six commissioners; three each appointed by the President of the United States and the Governor-in-Council (Prime Minister and Cabinet) of Canada. The IJC has quasi-judicial, arbitrational and advisory powers over the boundary waters between the two countries. The IJC's judicial powers stem from its authority to approve all new "uses, obstructions and diversions" which affect the levels and flows of boundary waters or those crossing the boundary. The Boundary Waters Treaty assigned the IJC the power to arbitrate in all matters of difference arising between the two countries and referred by both to the Commission. This power has yet to be used. Finally, the Treaty enabled the governments of both countries to refer any matter to the IJC for investigation and recommendations. The IJC is the body that developed Orders of Approval for the regulation of outflows from Lake Superior (1914, 1978, and 1979) and Lake Ontario (1952, 1956). Administration for the distribution of flows in the Niagara River between the United States and Canada dates back to the provisions of the Niagara Treaty of 1950**,** which explicitly recognizes intra-basin flows through the Welland Canal and the New York Barge Canal. Outflows through the Lake Michigan Diversion at Chicago have been managed under Supreme Court oversight as early as 1905**.** During World War II, diplomatic letters between the U.S. and Canada provided for diversion of flows through Long Lac and the Ogoki River from the Albany River watershed into Lake Superior.

Great Lakes Water Quality Agreement of 1972 (as amended)

The Great Lakes Water Quality Agreement, first signed in 1972, renewed in 1978 and amended in 1987, expresses the commitment of the United States and Canada (the Parties) to restore and maintain the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem. Under the Agreement, the International Joint Commission monitors and assesses progress toward achieving the general and specific Agreement objectives, and reports at least every 2 years on the effectiveness of the programs and other measures undertaken pursuant to the Agreement along with advice and recommendations. Under the Agreement, the U.S. and Canada agree to encourage an increased understanding of the Great Lakes Basin Ecosystem by developing programs, practices and appropriate technology and to eliminate or decrease the amount of pollutants entering the Great Lakes System. Three boards, the Great Lakes Water Quality Board, the Great Lakes Science Advisory Board and the Council of Great Lakes Research Managers, assist the IJC in exercising its powers and responsibilities outlined in the Agreement. The Great Lakes Water Quality Agreement is one of the most significant environmental agreements in the history of the Great Lakes. In the revised GLWQA of 1978, as amended by Protocol signed November 18, 1987, the Parties agreed to develop and implement, in consultation with State and Provincial Governments, Lake wide Management Plans (LaMPs) for open lake waters and Remedial Action Plans (RAPs) for Areas of Concern (AOCs). Moreover, the Specific Objectives Supplement to Annex 1 of the GLWQA requires the development of Ecosystem Objectives for the Lakes as the state of knowledge permits. Annex 2 further indicates that the RAPs and LaMPs shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses and serves as an important step toward virtual elimination of persistent toxic substances.

Lake Superior Lakewide Management Plan (LaMP)
The LaMPs are intended to identify the critical pollutants that affect the beneficial uses and to develop strategies, recommendations and policy options to restore these beneficial uses.

The Great Lakes Water Quality Agreement specifies that the LaMPs are to be completed in four stages. These stages are: 1) when problem definition has been completed; 2) when the schedule of load reductions has been determined; 3) when remedial measures are selected; and 4) when monitoring indicates that the contribution of the critical pollutants to impairment of beneficial uses has been eliminated. These stage descriptions suggest that the LaMPs are to focus solely on the impact of critical pollutants to the Lakes. However, the group of government agencies designing the Lake Superior LaMP (http://www.epa.gov/glnpo/lakesuperior/2004) felt it was also an opportunity to address other equally important issues in the Lake basin. Therefore, the individual LaMPs may go beyond the minimal requirement for critical pollutants, and use an ecosystem approach, integrating environmental protection and natural resource management.

The LaMP process has proven to be a resource intensive effort and has taken much longer than expected. As a result, the public has had to wait years for a document to review. In the interest of advancing the rehabilitation of the Great Lakes, and getting more information out to the public in a timely manner, the Binational Executive Committee (BEC) passed a resolution in 1999 to accelerate the LaMP effort (BEC 1999). By accelerate, it was meant that there should be an emphasis on taking action and adopting a streamlined LaMP review and approval process. The LaMPs should treat problem identification, selection of remedial and regulatory measures, and implementation as a concurrent, integrated process rather than a sequential one. Consistent with the BEC resolution, the LaMP contains appropriate funded and proposed (non-funded) actions for restoration and protection to bring about actual improvement in the ecosystem. Actions include commitments by the Parties, governments and regulatory programs, as well as suggested voluntary actions that could be taken by non-governmental partners.

Lake Superior Binational Program
Lake Superior is unique, a vast resource of fresh water that has not experienced the same levels of development, urbanization and pollution as the other Great Lakes. Because of this uniqueness, the International Joint Commission recommended that Lake Superior be designated as a demonstration area where discharges and emissions of toxic substances that are long-lived in the environment and build up in the bodies of humans and wildlife, would not be permitted.

In response, Canada and the United States developed *A Binational Program to Restore and Protect the Lake Superior Basin*. This program has focused on the entire ecosystem of Lake Superior, its air, land, water, wildlife and humans. Government and tribal agencies and interested groups from Michigan, Minnesota, Ontario and Wisconsin, along with both federal governments, have taken steps that will restore degraded areas and protect this unique headwater lake through activities such as pollution prevention, enhanced regulatory measures and cleanup programs. With citizen and stakeholder partners, most notably the Lake Superior Binational Forum, objectives have been identified and a vision established for the cleanup and protection of the lake. The governments have funded pollution prevention activities, research to characterize the lake ecosystem and identify the sources of pollutants and their effect on biota, and projects to clean up, restore and protect habitat.

The Lake Superior Lakewide Management Plan was completed in 2000 and was prepared by the Lake Superior Binational Program's Superior Work Group with assistance from various other agencies and organizations including the Lake Superior Binational Forum.

Member agencies of the Lake Superior Binational Program are:

- 1854 Authority
- Agency for Toxic Substances and Disease Registry
- Bad River Band of Lake Superior Chippewa
- Department of Fisheries and Oceans
- Chippewa-Ottawa Treaty Fishery Management Authority
- Environment Canada
- Fond du Lac Band of Lake Superior Chippewa
- Grand Portage Band of Lake Superior Chippewa
- Great Lakes Indian Fish and Wildlife Commission
- Health Canada
- Keweenaw Bay Indian Community
- Michigan Department of Environmental Quality
- Michigan Department of Natural Resources
- Minnesota Department of Natural Resources
- Minnesota Department of Health
- Minnesota Pollution Control Agency
- Ontario Ministry of Natural Resources
- Ontario Ministry of the Environment
- Parks Canada
- Red Cliff Band of Lake Superior Chippewa
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Forest Service
- U.S. Geological Survey - Biological Resources Division
- U.S. National Park Service
- Wisconsin Department of Natural Resources

Convention on Great Lakes Fisheries

To facilitate coordinated, binational fisheries management, the governments of the United States and Canada negotiated and ratified the 1955 *Convention on Great Lakes Fisheries* which created the Great Lakes Fishery Commission. This bilateral agreement affirms the need for the two nations to collaborate on the protection and the perpetuation of the Great Lakes' fisheries resources.

The commission consists of four Canadian commissioners appointed by the Privy Council and four American commissioners (plus one alternate) appointed by the President. The commissioners are supported by a secretariat, located in Ann Arbor, Michigan.

The Convention charges the Commission with five major duties:

- to formulate a research program to identify measures to enhance the sustained productivity of any Great Lakes fish stock of common concern;
- to coordinate fisheries research on behalf of the two countries as well as undertake research when appropriate;
- to recommend appropriate fish management measures;
- to specifically formulate and implement a comprehensive sea lamprey control program; and
- to publish or authorize the publication of scientific information related to Great Lakes fisheries

In delivering its program, the commission relies on input and advice from boards it appoints, lake committees, citizen advisors, and state, provincial, tribal, and federal agency officials.

Funding for the commission is provided by the governments of Canada and the United States. The commission also has trust funds in both countries to accept private donations.

Great Lakes Basin Compact

The Great Lakes Basin Compact -- created through the collective legislative action of states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin established the Great Lakes Commission, an interstate agency serving the above mentioned states. The Compact, which was also granted congressional consent through Public Law 90-419 – includes nine articles which establish areas of responsibility for the Great Lakes Commission.

Through the compact, the party states solemnly agree to pursue the following through means of joint or cooperative action:

- To promote the orderly, integrated, and comprehensive development, use, and conservation of the water resources of the Great Lakes Basin
- To plan for the welfare and development of the water resources of the Basin as a whole as well as for those portions of the Basin which may have special needs.
- To make it possible for the states of the Basin and their people to derive the maximum benefit from utilization of public works, in the form of navigational aids or otherwise, which may exist or which may be constructed from time to time.
- To advise in securing and maintaining a proper balance among industrial, commercial, agricultural, water supply, residential, recreational, and other legitimate uses of the water resources of the Basin.
- To establish and maintain an intergovernmental agency (the Great Lakes Commission) to accomplish the purposes of the compact

The Great Lakes Commission is the only state/provincial organization of its kind in the world. Founded in both state and U.S. federal law and benefiting from a unique, binational partnership with Ontario and Québec, it promotes a consistent and coordinated interagency and integrated approach to issues associated with the Great Lakes-St. Lawrence River system. After nearly 50 years of history, the Great Lakes Commission continues to address a range of issues involving environmental protection, resource management, transportation and economic development. A committee and task force structure is the primary vehicle for identifying and addressing issues adopting policy positions by its membership. Observer organizations -- including U.S. and Canadian federal, regional and tribal governments -- participate extensively in Commission activities.

International Biosphere Reserve Designation by United Nations

In 1980, Isle Royale National Park was designated an International Biosphere Reserve by the United Nations, giving it global scientific and educational significance and conservation protection. Biosphere reserves are internationally recognized terrestrial and coastal or marine areas where management seeks to achieve sustainable use of natural resources while ensuring conservation of the biological diversity of the areas. The first biosphere reserves were designated in 1976 as part of the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Man and the Biosphere Program (MAB). Biosphere reserves are nominated by national governments for inclusion in the world network of biosphere reserves. Each nation's sites remain under the sovereign jurisdiction of the nominating country. Today, a total of 391 biosphere reserves are recognized in 94 countries. Of these, 47 are in the United States, with 23 involving 30 units of the national park system. Although in the past few years some people in the United States have expressed concern that international recognition as a biosphere reserve could cause loss of private property rights, such recognition 1) is sought and obtained voluntarily by the land manager, 2) does not change land ownership status, and 3) does not reduce private property rights. In fact, 13 of the 99 land management units that are part of the 47 biosphere reserves recognized in the United States involve some degree of non-governmental ownership.

A-7. Nonbinding Regional Agreements

Ecosystem Charter for the Great Lakes-St. Lawrence Basin

The Ecosystem Charter for the Great Lakes-St. Lawrence Basin summarizes commonly held principles for pursuing an "ecosystem approach" to Great Lakes-St. Lawrence Basin management. It builds upon landmark agreements such as the U.S. - Canada Boundary Waters Treaty of 1909 and the Great Lakes Water Quality Agreement of 1972/1978. Signatories, who include governmental agencies as well as non-governmental organizations, agree to use the Charter as guidance in developing their own work plans and priorities, as a means to enhance communication and cooperation with others, and as a means for assessing progress toward a shared vision for the future. This vision incorporates the interdependent goals of environmental protection and economic development of the Great Lakes Region. The Charter is a nonbinding "good faith" agreement; it does not replace or affect implementation of existing laws, agreements and policies. It is a “living document” that will be periodically reviewed and revised to ensure it reflects current thinking on the ecosystem approach.

The Charter includes principles describing the rights and responsibilities of all individuals in the Great Lakes-St. Lawrence Basin. All individuals have the right to access to clean air, clean water and healthy and productive soils, which implies a shared responsibility regarding the wise use, management, conservation and protection of the natural resources of the Basin. The Charter calls for cooperation among governmental entities, the private sector, citizen organizations and other interests in order to restore and maintain the chemical, physical and biological integrity of the Great Lakes-St. Lawrence Basin Ecosystem. Important steps toward this goal include understanding, respecting, rehabilitating and protecting ecological processes and natural resources, which can be achieved through:

1. Effective adoption and implementation of Remedial Action Plans and Lakewide Management Plans;
2. Provision of timely, accurate and accessible information to the public regarding the Great Lakes Basin Ecosystem; and by
3. Encouraging stewardship through educational efforts that promote greater understanding of the Ecosystem.

The Charter expresses the importance of virtually eliminating the input of persistent bioaccumulative toxic substances into the Basin Ecosystem and calls for a coordinated, multi-disciplinary research agenda in order to improve the understanding of the scientific, social and economic dimensions of the Great Lakes - St. Lawrence Basin Ecosystem.

<u>Great Lakes Charter of 1985 and Charter Annex of 2001</u>
The Great Lakes states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin and Canadian provinces of Ontario and Quebec, through the Council of Great Lakes Governors, established the Great Lakes Charter in 1985. The Charter is a voluntary agreement to assist and guide the Great Lakes states and provinces in cooperative management of the Great Lakes Basin waters through a series of principles and procedures. The Charter's primary purposes are to:

- conserve the levels and flows of the Great Lakes and its tributaries and connecting waters;
- protect and conserve the environmental balance of the Great Lakes Basin Ecosystem;
- provide for cooperative programs and management by the Great Lakes states and provinces;
- secure and protect current water resources management; and
- provide a secure foundation for future investment and development of the Great Lakes Basin waters

The Charter calls for the Great Lakes basin to be treated as a unified hydrological system and for the:

- design and development of a common data source regarding current and future water use, diversions and consumptive uses of each of the Great Lakes States and Provinces;
- implementation of programs to manage and regulate the diversion and consumptive uses of Basin water resources;
- implementation of consultation procedures applying to anyone who wishes divert more than 5,000,000 gallons (19 million liters) per day average in any 30-day period in which case the permitting state must solicit and carefully consider comments from all affected Great Lakes and Provinces before deciding whether to issue a permit, issue with conditions or deny a permit; and

- development of further research to provide improved information for future water planning and management decisions.

In addition, all of the Great Lakes states and provinces through the Great Lakes Charter, commit to the establishment of a Great Lakes basin water resources management program which shall include an inventory of the basin's surface and groundwater resources, information on current and future demands for diversions, withdrawals, and consumptive uses, and development of policies and procedures to further reduce consumptive uses and policies to guide the coordinated conservation, development, protection, use and management of Great Lakes Basin water resources.

The Great Lakes governors and premiers signed the Charter Annex, an amendment to the Great Lakes Charter of 1985, in June 2001. In agreeing to the Annex, the governors and premiers reaffirmed their commitment to the broad principles set forth in the Great Lakes Charter, but also acknowledged the need to re-examine the strength and adequacy of the Charter provisions, particularly regarding the legal foundations upon which current regional water management authorities rest. The Charter Annex is a non-binding agreement that creates a blueprint for water management programs to be created over the next several years. The Charter Annex objectives were developed based on state and provincial experience with water management and how these activities were influenced by the Great Lakes Charter and Section 1109 of WRDA 1986. The Charter Annex, through a series of six directives, commits the Great Lakes governors and premiers to the following:

- Outlining a framework for a set of binding agreements among the Great Lakes states and provinces;
- Establishing a series of principles for a new decision making standard for reviewing proposed withdrawals of Great Lakes water under the proposed new agreements.
- An ongoing process for involving the public in developing the agreement and standard;
- Formal Inclusion of the Premiers of Ontario and Quebec in consulting on proposed diversions of Great Lakes water from the United States; and
- Strengthening the regional water management decision support system.

<u>Great Lakes Toxics Substances Control Agreement</u>

The governors of the states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin signed the Great Lakes Toxics Substances Control Agreement in May 1986. The purpose of the agreement is to establish a framework for coordinated regional action to control toxic pollutants entering the Great Lakes system; to further the knowledge and understanding of toxic contaminants and ways to control them; and to establish common goals and redirect management practices and control strategies for toxic contaminants to ensure a cleaner Great Lakes ecosystem.

The agreement presents a series of six principles to address toxic contaminants in the Great Lakes. Through these principles, the agreement speaks to the following issues and needs:

- federal role in regulating toxic substances
- importance of clean water

- management of toxic substances through permitting
- wise management of hazardous wastes
- basin wide notice of discharge permits
- accidental discharge of pollutants
- atmospheric deposition of pollutants
- importance of monitoring and surveillance programs
- regional information exchange on toxic substances
- fish consumption advisories
- human exposure and public health assessments
- public involvement
- oversight and implementation of the Agreement

Appendix B. Partnership Sources

Building Partnerships to Enhance the Management and Operations of ISRO

Agencies, organizations and programs exist to collaborate with the National Park service and promote expanded park participation in areas related to air, land and water resources management particularly as these relate to Great Lakes restoration efforts. Most contacts have informational web sites (listed in the contact information) which can corroborate and expand on information provided here. Examples of some of these agencies, organizations and programs with contact information include the following, broken down by issue areas:

B-1. Laws, Policies and Great Lakes Governance

Council of Great Lakes Governors
Devoted to working cooperatively on public policy issues common to the Great Lakes states, the Council works directly for the eight Great Lakes Governors on projects and issues of common concern to them. The Council develops, implements, and coordinates project-specific initiatives to improve the region's environment and economy. The Council is unique among regional and national Governors' organizations because the members Governors insist that the initiatives and projects pursued have a direct impact on the health and welfare of the region's citizens.

One of the Council's priority issues relates to Great Lakes restoration. In 2002, in response to the request of members of the Great Lakes Congressional Task Force and under the leadership of its Chairman, Governor Bob Taft, the Council launched the Great Lakes Governors' Priorities Task Force. The premise of the Task Force's work to date has been that coordinated planning is needed to achieve comprehensive restoration and protection of the Great Lakes while making efficient use of limited resources. Working with the Great Lakes Congressional delegation, Great Lakes Mayors, and stakeholders throughout the region, the Great Lakes Governors believe a broad based plan can be constructed in the context of pending legislation, thus providing both a blueprint for restoration and protection and critically needed federal resources to implement it. This plan should build on the significant State and Federal investments to date, value broad public participation, foster sound public policy and sustainable behavior, address the environmental issues of the present and anticipate the challenges of tomorrow so that the Great Lakes experience full restoration and protection, balanced with economic prosperity.

Contact:
Council of Great Lakes Governors
35 East Wacker Drive, Suite 1850
Chicago, IL 60601
Phone: (312) 407-0177
Fax: (312) 407-0038
E-mail: glna@cglg.org
http://www.cglg.org/

Great Lakes Commission
The Great Lakes Commission is a bi-national public agency dedicated to the use, management and protection of the water, land and other natural resources of the Great Lakes-St. Lawrence system. In partnership with the eight Great Lakes states and provinces of Ontario and Québec, the Commission applies sustainable development principles in addressing issues of resource management, environmental protection, transportation and sustainable development. The Commission provides accurate and objective information on public policy issues, an effective forum for developing and coordinating public policy, and a unified, system-wide voice to advocate member interests.

The Commission undertakes an annual assessment of legislative priorities for the Great Lakes region through a program titled *Restore the Greatness: the Great Lakes Program to Ensure Environmental and Economic Prosperity*. This program provides a descriptive listing of the federal legislative and appropriations priorities of the Great Lakes Commission. Founded in U.S. federal and state law, the Commission has a statutory mandate to represent the collective interests of its member states: Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin. The Commission works with the U.S. Congress in partnership with its member states to promote sound public policy on issues of environmental protection, resource management, transportation and sustainable development.

Great Lakes Commission recommendations target specific programs, authorizations and appropriations. They are based largely on federal programs that have been authorized, yet inadequately funded, as well as important "new start" initiatives.

Contact:
Great Lakes Commission
Eisenhower Corporate Park
2805 S. Industrial Hwy, Suite 100
Ann Arbor, MI 48104-6791
Phone: (734) 971-9135
Fax: (734) 971-9150
http://www.glc.org/

International Joint Commission
The International Joint Commission (IJC) was created under the Boundary Waters Treaty of 1909. Consisting of six commissioners, three each appointed by the President of the United States and the Governor-in-Council (Prime Minister and Cabinet) of Canada, the IJC has quasi-

judicial, arbitrational and advisory powers. The IJC's judicial powers stem from its authority to approve all new "uses, obstructions and diversions" which affect the level and flow of boundary waters or those crossing the boundary. Without IJC approval, any construction which might have such an impact is not allowed, regardless of the wishes or either Canada or the United States. The Boundary Waters Treaty assigned the IJC the power to arbitrate in all matters of difference arising between the two countries and referred by both to the Commission. (This power has yet to be used.) Finally, the Treaty enabled the governments to refer any matter to the IJC for investigation and recommendations. In theory, either government can make a unilateral request, but in practice both governments have always agreed on the intent and wording of a reference before sending it to the Commission. It is the IJC's investigatory and advisory roles that will be of particular interest to the National Park Service in the management of Isle Royale's water resources. The two governments have asked the IJC to investigate water pollution, both point and non-point, six times since the IJC was first created:

1912	Boundary Waters Pollution Investigation;
1946/48	Connecting Channels Pollution Reference;
1964	Lower Lakes Pollution Reference-this reference served as a precursor to the Great Lakes Water Quality Agreement of 1972;
1972	Upper Lakes Pollution Reference-part of Great Lakes Water Quality Agreement of 1972;
1972	Pollution from Land Use Activities Reference-commonly PLUARG and part of Great Lakes Water Quality Agreement of 1972.

Contact:
International Joint Commission
Great Lakes Regional Office
PO Box 32869
Detroit, MI 48232
Phone: (313) 226-2170
Fax: (519) 257-6740
http://www.ijc.org/

<u>Northeast-Midwest Institute</u>

The Northeast-Midwest Institute is a Washington-based, private, non-profit, and non-partisan research organization dedicated to economic vitality, environmental quality, and regional equity for Northeast and Midwest states. Formed in the mid-1970's, it fulfills its mission by conducting research and analysis, developing and advancing innovative policy, providing evaluation of key federal programs, disseminating information, and highlighting sound economic and environmental technologies and practices.

The Institute is unique among policy centers because of its ties to Congress through the Northeast-Midwest Congressional and Senate Coalitions. The House and Senate Great Lakes Task Forces, associated with the Northeast-Midwest Coalitions, promote appropriation and authorization bills to enhance environmental quality and economic development throughout the Great Lakes basin. The bipartisan Task Forces -- co-chaired by Reps. John Dingell (D-MI), Vernon Ehlers (R-MI), Steven LaTourette (R-OH), and James Oberstar (D-MN) and Senators

Carl Levin (D-MI) and Mike DeWine (R-OH) -- have advanced numerous provisions within the Water Resources Development Act, fought for inclusion of Great Lakes interests in the Conservation and Reinvestment Act and other national environmental legislation, and addressed Great Lakes water diversions. Throughout 2004, the Great Lakes Task Forces will be particularly active on measures to protect against invasive species, to restore the Great Lakes ecosystem, and to provide adequate appropriations for Great Lakes programs.

The Northeast-Midwest Institute organizes periodic Capitol Hill briefings on key issues affecting the Great Lakes, including restoration, nonpoint source pollution, contaminated sediments, lake levels, invasive species, and air deposition. Each year, the Institute hosts a Great Lakes Summit at which the region's leaders share news and discuss cooperative ventures; and, in conjunction with the Great Lakes Commission, it also sponsors the annual Great Lakes Congressional Breakfast.

The Institute publishes the bimonthly Great Lakes Congressional Report, providing updates about federal legislation, appropriations, and regulations affecting the region's environment. The Institute's Web site also includes more frequent dispatches that report current news about congressional actions affecting the Great Lakes. Great Lakes Task Force members pay particular attention to appropriations.

Contact:
Northeast-Midwest Institute
218 D St SE
Washington DC 20003-1900
Phone: (202) 544-5200
Fax: (202) 544-0043
http://www.nemw.org/

B-2. Federal Resource Management Agencies and Institutions involved with Great Lakes Issues

U.S. Environmental Protection Agency - Great Lakes National Program Office
U.S. EPA's Great Lakes National Program Office (GLNPO), located in Chicago, Illinois, brings together Federal, state, tribal, local, and industry partners in an integrated, ecosystem approach to protect, maintain, and restore the chemical, biological, and physical integrity of the Great Lakes. The program monitors Lake ecosystem indicators; manages and provides public access to Great Lakes data; helps communities address contaminated sediments in their harbors; supports local protection and restoration of important habitats; promotes pollution prevention through activities and projects such as the Canada-U.S. Binational Toxics Strategy (BNS); and provides assistance for community-based Remedial Action Plans for Areas of Concern and for Lakewide Management Plans. Each year, GLNPO uses its funding to assist Great Lakes partners in these areas through grants, interagency agreements, and contracts.

The Boundary Waters Treaty of 1909 and the 1987 Great Lakes Water Quality Agreement (GLWQA) with Canada provide the basis for GLNPO's international efforts to manage this shared resource. Additional responsibilities are defined in Section 118 of the Clean Water Act, Section 112 of the Clean Air Act Amendments, and the Great Lakes Critical Programs Act of 1990. The Great Lakes 5-Year Strategy, developed jointly by EPA and its multi-state, multi-agency partners and built on the foundation of the GLWQA, provides the agenda for Great Lakes ecosystem management: reducing toxic substances; protecting and restoring important habitats; and protecting human/ecosystem species health.

Contact:
U.S. Environmental Protection Agency
Great Lakes National Program Office
77 W. Jackson Boulevard (G-17J)
Chicago, Illinois 60604-3511
Phone: (312) 353-2117
Fax: (312) 353-2018
http://www.epa.gov/glnpo/

U.S. Environmental Protection Agency -Office of Water

The U.S. EPA maintains an Office of Water (OW), whose mission is "to prevent pollution wherever possible and to reduce risk for people and ecosystems in the most cost-effective ways possible". The OW in cooperation with others, including the ten EPA regions, is responsible for implementing the Clean Water Act and the Safe Drinking Water Act, and portions of the Coastal Zone Act along with several other statues. Within the Office of Water, the Office of Wetlands, Oceans and Watersheds has established the Nonpoint Source (NPS) Management Program under section 319 of the Clean Water Act. The NPS Management Program provides grants to states, territories and tribes to implement NPS pollution controls. Awarded funds have supported programs aimed at controlling runoff from urban sources, septic systems, and construction, as well as managing wetlands and NPS pollution from forestry, habitat degradation and changes to stream channels. In cooperation with the National Oceanic and Atmospheric Administration, the EPA helps administer section 6217 of the 1990 Coastal Zone Act Reauthorization Amendments which tackles nonpoint pollution affecting coastal waters.

In April 2000, the States and the EPA formed a State - EPA NPS Partnership to identify, prioritized and solve nonpoint source problems. The States and EPA have established seven work groups to focus on nonpoint source topic-specific needs, including: watershed planning and implementation; rural nonpoint sources; urban nonpoint sources; nonpoint source grants management; nonpoint source capacity building and funding; information transfer and outreach; and nonpoint source results.

Each Region of the EPA also has its own Water Division. Region 5, which includes Illinois, Indiana, Michigan, Minnesota, Ohio and Wisconsin, has established the Watersheds and Nonpoint Source Programs Branch (NPS). The NPS supports and enhances State, Tribal, and local water quality management efforts through the following:

- Enforcement and compliance assistance for the Wetlands program,
- Wetland State program development and assistance,
- Development and implementation of nonpoint source pollution control programs,
- Development and implementation of the Clean Lakes program, and

- The development and implementation of the Total Maximum Daily Load Program.

Contact:
Water Division (W-16J)
US EPA Region 5
77 W. Jackson Blvd
Chicago, Illinois 60604-3590
Phone: (312) 353-2147
Fax: (312) 886-0168.
http://www.epa.gov/region5/water/org.htm

National Oceanic and Atmospheric Administration - Coastal Zone Management Program

The National Oceanic and Atmospheric Administration's (NOAA) - Coastal Zone Management Program (CZMP) is authorized by the Coastal Zone Management Act of 1972 and administered at the federal level by the Coastal Programs Division (CPD) within NOAA's Office of Ocean and Coastal Resource Management (OCRM).

The CPD is responsible for advancing national coastal management objectives and maintaining and strengthening state and territorial coastal management capabilities. CPD supports states through financial assistance ($57 million in FY 1999), mediation, technical services and information, and participation in priority state, regional, and local forums. The CZMP's unique state-federal partnership leaves day-to-day management decisions at the state level in the 33 states and territories with federally approved coastal management programs. Currently, 95,331 national shoreline miles (99.9 percent) are managed by the Program. Of the remaining 108 miles, 45 lie within Indiana, which is in the process of program development, and the rest within Illinois, which is not participating.

State and federal coastal zone management efforts are guided by the CZMP's Strategic Framework, which is organized around three major themes:

Sustaining Coastal Communities;
Sustaining Coastal Ecosystems, and
Improving Government Efficiency.

Contact:
NOAA, Office of Ocean and Coastal Resource Management
Coastal Programs Division, N/ORM3
1305 East-West Highway, SSMC4
Silver Spring, Maryland 20910
Phone: (301) 713-3155
Fax: (301) 713-4367
http://www.ocrm.nos.noaa.gov/czm/

National Oceanic and Atmospheric Administration - Great Lakes Environmental Research Laboratory

The Great Lakes Environmental Research Laboratory (GLERL), located in Ann Arbor, Michigan, is a U.S. Department of Commerce (DOC) facility operated by the National Oceanic and Atmospheric Administration (NOAA), Office of Oceanic and Atmospheric Research (OAR), through the NOAA Environmental Research Laboratories (ERL). GLERL's mission is to conduct integrated, interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine water, with special emphasis on the Great Lakes. GLERL's research provides federal, state, and international decision and policy makers with scientific understanding of:

- The sources, pathways, fates, and effects of toxicants in the Great Lakes.
- Natural hazards such as severe waves, storm surges, and ice.
- Ecosystems and their interactions, including the implications of invasion by nuisance species, for example, zebra mussels.
- The hydrology and water levels of the Great Lakes.
- Regional effects related to global climate change.

The official mission statement (1978) reads as follows:

"The Great Lakes Environmental Research Laboratory (GLERL) conducts integrated, interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine waters, with a special emphasis on the Great Lakes. The laboratory performs field, analytical, and laboratory investigations to improve understanding and prediction of coastal and estuarine processes, and the interdependencies with the atmosphere, and sediments. It places special emphasis on a systems approach to problem-oriented research to develop environmental service tools. Assistance is also provided to resource managers and others who wish to apply the information, tools, and services developed."

Contact:
Great Lakes Environmental Research Laboratory (GLERL)
2205 Commonwealth
Ann Arbor, MI
48105-2945
Phone: (734) 741-2235
Fax: (734) 741-2055
http://www.glerl.noaa.gov/

Great Lakes Sea Grant Network

Sea Grant is a network of approved colleges and programs working in partnership with government and the private sector to meet the changing needs of Americans living in the Great Lakes region. Sea Grant is a unique partnership of public and private sectors that combines research, education and technology transfer for public service - is a national network of universities meeting the changing environmental and economic needs of Americans in coastal ocean and Great Lakes regions.

Sea Grant has an outstanding record of achievement in transferring the results of university research to a wide range of audiences and giving special assistance to coastal communities, businesses and individual citizens. Congressional committees have repeatedly cited Sea Grant as one of the most efficient and cost-effective programs funded by the U.S. government. A 1981 analysis, for example, estimated that the *annual* benefits to the national economy from Sea Grant-sponsored research and outreach surpassed the federal government's *total* investment in the program over the preceding 12 years, and the program's benefits continue to grow exponentially.

Through its network of Advisory Service (Extension) agents and its use of modern communications and education techniques, the Great Lakes Sea Grant Network plays a central role in supplying the region and the nation with usable solutions to pressing problems and providing the basic information needed to better manage Great Lakes resources for present and future generations of Americans.

The Great Lakes Fisheries Leadership Institute is new program is supported by the Great Lakes Sea Grant Network. It is designed to provide emerging fishery leaders with the knowledge and skills to effectively interact with Great Lakes fishery management organizations.

Contact:
Great Lakes Environmental Research Lab, Sea Grant Lakes Network
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Ann Arbor, MI 48105
Phone: 734-741-2287
Fax: 734-741-2055
http://www.glerl.noaa.gov/seagrant/

U.S. Geological Survey - Water Resources Division

The U.S. Geological Survey (USGS) is the Nation's largest water, earth, and biological science and civilian mapping agency, the U.S. Geological Survey (USGS) works in cooperation with more than 2,000 organizations across the country to provide reliable, impartial scientific information to resource managers, planners, and other customers. This information is gathered in every State by USGS scientists to minimize the loss of life and property from natural disasters, to contribute to the conservation and the sound economic and physical development of the Nation's natural resources, and to enhance the quality of life by monitoring water, biological, energy, and mineral resources.

The Water Resources Division (WRD) of USGS has the principal responsibility within the federal government to provide the hydrologic information and understanding needed by others to achieve the best use and management of the Nation's water resources. To accomplish this mission, the WRD, in cooperation with state, local, and other federal agencies provides the following services:

- Systematically collects and analyzes data to evaluate the quantity, quality, and use of the Nation's water resources and provides results of these investigations to the public.
- Conducts water resources appraisals describing the occurrence, availability, and physical,

chemical and biological characteristics of surface and ground water.

Conducts basic and problem-oriented hydrologic and related research that aids in alleviating water resources problems and provides an understanding of hydrologic systems sufficient to predict their response to natural or human caused stress.

Coordinates the activities of Federal agencies in the acquisition of water resources data for streams, lakes, reservoirs, estuaries, and ground water.

Provides scientific and technical assistance in hydrologic fields to other Federal, State, and local agencies, to licensees of the Federal Energy Regulatory Commission, and to international agencies on behalf of the Department of State.

Administers the State Water Resources Research Institutes Program and the National Water Resources Research Grants Program.

Contact:
U.S. Geological Survey - Water Resources Division
Michigan District Office
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Lansing, MI 48911
Telephone: (517) 887-8903
Fax: (517) 887-8937
http://water.usgs.gov/

<u>U.S. Geological Survey - Great Lakes Science Center</u>

The Great Lakes Science Center traces its beginnings to 1871 when Congress, by joint resolution, established the United States Fish Commission and charged it with responsibility for investigations and inquiries concerning the supply of food fishes of the coasts and lakes of the United States and the determination of protective, prohibitory, or precautionary measures to be adopted. Initial investigations began in 1871 in Lake Michigan-the Lake with the longest shoreline within the United States and the largest number of fisheries. The U.S. Fish and Wildlife Service and its two Bureaus, the Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife evolved from these early investigations.

Activities of the Bureau in the Great Lakes and Central Region prior to 1920 were limited to infrequent surveys, mostly statistical, of the fisheries of the Great Lakes and the Mississippi River system and to the operation of fish cultural stations. The earliest continuing work on the Great Lakes began in 1920 when the Bureau began supporting the research of Dr. Walter N. Koelz and Dr. John Van Oosten at the University of Michigan. These early studies focused on the taxonomy and life histories of coregonids (whitefishes, ciscoes, chubs). The current Great Lakes Science Center was established in 1927 as the Great Lakes Biological Laboratory, with John Van Oosten as its Director. This program was started as a consequence of the furor generated by the collapse of the cisco fishery in Lake Erie in 1925. The Great Lakes Science Center has always resided in the Department of Interior but has changed bureaus and undergone several name changes over the last half century.

The Great Lakes Science Center is dedicated to providing scientific information for the management of our nation's biological resources. The Center is headquartered in Ann Arbor, Michigan, and has biological stations and research vessels located throughout the Great Lakes

Basin. The Great Lakes Science Center's research spans a range of studies including fish populations and communities, aquatic habitats, terrestrial ecology, nearshore and coastal communities and the biological processes that occur in this complex ecosystem of the Great Lakes.

Contact:
U.S. Department of the Interior
U.S. Geological Survey
Great Lakes Science Center
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Phone: (734) 994-3331
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http://www.glsc.usgs.gov/

U.S. Army Corps of Engineers (USACE)
The United States Army Corps of Engineers (USACE) is made up of approximately 34,600 civilian and 650 military men and women. Our military and civilian engineers, scientists and other specialists work hand in hand as leaders in engineering and environmental matters. The USACE's diverse workforce of biologists, engineers, geologists, hydrologists, natural resource managers and other professionals meets the demands of changing times and requirements as a vital part of America's Army. The mission of USACE is to provide quality, responsive engineering services to the nation including:

Planning, designing, building and operating water resources and other civil works projects (Navigation, Flood Control, Environmental Protection, Disaster Response, etc.);
Designing and managing the construction of military facilities for the Army and Air Force (e.g., military construction); and
Providing design and construction management support for other Defense and federal agencies.

In the Great Lakes region, the USACE provides services and support through the Great Lakes and Ohio River Division located in Cincinnati, Ohio and the Detroit, Buffalo, Chicago and St. Paul Districts.

The Detroit District, established in 1841, covers 82,000 square miles of land inhabited by about 14 million people and has 4,000 miles of Great Lakes shoreline. The District's major mission is to investigate, plan, design, construct, operate and maintain congressionally authorized water resource projects related to navigation, flood control, beach erosion and other activities. The Detroit District operates and maintains the World Famous Soo Locks, plus 102 harbors on Lakes Superior, Michigan, Huron, St. Clair and the State of Michigan portion of Lake Erie. The Detroit District manages the Great Lakes Water Control Data System, making it the Corps center for hydrometeorologic and water level data collection and dissemination for the Great Lakes system.

The Buffalo District, established in 1824, covers 38,000 square miles ranging from Massena, New York, to Toledo, Ohio, encompassing the U.S. drainage basins for both lower Great Lakes and the St. Lawrence River. It comprises a significant portion of the industrial heartland. There are approximately 300 employees in four offices and district headquarters. The Buffalo District program totals approximately $40 million annually with half going toward maintenance of Great Lakes ports, including 100 miles of federal channels and 38 miles of dikes and breakwaters.

The Buffalo District assists the water resources effort by planning, designing, constructing and maintaining navigation, flood control and public erosion control projects. Its substantial expertise in water resource management involves it in ongoing programs related to water quality and water supply. It also enforces a regulatory authority over shoreline and wetland development. A normally dry dam at Mt. Morris, built in 1952 by the Buffalo District, protects the Rochester, N.Y. area and has already prevented damage of more than $350 million. The Black Rock Lock on the Niagara River is another facility built and operated by the district. The district also designed and constructed the Eisenhower and Snell locks on the St. Lawrence Seaway.

The Chicago District is responsible for water resources development in the Chicago metropolitan area, a unique urban area of about 5,000 square miles with a population of about 8 million. The district is involved in a variety of projects stemming from its primary mission areas of Flood Control, Shoreline Protection, Navigation, Environmental Protection, Emergency Management and Support for Others.

The St. Paul District is involved exclusively with USACE regulatory programs covered under Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act. Under Section 10, a USACE permit is required to do any work in, over or under a navigable water of the U.S. Water bodies have been designated as Navigable Waters of the U.S. based on their past, present, or potential use for transportation for interstate commerce. These waters include many of the larger rivers and lakes, such as the Minnesota, St. Croix, and Mississippi rivers; and Lake Superior and the Mississippi headwaters lakes. Under Section 404, a USACE permit is required for the discharge of dredged or fill material into waters of the U.S. Many water bodies and wetlands in the nation are waters of the U.S. and are subject to the Corps' Section 404 regulatory authority. The St. Paul District's regulatory jurisdiction covers the states of Minnesota and Wisconsin. Early in 2000, the St. Paul District replaced all USACE Section 404 nationwide permits across Minnesota and Wisconsin with a combination of statewide regional general permits and letter-of-permission evaluation procedures.

Contact:
Detroit District Headquarters
U.S. Army Corps of Engineers
477 Michigan Ave.
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http://www.lre.usace.army.mil/

U.S. Fish and Wildlife Service

The mission of the U.S. Fish and Wildlife Service's mission is: to work with others, to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the

American people. The Fish and Wildlife Service (FWS) is the only agency of the U.S. Government with that primary mission. The FWS helps protect a healthy environment for people, fish and wildlife, and helps Americans conserve and enjoy the outdoors and our living treasures. The FWS's major responsibilities are for migratory birds, endangered species, certain marine mammals, and freshwater and anadromous fish.

The FWS's origins date back to 1871, when Congress established the U.S. Fish Commission to study the decrease of the nation's food fishes and recommend ways to reverse the decline. Meanwhile, in 1885, Congress created an Office of Economic Ornithology in the Department of Agriculture. The office studied the food habits and migratory patterns of birds, especially those that had an effect on agriculture. This office gradually grew in responsibilities and went through several name changes until finally renamed the Bureau of Biological Survey in 1905.

In addition to studying birds and mammals, the FWS's responsibilities included managing the nation's first wildlife refuges, controlling predators, enforcing wildlife laws, and conserving dwindling populations of migratory birds. The Bureaus of Fisheries and Biological Survey were transferred to the Department of the Interior in 1939. In 1940, they were combined and named the Fish and Wildlife Service. Further reorganization came in 1956 when the Fish and Wildlife Act created the United States Fish and Wildlife Service and established two bureaus, Sport Fish and Wildlife and Commercial Fisheries. In 1970, the Bureau of Commercial Fisheries was transferred to the Department of Commerce and renamed the National Marine Fisheries Service.

For many years the FWS was the principal federal wildlife and fisheries research agency. In the 1940's, FWS research biologists conducted some of the first investigations into the effects of the pesticide DDT in wildlife. FWS researchers also revealed the life cycle of the parasite that causes whirling disease in trout. In addition, FWS biologists developed many of the captive breeding techniques that have benefited such rare species as whooping cranes, California condors and black footed ferrets. The FWS's research function briefly became an independent agency and was eventually reorganized as part of the U.S. Geological Survey in 1996. The FWS employs approximately 7,500 people at facilities across the country including a headquarters office in Washington, D.C., seven regional offices, and nearly 700 field units. Among these are national wildlife refuges, national fish hatcheries and management assistance offices, law enforcement and ecological services field stations.

Contact:
U.S. Fish and Wildlife Service
Region 3, Great Lakes-Big Rivers Region
1 Federal Drive
BHW Federal Building
Fort Snelling, MN 55111
Phone: (612) 713-5360
V/TTY: (800) 657-3775
http://midwest.fws.gov/level1/welcome.htm

Great Lakes Fishery Commission

The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries between Canada and the United States in 1955. The Commission has two major responsibilities:

> To develop coordinated programs of research on the Great Lakes, and, on the basis of the findings, to recommend measures which will permit the maximum sustained productivity of stocks of fish of common concern; and
>
> To formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes.
>
> The commission consists of four Canadian commissioners appointed by the Privy Council and four American commissioners (plus one alternate) appointed by the President. The commissioners are supported by a secretariat, located in Ann Arbor, Michigan.

In delivering its program, the commission relies on input and advice from boards it appoints, lake committees, citizen advisors, and state, provincial, tribal, and federal agency officials. Funding for the commission is provided by the governments of Canada and the Untied States. The commission also has trust funds in both countries to accept private donations. Each state, provincial, federal and tribal natural resource agency in the Great Lakes basin signed the *1980 Joint Strategic Plan for Management of Great Lakes Fisheries*, which identifies the commission's individual lake committees as the major action arms for implementing the plan and developing.

Contact:
Great Lakes Fishery Commission
2100 Commonwealth Blvd, Suite 100
Ann Arbor, MI 48105
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Fax: (734) 741-2010
Email: info@glfc.org (For general information)
http://www.glfc.org/

B-3. Nongovernmental Organizations, Institutes and Associations Involved in Great Lakes Issues

International Association for Great Lakes Research

The International Association for Great Lakes Research (IAGLR) is a scientific organization made up of researchers studying the Laurentian Great Lakes and other large lakes of the world, as well as those with an interest in such research. Specifically, IAGLR does the following:

- promotes all aspects of large lakes research; and
- communicates research findings through publications and meetings.

To support these objectives, IAGLR:

- holds an Annual Conference, attended by hundreds of Great Lakes researchers;

- publishes the Journal of Great Lakes Research, an interdisciplinary scientific journal with four issues per year; and
- gives several Awards and Scholarships to recognize excellence in Great Lakes research.

Contact:
IAGLR
2205 Commonwealth Blvd.
Ann Arbor, MI 48105
Phone: (734) 665-5303
Fax: (734) 741-2055
E-mail: office@iaglr.org
http://www.iaglr.org/

Great Lakes Protection Fund
The Great Lakes Protection Fund is a private, nonprofit corporation formed in 1989 by the Governors of the Great Lakes States. It is a permanent environmental endowment that supports collaborative actions to improve the health of the Great Lakes ecosystem. The Fund's Board of Directors is comprised of two governor appointed representatives from each member state. The Board of Directors meets quarterly and governs the Fund's operation. To date, the Fund had made 198 grants and program related investments representing more than $42.3 million in regional projects to improve the health of the Great Lakes ecosystem.

The Fund seeks projects that:
- lead to tangible improvements in the health of the Great Lakes ecosystem,
- promote the interdependence of healthy ecological and economic systems, and
- are innovative, creative, and venturesome.

The Great Lakes Protection does provide financial support to governmental entities and could be a source of funding for Isle Royale related research, particularly if that research is transferable to other areas of the Great Lakes.

Contact:
Great Lakes Protection Fund
1560 Sherman Avenue, Suite 880
Evanston, IL 60201
Phone: (847) 425-8150
Fax: (847) 424-9832
http://www.glpf.org/

The Nature Conservancy's Great Lakes Program
The Nature Conservancy, through its Great Lakes program, preserves the plants, animals and natural communities that represent the diversity of life in the region by protecting the lands and water they need to survive. Great Lakes States' Chapters include: Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin. By focusing on key systems that support much of the special biodiversity of the Great Lakes ecoregion, the Conservancy

promotes on-the-ground strategies to address the principle threats to the basin's globally significant biodiversity.

To address the growing need for cooperation, The Nature Conservancy worked with a variety of partners and led a large-scale study to identify the lands and waters which are critical to the conservation of biodiversity in the Great Lakes region. Contributors to the study included hundreds of scientists and experts from federal, state, provincial and local agencies, academia, industry and conservation organizations. This process resulted in the "Blueprint for Conservation of Great Lakes Biodiversity." The Conservation Blueprint scientifically and systematically identifies native species, natural communities and aquatic systems characteristic of the region. It then determines where they need to be protected to ensure their long-term survival.

The Great Lakes ecoregional planning initiative is only the beginning of many opportunities to share information and work together to conserve Great Lakes biodiversity. Designing a vision for Great Lakes conservation has not been accomplished by the Conservancy alone. Partnership has been, and will continue to be, vital to the collective conservation success in the Great Lakes region with the hope that strategic collaboration will lead to greater conservation success for the Great Lakes region.

Contact:
The Nature Conservancy
Great Lakes Program
8 S. Michigan Avenue, Suite 2301
Chicago, IL 60603
Phone: (312) 759-8017
Fax: (312) 759-8409
E-mail: greatlakes@tnc.org
http://nature.org/wherewework/northamerica/greatlakes/

<u>National Wildlife Federation-Great Lakes Natural Resource Center</u>
The Great Lakes Field Office in Ann Arbor, Michigan, unites people throughout the eight-state Great Lakes region, the U.S. and Canada to protect the world's greatest freshwater seas, the surrounding ecosystem, and the benefits they provide to people and wildlife. Many plants, animals, and wild places in the region have been damaged by point and nonpoint sources of pollution. The National Wildlife Federation (NWF) has scientists, lawyers, organizers and educators all contributing their skills to protect and restore the Great Lakes. NWF staff members educate, inspire and assist people to stop the toxic pollution and habitat destruction in the lakes.

Contact:
Great Lakes Natural Resource Center
National Wildlife Federation
213 W. Liberty, Suite 200
Ann Arbor, MI 48104-1398
Phone: (734) 769-3351
Fax: (734) 769-1449
E-mail: greatlakes@nwf.org

http://www.nwf.org/resourceLibrary/index.cfm?officeID=F7439239-65BF-0A01-01BD9365CEBF53C0

Great Lakes Sport Fishing Council
The Great Lakes Sport Fishing Council is a bi-national regional advocacy organization comprised of many local and state organizations from the Great Lakes region. The Council is a 501(c)(3) not-for-profit organization concerned about the present and future of sport fishing in the Great Lakes region. Its members are also concerned about the air we breathe, the water we drink, and the fish and wildlife which share this region with us.

The Council's premier newsletter, the *Great Lakes Basin Report*, deals with the many issues impacting the region and its economy, including exotics, Sea Grant and Coast Guard activities, environmental issues, safety bulletins, legislative updates, as well as DNR/MNR activities. The Great Lakes Sport Fishing Council is actively involved in wise resource management and stocking programs as well as Remedial Action Plans (RAPs) and Lakewide Management Plans (LaMPs). The Council is concerned about toxics and containments-both point source and nonpoint source pollution. As a member of various regional federal committees, the Council represents the views of the sport fishing community and is actively involved in and reports on the activities of US Fish & Wildlife Service, National Biological Service, U.S. Coast Guard, Great Lakes Fishery Commission and Great Lakes Commission. The Council also closely monitors the activities of U.S. EPA as they impact the Great Lakes region.

Founded in 1973, the Great Lakes Sport Fishing Council maintains state/provincial directors in all eight Great Lakes states and Ontario and is headquartered in Elmhurst, Illinois. Granted non-profit mailing status by the US Postal Service, the Council has also been given state sales tax exemption by the Illinois Secretary of State.

Contact:
Great Lakes Sport Fishing Council
P.O. Box 297
Elmhurst, IL 60126
Phone: (630) 941-1351
Fax: (630) 941-1196
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http://www.great-lakes.org/

B-4. Conferences, Partnerships and Programs to Protect and Conserve the Great Lakes

State of the Lakes Ecosystem Conference (SOLEC)
The SOLEC conferences are hosted by the U. S. Environmental Protection Agency and Environment Canada on behalf of the two Countries every two years in response to the binational Great Lakes Water Quality Agreement. The conferences are intended to provide a forum for exchange of information on the ecological condition of the Great Lakes and surrounding lands. A major purpose of this is to reach a large audience of people in the government (at all levels), corporate and not-for-profit sectors who make decisions that affect the lakes. Other conferences are expected to meet the need for exchange of research results and for large gatherings of the general public.

Held in even numbered years, the conferences are the focal point of a process of gathering information from a wide variety of sources and engaging a variety of organizations in bringing it together. In the year following each conference the Governments have prepared a report on the state of the Lakes based in large part upon the conference process.

The SOLEC process views the ecosystem in terms of the state or "health" of the living system and its underlying physical, chemical and biological components. Human health is considered to be part of the living system. SOLEC conferences are intended to focus on the state of the Great Lakes ecosystem and the major factors impacting it rather than the status of programs needed for its protection and restoration. Evaluation and redirection of programs are addressed through other means.

The first conference, held in 1994, addressed the entire system with particular emphasis on aquatic community health, human health, aquatic habitat, toxic contaminants and nutrients in the water, and the changing Great Lakes economy. The 1996 conference focused on the nearshore lands and waters of the system where biological productivity is greatest and humans have had maximum impact. Emphasis was placed on nearshore waters, coastal wetlands, and land by the Lakes, and the impact of changing land use, and information availability and management. For each conference an integration paper was prepared for participants, bringing all the topics together. Also for both conferences indicators were chosen and, based on expert opinions, subjective assessments were provided as to conditions in terms of good, fair, poor, etc. SOLEC '98 supported further development of easily understood indicators to objectively represent the condition of ecosystem components. These are used every two years to inform the public and report progress in achieving the purpose of the Water Quality Agreement: to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes ecosystem.

In addition to reporting on the health of the living system, the conferences report on the underlying conditions. This reflects the increased recognition that the condition of the ecosystem is being determined by three major factors: habitat loss, pollution, and exotic species; all of which are being driven by human activities.

The SOLEC indicators are intended to provide an umbrella or overarching set which provide a general system wide overview. They will draw upon and complement indicators used for more specific purposes such as Lakewide Management Plans or Remedial Acton Plans for geographic Areas of Concern.

Contact:
SOLEC Senior Advisor
US Environmental Protection Agency - Great Lakes National Programs Office
77 West Jackson Blvd.
Chicago, IL 60604
phone: (312) 353-3612
fax: (312) 353-2018
http://www.on.ec.gc.ca/solec/

Great Lakes Observing System (GLOS)
A valuable tool for keeping tabs on a wide range of conditions in the Great Lakes is currently under development through a cooperative effort by the Great Lakes Commission and the National Oceanic and Atmospheric Administration (NOAA). The Great Lakes Commission is working on this collaborative effort to create an integrated Great Lakes Observing System (GLOS) to provide critical real-time data for multiple users, including, among others, resource managers, researchers, homeland security interests, the commercial shipping industry and the recreational boating community. GLOS will be a regional node of NOAA's multi-year, national Integrated Ocean Observing System (IOOS) initiative. NOAA's investment in the GLOS effort will provide for full integration of many disparate observations in a cohesive, "one-stop-shopping" web locale.

The Integrated Ocean Observing System is a coordinated national and international network of observations, data management and analysis that systematically acquires and disseminates data and information on the past, present and future states of the oceans and coastal zones, including the Great Lakes. Regional associations of major stakeholders (data providers and users) are being established to develop products and services tailored to the unique needs of each region and to design, implement and operate coastal observing systems that meet these needs.

Contact:
Great Lakes Commission
Program Manager, Data and Information Management
Eisenhower Corporate Park
2805 S. Industrial Hwy, Suite 100
Ann Arbor, MI 48104-6791
Phone: 734-971-9135
Fax: 734-971-9150
http://www.glc.org/glos/

Great Lakes Coastal Wetlands Consortium
The Great Lakes Coastal Wetlands Consortium consists of scientific and policy experts drawn from key U.S. and Canadian federal agencies, state and provincial agencies, non-governmental organizations, and other interest groups with responsibility for coastal wetlands monitoring. Approximately two dozen agencies, organizations and institutions have been brought into the Consortium as Project Management Team members. This is an unprecedented assembly of coastal wetlands expertise. In addition, other members are brought in as small project teams are formed to address discrete project elements and pilot studies. The Consortium is coordinated by staff at the Great Lakes Commission (GLC) in Ann Arbor, Michigan and has been funded by the U.S. EPA Great Lakes National Program Office in Chicago, Illinois.

The Consortium's purpose is to design an implement able, long-term program to monitor Great Lakes coastal wetlands. This is being accomplished through the development of indicators to assess the condition of Great Lakes coastal wetlands. The selected indicators were selected through the State of the Lake Ecosystem Conference (SOLEC) process. The Consortium will provide scientific support for this monitoring program; create a database that is publicly accessible; recruit the leadership required to implement the long-term monitoring program; and develop a network of fund raisers and agencies who will support the Great Lakes coastal wetlands monitoring program.

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http://www.glc.org/wetlands/

Great Lakes Air Deposition (GLAD) Program
The Great Lakes Air Deposition Program overarching principles are to: (1) better understand the impacts of deposition of pollutants of concern to all water bodies in the Great Lakes region, (2) ensure continued progress in reducing sources and loadings of atmospheric deposition to the Great Lakes region, and (3) reduce the environmental and public health impacts associated with air emissions and subsequent atmospheric deposition.

In pursuit of these objectives, the Program Management Team has formed more immediate and specific priorities for addressing air deposition in the Great Lakes region. These priorities are separated into five categories that collectively support the program's three overarching principles identified above:

Air Deposition Monitoring
Emissions Inventory Development
Source Characterization and Emissions Factor Development
Atmospheric and Multi-Media Modeling
Assessment of Effects on Wildlife and Human Health.

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http://www.glc.org/glad/

Isle Royale Net Environmental Benefit Analysis
On January 6 through 8, 2004 a Net Environmental Benefit Analysis (NEBA) was held in Duluth, Minnesota to look at the potential impacts and removal options available in the event of a 30,000 gallon spill of oil from a grounded freighter on Passage Island. Twenty-five responders and resource managers from federal, state and local agencies as well as private and non-profit

organizations participated in the process (see attached list of participants). This meeting was one of a number of ongoing activities focusing on the prevention and response options available to Isle Royale National Park. This NEBA was the first one completed for a freshwater environment. Because of this, standard NEBA documentation and processes were modified as needed to meet group requirements. The Great Lakes Commission is currently in the process of compiling a detailed report of the processes leading to the NEBA, the discussions held during the NEBA, preliminary findings and proposed next steps to ensure that this information is captured and integrated into the planning, preparedness and response efforts for Isle Royale.

Isle Royale National Park preserves 132,018 acres of land-based wilderness that was federally designated October 20, 1976. The park consists of one large island surrounded by about 400 smaller islands, encompassing a total area of 850 square miles including submerged land which extends four and a half miles out into Lake Superior. Due to Isle Royale's biological and ecological uniqueness, it was designated an International Biosphere Reserve in 1980. Isle Royale encompasses a remote and primitive wilderness archipelago isolated by the size and power of Lake Superior. Isle Royale is world renowned for its long-term wolf/moose predator/prey study. The park offers outstanding possibilities for research in a remote, relatively simple ecosystem where overt human influences are limited. Park waters contain the most productive native fishery and genetically diverse trout populations in Lake Superior. Many species of flora and fauna in Isle Royale National Park are state and federally listed threatened and endangered, last known populations or genetically distinct populations. Human health and safety were not considered during this NEBA process. The assumption of this report is that human health and safety factors will need to be weighed in the final decision for employing each removal strategy.

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Natural Heritage Network
The Natural Heritage Network comprises 85 independent programs for the collection of data about the plants, animals, and ecological communities of the Western Hemisphere. These natural heritage programs are found in all 50 U.S. states, 10 Canadian provinces and 14 Latin American and Caribbean countries. All the Great Lakes states house their programs under their natural resources agencies.

The role of these natural heritage programs is to gather, manage, and distribute detailed information about the biological diversity found within their jurisdictions. Natural heritage programs compile information on the exact locations and conditions of rare and threatened species and ecological communities. Consistent standards for data collection and management allow data from different programs to be shared and combined. Financial support for state natural heritage programs comes from multiple sources including The Nature Conservancy (TNC), state governments, universities and other grant sources.

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<u>Great Lakes Bi-national Toxics Strategy</u>
The Bi-national Toxics Strategy has been developed under the auspices of the Bi-national Executive Committee (BEC), which is charged with coordinating the implementation of the binational aspects of the 1987 Great Lakes Water Quality Agreement. The BEC is co-chaired by Environment Canada and the United States Environmental Protection Agency, and includes representatives from the Great Lakes states, the Province of Ontario, as well as other federal agencies in Canada and the U.S.

The purpose of this bi-national strategy is to set forth a collaborative process by which Canada and the U.S. will work towards the goal of virtual elimination of persistent toxic substances resulting from human activity, particularly those which bioaccumulate, from the Great Lakes basin, so as to protect and ensure the health and integrity of the Great Lakes ecosystem. The goal of virtual elimination will be achieved through a variety of programs and actions, but the primary emphasis will be on pollution prevention.

The Strategy reaffirms the two countries' commitment to the sound management of chemicals, as stated in *Agenda 21: A Global Action Plan for the 21st Century* and adopted at the 1992 United Nations Conference on Environment and Development. The Strategy will also be guided by the principles articulated by the International Joint Commission' s Virtual Elimination Task Force in the Seventh Biennial Report on Great Lakes Water Quality.

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<u>IJC-Council of Great Lakes Research Managers</u>
The Council of Great Lakes Research Managers has served as the International Joint Commission's principal advisor on research programs and research needs since 1984. The purpose of the Council is to enhance the ability of the Commission to provide effective leadership, guidance, support and evaluation of Great Lakes research as it applies to the

provisions of the Great Lakes Water Quality Agreement of 1978. Membership is evenly divided between the United States and Canada, consisting of individuals managing federal, state and provincial research programs and representatives from academic institutions and private industry.

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IJC-Science Advisory Board (SAB)
Under the *Great Lakes Water Quality Agreement*, the Great Lakes Science Advisory Board was established to provide scientific advice to the International Joint Commission and the Great Lakes Water Quality Board and is responsible for developing recommendations on all matters related to research and the development of scientific knowledge pertinent to Great Lakes water quality. Such a broad mandate requires a multi-disciplinary approach and accordingly, members are appointed from each country by the IJC with expertise in the natural, physical and social sciences.

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IJC-International Air Quality Board
In 1966 the Governments asked the International Joint Commission to observe air quality along the entire Canada and United States boundary and, as appropriate, draw air pollution problems to the attention of Governments. The Commission established the International Air Quality Advisory Board to identify and provide advice on air pollution issues with trans-boundary implications.

The Board includes five members from Canada and five from the United States who have expertise in various aspects of air pollution effects and control. They are appointed by the Commission and serve as advisors in their personal and professional capacities. The role of the Board is entirely advisory in nature. Information and advice is provided to the Commission by the Board through semi-annual progress reports, workshops, technical analyses and published reports on the many aspects of trans-boundary air pollution.

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IJC-International Lake Superior Board of Control
This Board was established by the International Joint Commission in its 1914 Order of Approval granting permission for increased hydropower development in the St. Mary’s River. The Board's duties include setting Lake Superior outflows, and overseeing the operation of the various control works. Activities related to these responsibilities include: conducting studies to develop and improve the regulation plan; monitoring repairs and maintenance of the control facilities; and directing flow measurements in the St. Mary’s River for the purpose of determining the discharge capacities of the various control works.

The Board provides the Commission with advice on matters related to: adverse hydrologic conditions on the lakes; modification of the control facilities; and levels and flows in the St. Mary's River, including the environmentally sensitive St. Mary's Rapids. The Board meets at least twice yearly, semi- annually provides the Commission with a report on its activities, and annually meets with the public.

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APPENDIX C PROJECT STATEMENTS

C-1. Conduct a Spatial Survey and Biological Inventory of Shoreline Splash Pools at Isle Royale National Park

Problem Statement

Unique among Isle Royale's many aquatic resources are the small rock pool habitats situated along the Lake Superior shoreline. These rock pools are exposed to extreme climatic elements of wind, waves and ice, but provide habitat for regionally rare aquatic biota. Because of their location, shoreline rock pools are vulnerable to a variety of stressors ranging from fuel and oil spills to lake level fluctuations, climate change, and species invasions. Previous studies of Isle Royale's rock pools have provided important ecological insights and an indication of species composition, but have been limited to a small number of barrier islands, have not comprehensively addressed rock pool biota, and have not addressed potential threats. Here we propose a series of activities that would serve to identify and map rock pools park-wide, determine use of the rock pools by key taxa, evaluate species-environment relationships, assess which rock pools would be affected by potential stressors, and provide recommendations for future rock pool monitoring.

Introduction

Isle Royale National Park (ISRO) is a remote island archipelago situated in northwestern Lake Superior. In addition to its diverse inland lakes, wetlands, beaver ponds and streams, ISRO park boundaries also include over 165,000 hectares of Lake Superior waters and an impressive 543 kilometers of Lake Superior shoreline (Lafrancois and Glase 2005). The extensiveness of these shorelines is attributable to the many long fingerlike coves and harbors on the main island and to the hundreds of smaller barrier islands surrounding it.

Much of the Isle Royale shoreline is characterized by bedrock slopes that are sparsely vegetated and highly exposed to wind, storm waves and ice scour. These elements combine to create a unique and considerably harsher environment than what is experienced elsewhere on the island or on the nearby mainland. Such conditions also contribute to the formation of depressions in the shoreline bedrock, which fill with water from rainfall and wave wash. The filled depressions, or rock pools, vary widely in size, permanence and proximity to Lake Superior, but are biologically active and generally support a simple community of aquatic invertebrates, algae, and amphibians (Van Buskirk 1992).

Owing to their severe environment, the rock pool biota is simple, unique and regionally rare. The rock pools represent one of the most southern localities for *Aeshna juncea*, a dragonfly typically found in arctic ponds and peat bogs (Van Buskirk 1992, 1993). Additionally, on Isle Royale the boreal chorus frog *Pseudacris triseriata maculata* breeds almost exclusively in shoreline rock pools (Smith 1983). Terrestrial habitats surrounding the rock pools also feature rare floral elements characteristic of arctic and alpine environments (Judziewicz 1999). Janke (1984) noted that shoreline plant communities at Isle Royale were outstanding and very fragile natural features of the park, and that careful management was required. The same may be said of the rock pool communities.

Some of Isle Royale's rock pools have been investigated over the past two decades. Dr. David Smith (Williams College, Massachusetts) and others have monitored many pools on 11 different islands and conducted a series of basic ecological studies (Smith 1983, Smith 1987, Van Buskirk 1992, Van Buskirk 1993, and Smith and Van Buskirk 1995). Their work indicates, among other things, that pool size and distance from Lake Superior affect the ecology and species composition of the rock pools (Smith 1983). Boreal chorus frog tadpoles (*Pseudacris triseriata*) are constrained mainly to pools of intermediate size and shoreline position, because small pools and those next to Lake Superior do not persist long enough to ensure metamorphosis, and large, permanent pools next to the forest edge are inhabited by predaceous dragonfly and salamander larvae. Current genetics work by Dr. Smith and others aims to determine which types of pools are chorus frog population sources and centers. The abundance and distribution of rock pools and their use by chorus frogs are not, however, known on a park-wide basis.

Paradoxically, the same characteristics that make for unique rock pool organisms at Isle Royale (i.e., exposure to harsh microclimates, variable hydroperiods, and disturbance from Lake Superior) also make them vulnerable to a variety of environmental hazards. Potential stressors include fuel or oil spills, lake level fluctuations, changes in climate and precipitation patterns, and species invasions. Results of a Net Environmental Benefit Analysis indicated that a nearby spill of fuel oil would be catastrophic for some shoreline biota, with population collapse likely for the boreal chorus frog (Interagency Spill Response Planning Team 2004). Changes in Lake Superior water levels, induced by climate change or water management in the Great Lakes Basin, have implications for the availability and distribution of shoreline splash pool habitats. Climate change models for the Great Lakes region suggest changes in seasonal precipitation and increased storm intensity are likely (Kling *et al.* 2003). Breeding behavior, reproductive success, and competitive interactions of rock pool fauna would be affected by exotic species invasions or climate-related changes in hydroperiod and Lake Superior wave action.

Isle Royale's shoreline rock pools represent some of the park's most unique and most vulnerable habitats. In order to plan effective responses to likely stressors, baseline information is needed to understand the distribution and biological composition of shoreline rock pools on a park-wide basis. As an initial step toward addressing these needs, we propose to:

- Identify and map shoreline rock pools park-wide
- Investigate use of the pools by breeding boreal chorus frogs, *Aeshna juncea* dragonflies, and other arctic disjunct species
- Categorize pools and conduct more comprehensive ecological surveys on a subset of pools
- Explore species-environment relationships and assess pool vulnerability to stressors
- Develop a strategy for long-term rock pool monitoring

Recommended Activities

The proposed action consists of several phases. The first of these phases is the most basic and involves identifying and **mapping** existing rock pools and determining which and how many are currently used as breeding habitats for boreal chorus frogs. Phase two involves categorizing the rock pools based on their size, chemistry, proximity to Lake Superior, or other relevant factors, and intensively **surveying** a subset of pools from each category for water quality and biology.

Phase 3 involves **analyzing data** to explore species environment relationships and to assess stressor risks. The final phase involves **reporting** and developing long-term **monitoring** recommendations for the rock pools and their biota.

Phase 1: Mapping

Early in the summer and after the hatching of tadpoles, a park-wide survey of rock pools will be initiated. All significant splash pools (size to be determined in future discussions with David Smith) will be identified and their locations noted using a GPS unit. Information on each pool will be entered into a GIS. Elevation above Lake Superior will be determined, horizontal distance from both Lake Superior and the nearest forest or upland vegetation edge will be measured, and shoreline aspect will be noted. Morphometric measurements at each pool will include maximum depth, maximum length, and maximum width or breadth. Distance to nearest adjacent rock pool will also be determined. Presence or absence of boreal chorus frog tadpoles will be evaluated by visual inspection. Field water quality measurements at each pool will include temperature, conductivity, and pH. Relative amount of particulate organic matter on the rock pool bottoms will be assessed visually and assigned a categorical rating of low, medium or high. Depending on initial field assessments, these categories may have quantitative bounds (for example, low = 0-1 cm accumulated, medium = > 1-2 cm, etc.).

Phase 2: Ecological Surveys

Using the above physical and chemical attributes, rock pools will be grouped into categories using principal components analysis. A subset of pools from each category will be randomly selected for further investigation. During mid-summer, these pools will be re-visited and sampled for water quality and biology. Water quality parameters measured in the field will include temperature, conductivity and pH. Additionally, water samples will be collected and returned to the lab for analysis for nutrients, dissolved organic carbon, and chlorophyll *a*. Suspended and benthic algal samples for chlorophyll *a* will be collected in the field, filtered, and placed on ice for later analysis. Algal samples will also be collected and preserved for later species identification; special attention will be given to any arctic disjuncts. Zooplankton and benthic macroinvertebrates will be collected using a small net and, if possible, identified and enumerated in the field. A small number of specimens will be preserved as vouchers. Finally, tadpoles and larval salamanders will be identified and enumerated at each pool. Tadpole tail clips may also be collected for later genetic analysis by David Smith.

Phase 3: Data Analysis

Information derived from the field sampling could be used to explore how biological composition in the rock pools relates to rock pool position, morphometry and water chemistry characteristics, and also how vulnerable certain pool types or taxa would be to potential stressors.

1) *Species-environment relationships:* Potential questions to explore include which types of pools contain the most diverse invertebrate assemblages, which pools provide the best habitat for species of interest, such as the boreal chorus frog or the dragonfly *Aeshna juncea*, and whether or not species composition differs among pools according to pool chemistry, size, and proximity to Lake Superior or the forest edge. These relationships will be explored using a multivariate statistical method such as canonical correspondence analysis or redundancy analysis. Special attention will be given to whether organisms

originated in the pools themselves or were transported from Lake Superior waters via wave action. This information will also help indicate the relative influence Lake Superior may have had on different pools during the study year.

2) *Risk analysis for potential stressors:*
   a. Fuel or oil spills – rock pools on parts of the island closest to shipping lanes and on parts of the shoreline closest to Lake Superior would be most vulnerable to damage from fuel or oil spills. High risk areas could be defined in GIS, and the percentage of pools that fall in this category park-wide could be calculated. Additionally, the number of these high risk pools likely to be used by chorus frogs could be estimated based on the percentage of these pools inhabited by tadpoles during the study year.
   b. Lake level fluctuations – water level fluctuations on Lake Superior occur naturally, but are also influenced by water management at the Soo Locks, diversions from the Lake Superior basin, and potentially climate change. Using information on pool distribution and pool elevation above Lake Superior, the number of pools affected by potential changes in water levels and splash zone elevations could be estimated. Under a scenario of rising lake levels, pools close to Lake Superior would become inundated and those further from Lake Superior would receive more frequent disturbance from storm waves and scouring from shore ice. Under a scenario of falling lake levels (more likely), many rock pools would cease to receive wave wash from Lake Superior and would likely fill with organic matter or desiccate. Determining risks associated with such lake level changes may require more detailed elevation surveys.
   c. Climate change – climate change scenarios for the region predict changes in temperature and precipitation patterns and increases in storm frequency and intensity. Increases in temperature and declines in precipitation would lead to rock pool desiccation, particularly for small, precipitation-dependent pools outside the Lake Superior splash zone. Increases in storm frequency and intensity, on the other hand, would likely increase water inputs to rock pools from Lake Superior waves, particularly for rock pools closest to the shoreline. Numbers of pools in both of these categories could be estimated.
   d. Species invasions – introduction of zebra mussels, spiny water fleas or other exotic invertebrates would have severe consequences on these species-poor ecosystems. Pools situated closest to Lake Superior are most vulnerable to such species invasions, and numbers of pools in this category could be estimated.

Phase 4: Reporting and monitoring recommendations

Results of the proposed survey will be reported to the park in a comprehensive report or presentation including species lists and maps, and may also be written up as manuscripts suitable for publication in a regional or national journal. Results may also be presented at regional meetings such as the Western Great Lakes Research Conference. The report will include detailed management recommendations and suggestions for future research and monitoring. Monitoring recommendations should be attentive to the physical, chemical and biological attributes addressed in this survey as well as to the potential stressors discussed above. The outcome of this survey will be used to determine the feasibility of long-term, park-wide monitoring of rock pool abundance and distribution. The biological survey data will help evaluate which taxa are of greatest management interest, which environmental variables are most important to the resident biota, and which subset of pools would be most useful for future biological monitoring.

Logistics and Budget

To the extent possible, this project will be accomplished by volunteer scientists and existing National Park Service staff from the park, the Great Lakes Network, and the Midwest Region. The Midwest Region's aquatic ecologist will work to coordinate the project and develop study plans with park resource management staff and cooperating researchers. ISRO will provide in-kind planning and field support. The Great Lakes Network will provide in-kind oversight for developing rock pool monitoring plans and assembling GIS layers. Likely research cooperators include vertebrate biologist David Smith (Williams College), who has conducted long-term work on Isle Royale rock pools and expressed an interest in extending this work to other parts of the park, invertebrate ecologist Toben Lafrancois (University of Minnesota), who is skilled in aquatic invertebrate taxonomy and has worked intensively on rock pools of the desert southwest, and diatomist Mark Edlund (Science Museum of Minnesota, St. Croix Watershed Research Station), who is an expert in algal taxonomy and is interested in diatom species composition in the rock pools.

Many of the supplies and equipment needed for this project are already on hand at the park, the Midwest Region, or cooperators' labs. These include GPS units, field meters for temperature, conductivity and pH, and collection nets and identification trays for biological work. A limited amount of project money may be needed to support travel and lodging for visiting scientists, transportation around the islands to study sites (likely kayak rental), purchase of sample containers and preservatives, and analysis of water quality samples. Some support for water quality analysis may be available through the laboratory at the St. Croix Watershed Research Station. The entire project could likely be accomplished for well under $5,000.

Timeline

Activity	Jan-May 2005	May-Jun 2005-06	May-Aug 2005	Sep-Dec 2006	Jan-May 2007
Project planning	x				
Mapping		x			
Ecological survey			x		
Data analysis				x	
Reporting					x

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C-2. Inventory of Nearshore Fishes and Description of Nearshore Fish Population Densities and Community Structures at Apostle Islands National Lakeshore and Isle Royale National Park

Problem Statement

No known research has been conducted to inventory fish species and to describe fish population densities and community structures in the nearshore zone (depth less than 15 m) of Lake Superior. This research has been identified as a high priority need by Apostle Islands National Lakeshore (APIS) and Isle Royale National Park (ISRO). Addressing that need was also ranked as a high priority by park staff and fish biologists at the recent National Park Service Great Lakes Network Inventory and Monitoring workshop. Park boundaries extend into Lake Superior 0.25 mile around the Apostle Islands National Lakeshore and 4.5 miles around Isle Royale National Park. The diversity and complexity of nearshore aquatic habitats may support a higher diversity of fishes than are found in the offshore zone of the lake (Hoff and Bronte 1999, USGS unpublished data). By inventorying nearshore fishes and by quantifying densities of fishes, nearshore fish communities can be described. Inventories of fishes and communities will enable monitoring programs to track changes in fish populations and communities as the result of species reintroductions, species rehabilitations, changes in management approaches, and environmental and biological perturbations. Monitoring populations and communities will allow the NPS to work with agency partners (U.S. Geological Survey, State Departments of Natural Resources, U.S. Fish and Wildlife Service, and Tribal Agencies) to scientifically manage and protect nearshore fishery resources, which has not been possible until those resources are described and quantified. Descriptions of population densities and community structures will also provide the parks with information useful for developing interpretative programs to educate visitors on natural resources influenced by recreational use inside the parks, commercial use inside and outside the parks, and habitat and environmental alterations outside the parks.

Objectives

It is the mission of the USGS Great Lakes Science Center to provide data and information to help the National Park Service manage its natural resources scientifically. This study proposes to inventory fish species and to describe fish population densities and community structures in the nearshore area (0-15m) of the APIS and ISRO. Analysis of the inventory data will reveal a variety of nearshore fish communities and their structures. For example, nearshore zones characterized by rocky, wave-swept open lake shores will harbor very different species assemblages than those found in shallow, weedy areas at the head of protected coves and harbors. Comparison of these communities will reveal different structures and comparison with those in offshore areas in APIS will likely show that many open lake species are very dependent on nearshore habitat for spawning and rearing of young. Information collected will guide the development and implementation of programs to monitor nearshore fish populations and communities in each park. That monitoring will enable assessment of environmental quality changes, habitat alterations, species rehabilitations, species invasions, and changes in management approaches.

Goals

To characterize nearshore fish communities for the Apostle Islands and for Isle Royale National park units by:

a) conducting an inventory of nearshore fish species
b) estimating fish population densities
c) describing community structure
d) relating characteristics of nearshore communities to offshore communities in the APIS park unit
e) providing guidance for establishing a long-term monitoring program for fish communities of the APIS and ISRO park units

Methods

Field

Seines and bottom trawls will be employed to conduct sampling of nearshore fish communities in APIS and ISRO. These active sampling methods will allow us to estimate densities of fish per unit of area swept and will allow direct comparison with annual spring bottom trawl assessments conducted by USGS in U.S. waters of Lake Superior. Our intention is to conduct sampling in nearshore zones (wetted edge to 15 m depth) to complement USGS spring trawling that is conducted at depths >15 m. In the APIS park unit, where USGS has conducted spring trawl assessments for >25 yr at 10 locations, we will be able to characterize fish communities at those locations from wetted edge to depths >100 m, and in most cases beyond the .25 mile park boundary. No offshore bottom trawl assessments have ever been conducted at ISRO, so our sampling and analysis for ISRO will be limited to characterizing nearshore fish communities.

Nearshore sampling of fish communities will be conducted during the late summer when fish are more likely to be abundant in warm, shallow nearshore habitats and age-0 fish are of sufficient size to be susceptible to capture. Note that the lake-wide USGS fish community assessment is conducted in spring because offshore fishes are concentrated near the bottom at depths >15 m at that time of year and are susceptible to capture by bottom trawls.

To inventory and characterize fish communities in APIS and ISRO, 24 sampling sites will be established in each park unit. Offshore and estuary stations will provide contrast to characterize the structure of nearshore fish communities. In the APIS park unit, 10 nearshore stations will be established inshore from the offshore USGS spring assessment stations, and 11 additional stations will be established in a stratified-random fashion so that the prevalent shoreline types (low and high gradient sand; low and high gradient rocky) are equally represented, and 3 stations will be established in estuaries or stream mouths (Sand Island and north and south Stockton Island). In fall 2002, underwater video surveys were taken at several stations in APIS to provide visual records of the prevalent shoreline types. At ISRO, 21 nearshore stations will be established in a stratified-random fashion among prevalent shoreline types (low gradient fine substrate, intermediate gradient coarse substrate, high gradient rocky, and bedrock). Our surveys of ISRO nearshore habitat in 2001-2003 will allow us to determine the distribution and abundance of the prevalent shoreline habitats and guide the establishment of a representative array of study sites to characterize nearshore fish communities in 2004. At ISRO, 3 stations will be established in river estuaries (Washington Creek, Big Siscowet River, and McCargoe Creek).

Sampling in nearshore habitat will be accomplished with seines and bottom trawls. For the habitat zone between wetted edge and 1.5 m depth, a 15-m bag seine (6.4-mm bar mesh) will be used to sample fish. One end of the seine will be held on shore while another end will be pulled straight from shore to a depth of 1.5 m, and then the seine will be swept in an arc to shore. The radius of the arc will be measured, and that will be used to compute the area swept by the seine. For the habitat zone > 1.5 m depth, a small boat (~7.2 m) capable of towing 6 m bottom trawl with a 6.4-mm bar mesh cod end will be used to sample fish. Trawls will be deployed in the nearshore zone at depths of 1.0-1.5 m and towed to depths of 15 m so as to complement USGS offshore trawl sampling. Area swept by the trawl will be calculated by the width of the trawl opening (5 m) by the length of the tow. Where offshore sampling stations exist (APIS), the end point of the nearshore sampling station will be the starting location for the offshore stations. Sampling in estuaries will be conducted with seines where depths are 1.5 m or less and with bottom trawls where depths exceed 1.5 m. For each sampling station, water temperature will be measured at the wetted edged and temperature profiles will be recorded at depths of 1.5 and at 15 m.

For each sample at each station, up to 50 individuals of each species will be randomly selected and measured for total length and weighed to the nearest 0.1 gram. For species with more than 50 individuals per sample, additional fish will be counted and mass weighed. Vouchers of each species for each station will be preserved in 10 percent formalin.

Analytical methods

a) Inventory of fish species
Field data will be tabulated to provide species lists for each station and a summary for each park unit.

b) Describe fish population densities
Abundance and biomass of each species (number/hectare and kg/hectare, +/- standard deviation) will be computed for each station and for all stations combined. The results will be tabulated to show number and weight/hectare for each species by station and park unit.

c) Describe community structure
Community structure will be presented graphically to provide comparisons among the sample stations for each park unit. We will also compute commonly used indices of biotic diversity (Simpsons, Shannon-Weiner) and similarity (Schoener 1970) compare community structure among sampling locations and parks.

d) Relate nearshore and estuarine communities to offshore communities in APIS.
We will compare community structure and densities and biomass of each species from nearshore and estuarine areas to that from offshore areas in APIS.

Voucher specimens

Voucher specimens will be collected as permitted by each Park will be archived at the Great Lakes Biological Station.

Schedule

The approximate timeline for completing the project is as follows:

Year 1 (2001) - Purchase needed equipment and supplies. Commence researching and acquiring spatial themes (GIS coverages) that depict habitat structure useful for designing sample site layout and for analyzing fisheries data at the two parks.

Year 2 (2002) - Develop and submit draft database(s) and metadata files for the study. Databases must be in MS Access format and metadata must meet FGDC standards. Continue to search for GIS coverages and submit all such coverages to the Great Lakes Network GIS specialist. In coordination with the Network GIS specialist use GIS coverages to determine which areas of APIS and ISRO should be sampled to maintain scientific rigor and to ensure safety.

Spring Year 3 (2003) - Sample nearshore fish populations and communities at APIS.

Spring Year 4 (2004) - Sample nearshore fish populations and communities at ISRO.

Final report and all databases, GIS coverages and other deliverables (see below) will be submitted by April 30, 2005 (the year following completion of field work at ISRO).

Coordination and Logistics
Principal Investigators (PI) and key project staff will communicate directly with the Resource Management Specialist (RMS) at each park to coordinate when fieldwork will be conducted in their park. Such coordination will be done well in advance of the field season to provide the RMS sufficient time to complete any permitting and compliance work. It will be the responsibility of the RMS to provide the PI with all permits and to alert park management, rangers, and other NPS staff who may need to be aware of project staff.

Project staff will have their own transportation (boats, trailers, and vehicles), but request periodic housing at Isle Royale for 4 persons. The exact dates of housing needs is yet to be determined, but will be coordinated with the RMS well in advance of the field season, as housing may be limited to a first come first served basis. It is the PI's responsibility to secure such housing.

Budget

Year	Item		Expected Cost
FY 2001	Purchase equipment (boat, trawls, seines)		**32,000**
FY 2002	Develop databases and acquire GIS themes		**0**
FY 2003	Apostle Islands National Lakeshore		
	Fishery biologist $20/hr (725 hrs)		14,500
	Biological technicians 2 X $15/hr (233 hrs)		3,500
	Equipment and gas $75/day for 13 days		1,000
		Supplies:	478
		Subtotal:	19,478
		15% overhead for DOI IAAs	2,922
		Total amount requested for FY 2003:	**22,400**

FY 2004	Isle Royale National Park	
	Fishery biologist $20/hr (660 hrs)	13,240
	Biological technicians 1 X $15/hr (170 hrs)	2,550
	Student intern 8/hr (170 hrs)	1,360
	Equipment and supplies (trawls, seines, gas $200/day for 20 days)	4,000
	Per diem: 7 for 20 days @ 35/day:	4,900
	R/V Kiyi operations:	12,450
	Subtotal:	38,000
	15% overhead for DOI IAAs:	5,775
	Total amount requested for FY 2004:	**44,275**
	Total amount requested FY2001-FY2004	**98,675**

Overhead - USGS will assess a 15 percent overhead charge to DOI agencies for all carry-over and new funds awarded starting with FY03. Exact overhead rate structure will vary from year to year. The 15 percent overhead assessments have been figured into the above budget.

Statement of cost effectiveness - The Lake Superior Biological Station of the USGS Great Lake Science Center has been conducting fisheries assessments for more than 40 years on Lake Superior. Sampling fishes in Lake Superior requires specialized boats, gear, equipment, and techniques, and is expensive. Our expertise, location on Lake Superior, and ability to utilize specialized equipment enables this project to be as cost effective as possible.

Products and Deliverables

Annual progress reports will be submitted for each park unit via the web-based Investigators Annual Report (IAR) system by March of the following year. By April 30, 2005, draft databases (including metadata), GIS coverages and a draft final report will be submitted to the Great Lakes Network coordinator for peer review. The Park Service will then have 30 days to review the draft final report and databases. Within 30 days following peer review, final databases, GIS coverages and a final report will be submitted to the Great Lakes Network coordinator (by 30 June 2005). The final report will consist of (3) hard copies and one (1) electronic copy. This report will be in MS Word format and will include introduction, methods, results, discussion, and literature cited sections.

The report will provide an inventory of species and describe fish population densities and a synthesis of fish community structure for the nearshore areas of APIS and ISRO. The report will also synthesize existing information on the ecology of individual species and life history differences in the use of nearshore and offshore habitats. If appropriate, results will be submitted to peer-reviewed scientific journals. In the final report, we will provide recommendations for establishing a scientifically sound long term monitoring plan that is ecologically and fiscally appropriate to the goals of NPS.

Data will be entered into a pre-approved MS Access database that will be provided to the network coordinator at project completion. This database will include GPS locations for sampling stations that will be compatible with Arcview software and will comply with FGDC standards. Metadata that describe database structure and multivariate statistical outputs will be included in the Arcview compatible file. Metadata will also be entered into the National Biological Information Infrastructure (NBII) Metadata Clearinghouse using MetaMaker tool. Fish data will also be entered in the USGS database (Oracle software) at Lake Superior Biological Station in Ashland, Wisconsin.

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C-3. Research Change in Dissolved Organic Carbon and Nitrogen Inputs on Boreal Lake Foodwebs, Isle Royale National Park

Abstract

The extensive boreal biome is little studied relative to its global importance. Its high soil moisture and low temperatures result in large below-ground reservoirs of carbon (C) and nitrogen (N). The boreal biome is experiencing large increases in temperature which seem likely to increase terrestrial production and export of dissolved organic carbon (DOC) and nitrogen (DON) to the aquatic ecosystem. In the aquatic ecosystem, DOC and DON provide significant amounts of energy and nutrients to the producer base of the foodweb. The DOC concentration also regulates the quality of foodweb energy flow in lakes, UV light penetration, and it can be a factor in the toxicity of contaminants. For two decades we have conducted research on terrestrial and aquatic ecosystems in Isle Royale National Park. Our research indicates that increasing temperatures will increase DOC and DON export to lakes, and could alter concentrations sufficiently to significantly reduce production efficiency at the base of the aquatic foodweb. This proposed cooperative USGS-BRD, NPS, and university research will address that question.

Problem Statement

Terrestrial production and export of dissolved organic carbon (DOC) and nitrogen (DON) to the aquatic ecosystem is a function of soil temperature, moisture, seasonal hydrologic flowpath, and basin morphology (Dillon and Molot 1997, Battin 1999, Brooks *et al.*, 1999, Baker *et al.*,2000). In the aquatic ecosystem, DOC and DON provide significant amounts of energy and nutrients (Sun *et al.* 1997) especially in the boreal biome (Peterson *et al.*, 1986; Easthouse *et al.* 1992). High DOC concentrations also regulate the quality and efficiency of foodweb energy flow in lakes (Jansson *et al*. 2000), UV light penetration (Sommaruga *et al.*, 1999), and DOC can be a factor in reducing the toxicity of contaminants. An extensive 1980-82 survey of lakes in Isle Royale National Park (Stottlemyer *et al.* 1998) showed all to be humic (colored) in varying degrees. The DOC in these lakes appears primarily derived from allochthonous (terrestrial) sources. More colored, i.e. humic, lakes have an open-water (pelagic) food web based largely on bacterioplankton energy mobilization from DOC (Jansson *et al.* 2000). In contrast, in clear water lakes the pelagic food web is based mainly upon phytoplankton photosynthesis. The efficiency of energy use is lower in humic lakes where production is based on bacterioplankton because of the additional links in the food chain. Research in Europe and North America shows lake food web shifts between heterotrophic production (bacteria) and primary production (phytoplankton) can take place with modest changes (10 mg l-1) in DOC concentration. Climate change could affect the DOC loading to lakes and therefore their biodiversity, biotic structure, and productivity (Schindler 1998). On Isle Royale, warming soils will likely increase terrestrial DOC production and export to the aquatic ecosystem (Stottlemyer *et al.* 1998).

Background

A recent report by the Academy of Science's National Research Council (NRC 2000), and commissioned by the National Science Foundation, documented the high priority global environmental research needs where U.S. research dollars should be committed. The top priority research was the biogeochemical cycling of carbon, nitrogen, sulfur, phosphorus, and other elements in soil, air, and water, and how change in their balance will affect ecosystem function and biodiversity. A series of recent research summaries (Kennedy 2000, Kerr 2001) now provide a firm association between human activity and climate change. With recent data fed into improved models, the Intergovernmental Panel on Climate Change (IPCC) has revised upward its estimate of warming (6 - 10° C). With culpability comes the mandated obligation to quantify the effect of global change on ecosystem function and structure in national parks for a policy position. All systems can not be studied, but selected ecosystems representative of large acreages under National Park Service (NPS) management can be studied in some detail.

The National Park Service manages a total of about 4 million ha of boreal ecosystem or 15 percent of total NPS lands. Globally, the boreal forest (primarily Bailey's Subarctic Division) occupies about 1.3 billion ha, second only in size to moist tropical forests (Olson *et al.* 1983). About 10 percent of the boreal biome is covered by lakes (Schindler 1998). Climate warming, atmospheric deposition, and increased ultraviolet radiation caused by stratospheric ozone depletion - the `big three` of human stressors - will likely have serious environmental effects on the boreal biome. The three stressors dramatically change the chemical and energy interactions among terrestrial, wetland, stream, and lake ecosystems.

We have continuously studied the boreal Wallace Lake watershed ecosystem on Isle Royale National Park for nearly two decades (Stottlemyer *et al.* 1998). Isle Royale is located at the southern boreal ecotone between the temperate forest (northern hardwoods or Bailey's Warm Continental Division) and boreal biomes. At the scale of biomes, ecotones are usually correlated with the position of climate-driven air mass activity. Since the range limits of many species occur at biome edges, the biodiversity of ecotones is relatively high compared to the conterminous biomes (Risser 1995). However, since many organisms are at their physiological limits, ecotones are especially responsive to stress such as climate change. Ecotones also intensify or concentrate activities as the movement of organisms, nutrients, and other materials across the landscape. The sensitivity of chemical and biological processes within ecotones, especially at the base of foodwebs, affects the concentrations of dissolved nutrients and energy, as carbon, and their fluxes in water between the terrestrial and aquatic ecosystem. We have already documented a few such changes in response to the `big three` stressors for the Wallace Lake ecosystem (Stottlemyer and Toczydlowski 1999a & b, Herrmann *et al*. 2000).

Another dimension to this question is the relationship between light extinction, including UV, and lake DOC concentrations. In Wallace Lake the light extinction coefficient - a composite of lake light absorption by water, particles, and dissolved organics - is correlated to DOC concentrations.

A related question is how global change might alter the quality of DOC and the quality and quantity of dissolved organic nitrogen (DON) available to the lake (Easthouse *et al.* 1992, Kallbitz *et al.* 2000). The DOC and DON production and quality will likely be altered by the availability of soil inorganic N which we have shown responds to warming temperatures (Stottlemyer and Toczydlowski 1999b). Wallace Lake presently experiences a pronounced seasonal shift in the relative importance of inorganic N, as NO3-, and DON as an essential nutrient.

Another important issue is the relationship of DOC and the potential toxicity of metal contaminants. Many heavier metals in ionic form are toxic to aquatic organisms. Dissolved organic compounds of both high and low molecular weights can form metal-organic complexes greatly reducing the absorption and toxicity of metals to biota.

In sum, climate change almost certainly will alter the export of DOC and DON to such lakes, and therefore the efficiency and quality of lake primary productivity. Altered primary productivity will, in turn, restructure the higher trophic levels of the aquatic food web. Seasonally these small Isle Royale lakes serve as important habitat for aquatic bird reproduction among other higher organisms. However, to assess the relative effects of global change we must first quantify the extent of seasonal change in processes affecting lake DOC and DON concentrations where past data provide a sufficient context. Then a series of Isle Royale lakes, varying in watershed to lake area, topography (climate, flowpath to the lake), and vegetation must be examined to come up with a more general assessment of potential changes at the landscape-level.

Description of Action (Methods)

Our research objectives are as follows: 1) Quantify seasonal change in the net primary production: bacterioplankton production ratio; 2) Quantify the primary production: bacterioplankton respiration ratio; 3) Relate these two ratios to lake DOC concentration to locate the DOC concentration where shifts in production pathways may occur; and 4) Relate this finding to probable causal scenarios incorporating the effect of global change on terrestrial export of DOC and DON to the lake. We expect, based upon the lake chemistry record, that primary production will prevail in late summer and early fall, while bacterioplankton production will dominate in early and mid-summer. Once some additional understanding of Wallace Lake exists (first full year of study), for the remaining two years of proposed study selected components of the research will be extended to a spectrum of lakes on Isle Royale differing in seasonal range of DOC concentrations (Jansson *et al.* 2000).

This study will complement but rely heavily on past NPS and ongoing USGS-BRD sponsored Long Term Ecosystem Studies and global change research in the Wallace Lake ecosystem. A major objective of this research is to examine relationships among soil warming, moisture, and nutrient availability on DOC and DON production and flowpath to the aquatic ecosystem. In brief, this research uses a series of replicated small plots with soil lysimeters and meteorological instrumentation in each of the major vegetation types to examine how change in moisture and N availability affects the production and export of DOC and DON. For the basic design of this long-term study, see Stottlemyer and Toczydlowski (1999a) Field manipulation of temperature is not practical without alteration of the soil profile which confounds assessing temperature effects, so field measurements of the DOC and DON production relationship to temperature will largely be descriptive. To examine the effects of forest floor and soil temperature on DOC and DON production, we will use laboratory incubations at three temperatures where soil respiration, net N mineralization, and KCl- and deionized water-extractable DOC and DON are measured over time. For the general design of the laboratory study used, see Stottlemyer and Toczydlowski (1999b). The flowpath of subsurface flow to the aquatic ecosystem is the other major variable accounting for change in DOC and DON amounts. To quantify this, we are using the principles and basic design outlined in Stottlemyer and Toczydlowski (1999c).

Our proposed study will also examine seasonal change in upstream-downstream and lake DOC and DON quality. The methodology will likely follow that of Easthouse *et al.* (1992) and Sun *et al.* (1997). However, we are also developing methodology for analyzing DOC fractions at Michigan Technological University and for DON fractions at a cooperating laboratory at the University of Colorado - Boulder using samples from Olympic National Park, Washington, and the Fraser Experimental Forest, Colorado. There is good reason to suspect a significant seasonal change in DOC and DON quality, and therefore aquatic biological response, because of seasonal change in terrestrial physical factors and in-stream consumption rates before runoff reaches the lake.

Lake productivity sampling will take place monthly beginning immediately after snowmelt and continue into late September or early October. Winter sampling will be attempted since few datasets have such information (Jansson *et al.* 2000). Standard methods for determining production and respiration will be employed similar to those of Tranvik (1989), Tulonen (1993), and Jansson *et al.* (2000). Rates will be based upon lake volume (known) for Wallace Lake or for the lake epilimnion. Routine lake monitoring for light transmission, chemistry, and water height will be covered as part of the long-term ecosystem study.

The investigators for this study will be Robert Stottlemyer (PI), USGS-BRD Mid-continent Ecological Science Center, Ft. Collins, Colorado; David Toczydlowski, Dept. Biological Sciences, and Sarah Green, Chemistry Department, Michigan Technological University, Houghton, Michigan; and Larry Kallemyne, USGS-BRD, International Falls, Minnesota. Most of the field work will be provided by technical personnel and graduate students from Michigan Technological University.

Alternative Actions and Impacts Considered: This study will not involve any significant field experimental manipulations. Should small scale lake experiments become important, such as exclusion of UV radiation by shields, the work would be done using 1 m diameter limnocorrals and screens for short periods (days). Relevant experimental study has already been conducted, or will be conducted mainly in laboratory incubations as part of ongoing Isle Royale global change research.

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C-4. Developing an Early Detection and Monitoring System and Rapid Response Plan for Aquatic Invasive Species

Funded Status: Funded = 0.00 Unfunded = 225.00

Problem Statement
Nonindigenous aquatic invasive species (AIS) pose significant risks to the ecological and economic health of the Great Lakes-St. Lawrence system. Many of these invasions are the due to anthropogenic activities, such as ballast water transport from ocean-going commercial vessels and smaller commercial enterprises, including the aquaculture industry, aquarium trade, biological pest control, recreational boating, recreational fisheries enhancement, bait business and horticultural practices. AIS invasions are a significant force of ecological change, affecting population, community and ecosystem processes in the Great Lakes-St. Lawrence system. Further, they have significant and well-documented economic impacts on a range of water-dependent sectors.

Isle Royale National Park, due to its isolation from the mainland of the United States and Canada, is protected to a large degree from the introduction and spread of AIS. Many of the above mentioned vectors present a minimal threat to Isle Royale National Park. However, since Isle Royale is considered to have a somewhat simplified and fragile ecosystem, it is of vital importance that the land and water resources be protected from the threat of AIS.

A comprehensive early detection and monitoring program and rapid response plan for AIS have not been established on Isle Royale to protect Park water and water dependent natural resources. An early detection and monitoring program is needed to discover new introductions. A rapid response plan is needed to eradicate or control invasive species when they are detected. Without an effective early detection, monitoring and rapid response system, new AIS introductions may not be detected until after the point where implementation of technically and economically feasible eradication/control measures is possible.

The Great Lakes Panel on Aquatic Nuisance Species has recognized that comprehensive monitoring programs are needed to facilitate early detection of AIS and support rapid response efforts. Early detection, monitoring and rapid response planning for AIS were also identified as high priority at the April 2002 project scoping workshop. To address these needs, it is proposed that the National Park Service develop a program to advance an early detection, monitoring and rapid response regime for Isle Royale National Park.

Description of Recommended Project or Activity
This proposal will yield a set of guidelines and a framework for a coordinated early detection-monitoring system and rapid response plan for Isle Royale National Park, to help NPS staff detect and respond to new invasions of AIS. The guidelines and framework will be based upon a thorough examination of existing early detection, monitoring and rapid response programs and will be crafted with the input from experienced scientists, resource managers, educators and administrators.

It is proposed that the following activities be undertaken in support of the early detection and monitoring component of this project:

Early Detection and Monitoring

1) establish a project management team of NPS staff and recruit technical advisors from federal agencies, state agencies and universities with experience and expertise in early detection and monitoring to serve on a project advisory team throughout the life of the project;

2) identify species most likely to be introduced and most probable vectors and pathways for introduction of AIS into Isle Royale National Park;

3) review existing ISRO monitoring programs to identify where monitoring is taking place and what parameters are beings monitored;

4) assess the resulting monitoring coverage to discover gaps and develop a strategy for addressing gaps in monitoring coverage;

5) evaluate monitoring programs to discover ways the monitoring can be improved and/or altered to provide early detection information;

6) develop the guidelines and framework for an early detection and monitoring program for Isle Royale National Park;

Rapid Response

This project will also yield a rapid response plan available for use within Isle Royale National Park that, in the event of an AIS introduction, will facilitate the timely implementation of measures to maximize the probability of eradication or control.

A rapid response plan will be part of the framework and process for the early detection and monitoring of AIS and will include the selection and implementation of measures for eradication or control. In developing such a plan, review of models from the areas of resource management will be important (e.g., local, state/provincial, regional, tribal and federal emergency response plans for pollution events). The Region 5 Oil and Hazardous Substances Integrated Contingency Plan shows particular promise as a model and members of the federal/state Regional Response Team will provide considerable expertise to this project.

Existing species-specific AIS rapid response plans will also be assessed over the course of the project. For example, a review of the action plan established under the auspices of the U.S. Fish and Wildlife Service to prevent the introduction and dispersal of the Mediterranean strain of *Caulerpa taxifolia* in U.S. waters will be valuable (Keppner and Caplen 1999). This action plan recognizes that implementation of effective prevention and control programs requires centralized coordination and leadership, along with the support and participation of federal, state and local agencies as well as nongovernmental user groups and other interests. The plan features a primary point of contact that facilitates and coordinates federal responsibilities to control potential introduction and pathways for dispersal. Models developed by the Animal and Plant Health Inspection Service of the U.S. Department of Agriculture for noxious weed control will also be assessed.

The following specific tasks will be undertaken to develop a rapid response plan for AIS for Isle Royale National Park:

1) initiate a project scoping exercise to ensure that the rapid response plan can be developed in a timely and cost-effective manner and that input is received from all appropriate entities. The AIS rapid response plan must be developed and structured to ensure that timely implementation is technically, economically and politically feasible. Response mechanisms and management options delineated in the plan should be designed for use by trained NPS staff and other federal response personnel. The plan should be coordinated with existing comprehensive state and federal AIS management plans and related procedures/protocols.

2) develop the plan with input from the project advisory team. Plan development should also be coordinated with the national aquatic nuisance species (ANS) Task Force and the National Invasive Species Council in conjunction with their work on AIS rapid response. As part of this effort, the other ANS regional panels in the country will also be encouraged to participate in this initiative.

3) initiate a process for plan review and approval. The Region V Regional Response Team should be engaged in this project for the purpose of plan review and approval. The Region 5 RRT consists of representatives from 15 federal agencies and the states of Illinois, Indiana, Michigan, Minnesota, Ohio and Wisconsin. The RRT's are planning, policy and coordinating bodies for the 13 U.S. federal regions. Established by the National Response Team, the RRTs are responsible for planning and coordinating regional preparedness and response actions involving oil and hazardous materials and coordinating assistance and advice given to the federal on-scene coordinators in the event of major or substantial discharges or releases. Involvement of the RRT may be necessary if plan options include the use of chemicals or other methods that require pre-approval.

4) test the plan using an exercise approach. The Region V RRT will also provide good advice on how to test the plan and can help NPS staff prepare for an exercise to evaluate the plan. Exercises are staged to ensure that the plan is being followed properly, personnel are properly equipped and trained, resources are properly deployed and communications are conducted in a timely and efficient manner. Lessons learned from response plan exercises are invaluable to make sure that maximum resource protection is afforded in a timely and cost-effective way.

Literature Cited

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Budget
First year = $75K
Second year = $75K
Third year = $75K

Appendix D. Conversion Table

Temperature

- To convert degrees Celsius into degrees Fahrenheit, multiply by 1.8 and add 32
- To convert degrees Fahrenheit into degrees Celsius, subtract 32 and multiply by 0.55

Length, distance & area

- To convert inches to centimeters, multiply by 2.54
- To convert centimeters to inches, multiply by 0.39
- Feet to meters, multiply by 0.3
- Meters to feet, multiply by 3.28
- Yards to meters, multiply by 0.91
- Meters to yards, multiply by 1.09
- Miles to kilometers, multiply by 1.61
- Kilometers to miles, multiply by 0.62
- Acres to hectares, multiply by 0.4
- Hectares to acres, multiply by 2.47

Weight

- To convert ounces to grams, multiply by 28.35
- To convert grams to ounces, multiply by 0.035
- Pounds to kilograms, multiply by 0.45
- Kilograms to pounds, multiply by 2.21
- British ton to kilograms, multiply by 1016
- US tons to kilograms, multiply by 907

Volume

- To convert imperial gallons to liters, multiply by 4.55
- To convert liters to imperial gallons, multiply by 0.22
- US gallons to liters, multiply by 3.79
- Liters to US gallons, multiply by 0.26

Appendix E. Species List

Table 25. Zooplankton species list for 36 inland lakes on Isle Royale, sampled once each during 1995-1996. List compiled from Larson *et al.* (2000).

Group	Species Name
Cladocera	*Bosmina longirostris*
	Ceriodaphnia sp.
	Chydorus sp.
	Daphnia ambigua
	Daphnia galeata mendotae
	Daphnia pulex
	Daphnia retrocurva
	Diaphanosoma birgei
	Holopedium gibberum
Copepoda	*Acanthorcyclops vernalis*
	Diacyclops thomasi
	Diaptomus oregonenesis
	Mesocyclops edax
	Tropocyclops prasinus
Rotifera	*Asplanchna priodonta*
	Conochilus unicornis
	Filinia terminalis
	Hexarthra mira
	Kellicottia bostoniensis
	Kellicottia longispina
	Keratella cochlearis
	Keratella hiemalis
	Keratella quadrata
	Monostyla lunaris
	Ploesoma hudsoni
	Polyarthra dolichoptera
	Polyarthra major
	Pompholyx sulcata
	Synchaeta sp.
	Trichocerca elongata
	Trichotria tetractis

Table 26. Phytoplankton species list for Isle Royale inland waters. List derived from a survey (Toczydlowski *et al.* 1978) of phytoplankton from several water bodies including Chippewa Harbor and Siskiwit, Wood, Whittlesey, Intermediate, Richie, Feldtmann, Scholts and Wallace lakes in the late 1970s.

Group	Species Name
Chlorophyte-Chlorococcales	*Ankistrodesmus falcatus* (Corda) Ralfs
	Ankistrodesmus spp. Corda
	Ankstrodesmus spiralis (Turner) Lemmermann
	Chodatella sp. Lemmermann
	Coelastrum microporum Naegeli
	Coelastrum spp. Naegeli
	Crucigenia quadrata Morren
	Crucigenia spp. Morren
	Crucigenia tetrapedia (Kirch) West & West
	Dictyosphaerium ehrenbergianum Naegeli
	Dictyosphaerium pulchellum Wood
	Dictyosphaerium spp. Naegeli
	Golenkinia radiata Wille
	Kirchneriella obesa (W.West) Schmidl
	Oocystis spp. Naeeli
	Pedastrium integrum Naegeli
	Pediastrium duplex Meyen
	Pediastrium tetras (Ehrenberg) Ralfs
	Pediastrum boryanum Meneghini
	Pediastrum duplex var. *clathratum* (A. Braun) Lagerheim
	Pediastrum duplex var. *rugulosum* Raciborsk
	Pediastrum muticum Kuetzing
	Pediastrum spp. Meyen
	Quadrigula closterioidea (Bohlin) Printz
	Quadrigula lacustris (Chodat) G.M. Smith
	Quadrigula spp. Printz
	Scenedesmus abundans (Kirchner) Chodat
	Scenedesmus arcuatus Lemmeermann
	Scenedesmus armatus
	Scenedesmus bijuga (Turpin) Lagerheim
	Scenedesmus quadricauda Turpin
	Scenedesmus serratus (Corda) Bohlin
	Scenedesmus spp. Meyen
	Selenastrum gracile Reinsch
	Tetraedron caudatum (Corda) Hansgirg
	Tetraedron planctonicum G.M. Smith
	Tetraedron spp. Kuetzing
	*Tetraedron trigonum (*Naegeli) Hansgirg
	Treubaria Bernard

Chlorophyte-Tetrasporales	*Asterococcus* sp. Scherffel
	Gloeocystis sp. Naegeli
Chlorophyte-Volvocales	*Chlamydomonas* spp. Ehrenberg
	Volvox sp. L.
Chlorophyte-Zygnematales	*Arthrodesmus* spp. Ehrenberg
	Closterium gracile Brebisson
	Closterium spp. Nitzsch
	Cosmarium constrictum Delponte
	Cosmarium spp. Corda
	Desmidium grevillei DeBary
	Desmidium spp. C.A. Agardh
	Euastrum pulchellum Brebisson
	Euastrum sinuosum
	Euastrum spp. (Ehrenberg) Ralfs
	Gonatozygon spp. DeBary
	Hyalotheca dissiliens (J.E. Smith) Brebisson
	Hyalotheca spp. Ehrenberg
	Micrasterias rotata (Greville) Ralfs
	Micrasterias spp. C.A. Agardh
	Pleurotaenium trabecula Naegeli
	Spondylosium pygmaeum (Cooke) W. West
	Spondylosium spp. Brebisson
	Staurastrum curvatum W. West
	Staurastrum cuspidatum Brebisson
	Staurastrum gracile Ralfs
	Staurastrum paradoxum
	Staurastrum punctulatum (Brebisson)
	Staurastrum sociale
	Staurastrum spp. Meyen
Chrysophyte-Chrysocapsales	*Chrysocapsa* spp. Pascher
Chrysophyte-Chrysomonadales	*Botryococcus braunii* Kuetzing
	Cryptomonas spp. Ehrenberg
	Dinobryon bravericum Imhof
	Dinobryon cylindricum Imhof
	Dinobryon divergens Imhof
	Dinobryon setularia Ehrenberg
	Dinobryon sociale Ehrenberg
	Dinobryon spp. Ehrenberg
	Dinobryon stipitatum
	Kephyrion spp. Pascher
	Mallomonas arcaroides Perty
	Mallomonas pseudocoronata Prescott
	Mallomonas spp. Perty
	Synura uvella Ehrenberg
Chrysophyte-Heterococcales	*Centritractus dubius* Printz

	Characiposis spp. Borzi
	Ophiocytium spp. Naegeli
Chrysophyte-Heterosiphonales	*Botrydium granulata* Greville
Cyanophyte-Chroococcaceae	*Aphanocapsa* spp. Naegeli
	Aphanothece sp. Naegeli
	Chroococcus spp. Naegeli
	Coelosphaerium spp. Naegeli
	Merismopedia elegans A. Braun
	Merismopedia glauca (Ehrenberg) Naegeli
	Merismopedia spp. Meyen
	Microcystis spp. Kuetzing
Cyanophyte-Oscillatoriales	*Anabaena* spp. Bory
	Calothrix sp. C.A. Agardh
	Gloeotrichia sp. J.G. Agardh
	Lyngbya spp. Agardh
	Nostoc spp. Vaucher
	Oscillatoria spp. Vaucher
	Spirulina spp. Turpin
Diatom-Centrales	*Attheya* spp.
	Cyclotella antiqua Wm. Smith
	Cyclotella bodanica Eulenstein
	Cyclotella melosiroides Lemmermann
	Cyclotella meneghiniana Kuetzing
	Cyclotella operculata (Agardh) Kuetzing
	Cyclotella spp. Kuetzing
	Melosira crenulata (Ehrenberg) Kuetzing
	Melosira distans (Ehrenberg) Kuetzing
	Melosira granulata (Ehrenberg) Ralfs
	Melosira italica (Ehrenberg) Kuetzing
	Melosira spp. C.A. Agardh
	Rhizosolenia ericasis H.L. Smith
	Stephanodiscus niagarae Ehrenberg
	Stephanodiscus spp. Ehrenberg
Diatom-Pennales	*Achnanthes* spp. Bory
	Amphiprora ornata Bailey
	Amphora ovalis Kuetzing
	Asterionella formosa Hassal
	Cocconeis spp. Ehrenberg
	Cymbella spp. C.A. Agardh
	Diatoma spp. De Candolle
	Eunotia spp. Ehrenberg
	Fragilaria crotonensis Kitton
	Fragilaria spp. Rabenhorst
	Gomphonema acuminatum Ehrenberg
	Gomphonema spp. C.A. Agardh

	Gyrosigma spp. (Hassal) Cleve
	Navicula Ispp. (Bory) Cleve
	Neidium iridis (Ehrenberg) Pfitzer
	Neidium spp. Pfitzer
	Nitzschia sigmoidia (Nitzsch) Wm. Smith
	Nitzschia spp. Hassal
	Pinnularia spp. Ehrenberg
	Rhopalodia spp. Mueller
	Stauroneis phoenicenteron Ehrenberg
	Stauroneis spp. Ehrenberg
	Surirella angusta Kuetzing
	Surirella ovata Kuetzing
	Surirella spp. Turpin
	Synedra spp. Ehrenberg
	Tabellaria fenestrata (Lyngbye) Kuetzing
	Tabellaria flocculosa (Roth) Kuetzing
	Tabellaria spp. Ehrenberg
Euglenophyta	*Colacium arbuscula* Stein
	Euglena spp. Ehrenberg
	Phacus spp. Dujardin
	Trachelomonas spp. Ehrenberg
Pyrrophyta	*Ceratium carolinianum* Jorgensen
	Ceratium cornuum Claparede & Lachmann
	Ceratium hirundinella Dujardin
	Glenodinium gymnodinium Pennard
	Glenodinium pulvisculus Stein
	Glenodinium spp. Stein

Table 27. Benthic macroinvertebrate species list for Isle Royale inland waters. List compiled from several invertebrate studies, including Toczydlowski *et al.* (1978 -- Moskey Basin Beaver Pond, Wallace, Benson, and Forbes lakes, Lake John and Lake Richie outlets, Benson, Wallace, Indian Portage, Feldtmann and Washington creeks, and small unnamed creeks and standing waters in Moskey Basin); Johnson (1980 – Siskiwit River); Bowden (1981 -- Washington and Grace creeks, Little Siskiwit River); and Van Buskirk (1992 -- inland lakes, ponds, bogs, vernal ponds and Lake Superior rock pools island-wide). Presence of each taxon in individual studies is denoted with an "x". Van Buskirk (1992a) addressed only Odonata.

Group	Species Name	Toczydlowski 1978	Bowden 1981	Johnson 1980	Van Buskirk 1992
Amphipoda	*Crangonyx*				
	Hyalella azteca (Saussure)			x	
	Gammarus lacustris Sars	x	x	x	
Arachnoidea	Hydracarina			x	
	Trombidiformes	x	x		
Coleoptera	*Agabus* Leach	x	x	x	
	Celina Aube	x			
	Colymbetes Curtis	x			
	Deronectes Sharp			x	
	Dytiscus L.	x			
	Gyrinus Geoffroy	x			
	Haliplus Latreille	x			
	Hydrochara Berthold	x			
	Hyperodes LeConte	x			
	Illibius	x	x		
	Laccornis Des Gozis	x			
	Neoscutopterus (J. Balfour) Brown	x			
	Optioservus L.	x	x	x	
	Oreodytes Seidlitz			x	
	Peltodytes Regimbart	x			
	Stenelmis Dufour	x		x	
	Topisternis Solier	x			
Collembola	*Isotomurus palustris* Muller			x	
	Smynthuridae			x	
Diptera	*Anopheles* Meigan	x			
	Antocha		x		
	Arctopelopia Meigan	x	x		
	Atrichopogon Kieffer	x			
	Bezzia Kieffer	x	x	x	

Brilliea Kieffer	x	x	
Cordiocladius Kieffer	x		
Chironomus Meigan	x		
Chrysops Meigan	x	s	
Clinotanypus		x	
Cnephia mutats Malloch	x		
Conchapelopia Meigan	x	x	
Corynoneura Winnertz	x	x	
Cricotopus Van der Wulp	x	x	
Dasyhelea Kieffer	x		
Diamesa		x	
Dicranota Zetterstadt	x	x	
Dicrotendipes		x	
Dixella Dyar and Shannon	x		
Endochironomus		x	
Epoicocladius		x	
Erioptera Meigen			x
Eukiefferella Zavrel	x	x	
Eusimulium Fries	x		
Glyptotendipes Kieffer	x	x	
Harnischia		x	
Hemerodromia Melgen			x
Hexatoma		x	
Larsia	x		
Limnophila Macquart	x	x	x
Limonia		x	
Micropsectra Kieffer	x	x	
Microtendipes Kieffer	x	x	
Natarsia		x	
Nilotanypus		x	
Orthocladius Van der Wulp	x	x	
Palpomyia		x	x
Paracladopelma		x	
Parametriocnemus Goetghebuer	x	x	
Pedicia Latreille			x
Polypedilum Kieffer	x	x	
Pottastia		x	
Probezzia		x	
Procladius Edwards	x	x	
Prodiamesa		x	
Prosimulium		x	
Psectrocladius Kieffer	x	x	
Psectrotanypus		x	
Pseudochironomus		x	
Pseudolimnophila		x	
Rheocricotopus		x	

	Rheopelopia Meigan	x	x	
	Rheotanytarsus		x	
	Simulium Latreille		x	x
	Simulium decorum	x		
	Simulium jenningsi Malloch	x		
	Simulium tuberosum Lundstroem	x		
	Simulium venustrum verecundum Say	x		
	Simulium vittatum Zitterstadt	x		
	Smittia Holmgren	x		
	Stampellina Bause	x		
	Sympotthastia		x	
	Tabanus L.	x	x	x
	Tanypus		x	
	Tanytarsus Van der Wulp	x	x	
	Thienemanniella Kieffer	x	x	
	Tipula Linnaeus			x
	Trissocladius Kieffer	x	x	
	Zavrelimyia		x	
Ephemeroptera	*Baetis* Leach	x	x	x
	Caenis Stephens	x		x
	Ephemera Linnaeus			x
	Ephemerella Walsh	x	x	x
	Heptagenia Walsh			x
	Leptophlebia Westwood	x	x	
	Paraleptophlebia Lestage	x	x	x
	Pseudocloeon Klapalek		x	x
	Siphlonurus Eaton	x	x	
	Siphloplecton Clemons	x		
	Stenocron Traver	x		
	Stenonema Traver	x	x	x
	Tricorythodes Ulmer			x
Gastropoda	*Amnicola*		x	
	Armiger		x	
	Ferissia		x	
	Gyralus parvus Say (by Walker)			x
	Lymnaea Lamarck			x
	Physa		x	
	Physa gyrina Say (by Walker)			x
Hemiptera	*Belostoma* Latr.	x		
	Gelastocoris Kirkaldy	x		
	Gerris Fabricius	x	x	
	Notonecta L.	x		
	Rhogovelia Mayr			x
	Sigara		x	
	Trepobates Uhler	x		x

	Trichocorixa Kirkaldy	x			
Hirudinea	*Hirudinea*			x	
	Haemopis		x		
Hydroida	*Hydra* Hyman			x	
Isopoda	*Asellus*		x		
	Lirceus Rafinesque			x	
Lepidoptera	*Nymphula* Schrank	x		x	
Nematoda	Nematoda			x	
Nematomorpha					
Odonata	*Aeshna* Fabricius	x		x	
	Aeshna canadensis Walker				x
	Aeshna clepsydra Say				x
	Aeshna eremita Scudder				x
	Aeshna interrupta Walker				x
	Aeshna juncea Linneaus				x
	Aeshna sitchensis Hagen				x
	Aeshna subarctica Walker				x
	Aeshna umbrosa Walker				x
	Anax junius Drury				x
	Boyeria McLachlan	x	x	x	x
	Boyeria grafiana Williamson				x
	Calopteryx Leach	x			
	Coenagrion interrogatum Selys				x
	Cordulegaster Leach	x	x		
	Cordulegaster aequabilis Say				x
	Cordulegaster maculata Selys				x
	Cordulia shurtleffi Scudder				x
	Dorocordulia Needham	x			
	Dorocordulia libera Selys				x
	Dromogomphus spinosus Selys				x
	Enallagma Walsh	x			
	Enallagma boreale Selys				x
	Enallagma carunculatum Morse				x
	Enallagma exsulans Hagen				x
	Enallagma hageni Walsh				x
	Gomphus exilis Selys				x
	Gomphus spicatus Hagen				x
	Helocurdulia Needham	x			
	Ladona Needham	x			
	Lestes Hagan	x			
	Lestes congener Hagen				x
	Lestes disjunctus Selys				x
	Lestes dryas Kirby				x
	Lestes forcipatus Rambur				x
	Lestes unguiculatus Hagen				x
	Leucorrhinia Brittinger	x			

	Leucorrhinia frigida Hagen				x
	Leucorrhinia glacialis Hagen				x
	Leucorrhinia hudsonica Selys				x
	Leucorrhinia proxima Calvert				x
	Libellula L.	x			
	Libellula julia Uhler				x
	Libellula lydia Drury				x
	Libellula quadrimaculata Linn				x
	Nehalennia Needham	x			
	Nehallenia irene Hagen				x
	Ophiogomphus Selys	x	x	x	
	Ophiogomphus colubrinus Selys				x
	Pantala flavescens Fabricius				x
	Somatochlora Salys	x		x	
	Somatochlora franklini Selys				x
	Somatochlora kennedyi Walker				x
	Somatochlora minor Calvert				x
	Somatochlora williamsoni Walker				x
	Sympetrum costiferum Hagen				x
	Sympetrum danae Sulzer				x
	Sympetrum internum Montgomery				x
	Sympetrum obtrusum Hagen				x
	Sympetrum occidentale Bartenev				x
	Sympetrum semicinctum Say				x
	Tetragoneuria		x		
	Tetragoneuria spinigera Selys				x
Oligochaeta	Oligochaeta		x	x	
Pelecypoda	*Pisidium*		x		
	Sphaerium		x	x	
Plecoptera	*Amphinemura* Ris	x	x	x	
	Capnia		x		
	Hastaperla		x	x	
	Isoperla Banks	x	x	x	
	Leuctra Stephens	x	x	x	
	Nemoura		x		
	Taeniopteryx		x		
	Zealeuctra Ricker	x	x		
Porifera	Spongillidae			x	
Trichoptera	*Agapetus* Curtis	x			
	Agrypnia Curtis	x			
	Anabolia Stephens	x	x		
	Asynarchus McLachlan	x		x	
	Ceroclea			x	
	Coraclea Stephens	x			
	Cheumatopsyche Wallengren	x	x	x	
	Chimarra Stephens	x	x		

	Cyrnelius Banks	x		
	Diplectrona Westwood	x		
	Dolophilodes Ulmer	x	x	
	Glossosoma Curtis	x	x	x
	Grammotaulius		x	
	Grensia Ross	x		
	Helicopsyche von Siebold	x		x
	Hesperophylax		x	
	Hydatophylax Wallengren	x		
	Hydropsyche Pictet	x	x	x
	Hydroptila		x	x
	Ironoquia Banks	x		
	Limnephilus Leach	x		x
	Lepidostoma Rambur	x	x	x
	Molanna Curtis	x		x
	Mystacides Berthold	x		x
	Nemotaulius		x	
	Neophylax McLachlan	x	x	
	Ochrotrichia Mosely	x		x
	Oecetis McLachlan	x	x	x
	Onocosmoecus Banks	x		
	Oxyethira		x	
	Parapsyche		x	
	Phylocentropus		x	
	Platycentropus		x	
	Polycentropus Curtis	x	x	
	Potamyia Banks	x		
	Pseudostenophylax Martynov	x		
	Psilotreta		x	
	Psychoglypha Ross			x
	Ptilostomas		x	
	Pycnopsyche Banks	x		
	Rhyacophila Pictet	x	x	
	Triaenodes McLachlan	x		x
	Wormaldia		x	
Turbellaria	*Dugesia* Girard			x

Appendix F. Scoping Workshop Minutes, Participants List, and Agenda

Scoping Workshop
for the development of a
Water Resources Management Plan
for Isle Royale National Park

Summary Minutes

Best Western Franklin Square Inn,
Houghton, MI

April 24, 2002

Attendees List

See Attachment #1 (below)

Summary Minutes

Introductions and Workshop Objectives

Jack Oelfke, Isle Royale National Park (ISRO), welcomed the workshop attendees, initiated self-introductions, and reviewed the agenda (Attachment #2) Oelfke then outlined the objectives for the workshop. He noted that the Water Resources Management Plan was included in the Park's general management plan and stemmed from an identified need for more attention to water resources management issues and needs at ISRO. Oelfke stated that the Park is becoming more involved in water resources management activities. He mentioned that the National Park Service has contracted with the Great Lakes Commission (GLC) to prepare the WRMP.

Overview of NPS Planning Activities

Oelfke introduced David Vana Miller, NPS Water Resources Division to talk about the water resources management planning process. Vana Miller broadly addressed the NPS planning process, talked about the importance of planning and the specific objectives of water resources planning. He walked attendees through the different steps in the planning process including the progression from identified technical assistance needs of individual parks, to the preparation scoping reports, to the development of a WRMP. Vana Miller stated that because of the high value placed on ISRO water resources and the need to protect them, a decision was made to skip the scoping report step and go directly to the full-blown WRMP. Vana Miller concluded by saying that a WRMP serves as a road for water resources of the Park. It identifies high, medium and low priorities and identifies priority actions and recommendations for the conduct and development of policy, research, etc. For further information please refer to Attachment #3 Introduction to ISRO, It's Water Resources and Water Resources Management Activities

Oelfke then a slide slow presentation detailing the water resources and water resources management activities of ISRO. Oelfke stated that 75 percent of the Park area is water which includes a number of inland lakes on the main island. Ninety nine percent of the land is designated "federal wilderness" which affects the management and control of the resource. There are thirty two inland lakes that involve sport fishing activity. Fish populations are designated as a "nationally significant resource". Wildlife in the Park includes loons, bald eagles, otters, beavers, moose and wolves among others.

Other significant Park issues addressed by Oelfke include: Air born contaminants from mainland; Acid rain impacts; commercial shipping lanes through park waters; transport and storage of fuel used on the island; recreational sport diving on shipwrecks in area; recreational boating traffic and how this activity may affect loon nesting; fishing activity and the removal of fish from Park waters; state listed rare plants.

Oelfke outlined monitoring activities in the Park and mentioned the following species and areas of monitoring: Coaster Brook Trout; inland lakes fishery inventory; water quality monitoring—which is more hit and miss; plankton survey of lakes; fresh water muscle inventory—which includes pristine populations of rare muscles and common species in abundance

Oelfke concluded his presentation by highlighting up and coming activities and directions for ISRO. These items include: the addition of a fisheries biologist to the park staff; the need for an aquatic ecologist; the need for more money to inventory/monitor natural resources; the need to monitor recreational boating activities around the Park now, for the purpose of conducting a risk assessment next summer.

Identification and Evaluation of ISRO Water Resources – Facilitated Discussion

Tom Crane, Great Lakes Commission facilitated a discussion session to identify and evaluate water resources and water resources management issues for ISRO. Crane began by saying that this was opportunity discuss issues that as individuals and as a group are considered to be important. Crane also asked that the group identify and refer Commission staff to reports, data sets, inventories and other contacts that may have data and information pertaining to ISRO water resources. Crane then led the group in discussion and recorded ideas on a flip chart. Ideas generated during the discussion are organized by category and presented below:

Issues related to the physical water resources and information needs

1. There is a need for better general information on ISRO groundwater resources.
2. Need information on groundwater contributions to inland lakes.
3. Need information on water levels and flows changes for both Lake Superior and inland lakes.
4. Need to understand the hydrologic exchange rate (e.g., thermal behavior)

5. Need more detailed bathymetric information
6. Need for habitat substrate mapping

Issues related to the biological/ecological components of water resources and information needs

1. Aquatic Nuisance Species
    a. zebra mussels
    b. spiny water flea
    c. round goby
    d. purple loosestrife
    e. other
2. There is a need to look at ANS introductions by vector. Live wells on boats for instance – may be a potential source of biological contamination.
3. Need more detailed information on warm water and cold water fisheries.
4. Need more information on the benthic communities of the inland lakes as well as the Lake Superior waters surrounding the Island.
5. Need information on wetlands and vascular plants.
6. Fisheries information especially for the nearshore area.
7.

Issues related to the chemical components of water resources and information needs

1. The presence and effects of Mercury on wildlife (especially otters) needs to be studied and better understood.
2. The presence of mercury needs to be better understood in terms of old mercury (from mining) or from other anthropogenic sources (i.e., atmospheric).
3. The effects of atmospheric deposition of mercury and sulfur dioxide are an issue that needs to be monitored and quantified.
4.

Research, Monitoring, Programmatic and Inventory Needs

1. The Lake Superior Lakewide Management Plan (LaMP) should be looked at as a source of information, especially with regard to aquatic nuisance species.
2. There is a need for baseline monitoring of inland lakes.
    a. FNE Year data – data exists through 1986
    b. Watershed process studies
    c. Heavy metals data sets
    d. All types of monitoring is needed – chemical, physical and biological
3. There is a need to develop comprehensive research plans for ISRO water resources.
4. Individual research plans should be developed and provided to (coordinated with) Park staff.
5. Schedules of research vessels available for ISRO related research should be coordinated and broadly disseminated to researchers.
6. There is a need to integrate zooplankton data with fish data.
7. Need for a nearshore fisheries inventory.
8. Need to inventory the terrestrial/aquatic interface.
9. Inventory of rare, threatened and endangered species including:
    a. loons

    b. clams/mussels
    c. coaster brook trout
    d. rare plants
    e. freshwater sponges
    f. algae/phytoplankton
    g. lake trout
    h. whitefish
    i. chubs
10. There is a need for monitoring of the lower trophic levels.
11. Monitoring for sulfur dioxide at Ojibway Tower.
12. Use of Available Data should be studied
    a. regional air toxics database
    b. Canadian data (Swackhamer report)
    c. Fine scale modeling/research (UW-Milwaukee research)
13. Meteorological data should be utilized
    a. Nomad Data
14. Global Warming
    a. water temperature changes
    b. changes in trophic status (e.g., eutrophication)

Anthropogenic Impacts and Recreational Demands on ISRO Water Resources

1. Potable drinking water requirements for Island users
2. Recreational boating and personal water craft issues
    a. potential for spills and contaminants from recreational boats.
    b. motorized versus non-motorized uses
3. Navigation issues, such as:
    a. cruise ships
    b. commercial vessels
    c. research vessels
    d. potential for spills
    e. erosion concerns especially during high lake levels
    f. low lake levels concerns
    g. season extension issues related to ice breaking and ice levels
4. Pipelines for electrical power distribution
5. Dredging and dredge disposal issues
6. Scuba Diving especially as it relates to introduction of ANS

Park Management and Infrastructure Needs

1. Control of Boat traffic is an issue, especially small private boats such as canoes and kayaks
2. There is a need to develop a Park specific plan to control and prevent introductions of ANS

Administrative and Legal Issues

1. Legal authority to restrict certain types of activities needs to be viewed in light political viability and public interest.
2. Evaluate the protocols and possible restrictions for docking of research vessels (especially federal vessels).
3. Memorandums of Understanding (MOUs) should be evaluated as a tool to expedite agreements between agencies to control research vessel access to the Island.
4. Special designations for ISRO.
    a. designations already in place
    b. possible additional designations

Information/Education Needs

1. ANS Education Programs need to be used or developed
    a. Previously developed programs and materials should be used
    b. Continuing education in the ANS area should be stressed
    c. Boating community should become more involved

Human Health Issues and Information Needs

1. Recreational users and their need for potable water
2. Wastewater treatment issues
    a. planning for wastewater treatment – systems that will be adequate over long term
    b. outhouses and septic systems
3. Diseases – infectious parasites carried by wildlife.
4. Gray water disposal

Emergency Preparedness and Response

1. Storage and Handling of Park Service Fuel
    a. review or establish response plan
    b. inventory equipment
    c. make sure proper preparedness protocols are in place
2. Spills related to Commercial Navigation
3. Potential for spills from smaller water craft

Issues that should be addressed in the plan:

1. Aquatic nuisance and invasive species
2. Recreational Boating in general and use of motorized vessels in particular
3. Air deposition of pollutants
4. Groundwater resources and the need for potable water for human use.
5. wetlands inventory
6. lakeshore erosion

7. water level fluctuations
8. fuel storage and transfer

Tom Crane then summarized the roundtable discussion. He stressed that this list is not an end-all final list of issues, but that it is a start to ongoing process with further communications with participants and others to further define, clarify and add to WRMP list of issues for the island.

After a short break meeting participants were asked to designate their first, second, and third most important priority from the complied list of issues, which were posted on the wall around the room. GLC staff retained the list and voting results to compile for feedback to NP staff and meeting participants.

Issues	***Total Votes***	**# 1st place votes**	**#2nd place votes**	**#3rd place votes**
ANS prevention and control	16	10	5	1
Baseline monitoring of inland lakes	11	1	2	8
Atmospheric deposition of toxic contaminants	8	1	2	5
Prevention plan for invasive species	5	2	2	1
Wetlands information	4	3	1	0
Comprehensive monitoring programs	3	1	2	0
Bathymetric Mapping	2	0	0	2
Atmospheric sampling/ monitoring	1	1	0	0
Need for ongoing monitoring	1	0	1	0
Presence and affects of mercury on ISRO ecosystem	1	0	1	0
Global warming	1	0	1	0
Pollution from boats	1	0	1	0
Recreational uses of ISRO esp. relating to motorized versus non-motorized uses	1	0	0	1
Near-shore fisheries inventory	1	0	0	1

Crane then presented the project timeline and goals set for specific task completion. The schedule from the draft study plan was shown as an overhead and is included as Attachment #4.

With no further business, the meeting was adjourned at 3:30 p.m.

Scoping Workshop Attachment #1

Participants List
Water Resources Scoping Workshop
Isle Royale National Park
April 24, 2002
Houghton, MI

Name	Agency/Company	Phone	e-mail
Tom Crane	Great Lakes Commission	734-665-9135	tcrane@glc.org
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W. Charles Kerfoot	MTU	906-487-2791	wkerfoot@mtu.edu
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Brian Ruddy	NPS-ISRO	906-337-4991	brian_ruddy@nps.gov

Scoping Workshop Attachment #2

Water Resources Issues Scoping Workshop
For the development of a
Water Resources Management Plan for Isle Royale National Park
9:00 a.m. - 4:00 p.m.
April 24, 2002
Sponsored by: National Park Service
Assisted by: Great Lakes Commission
Best Western Franklin Square Inn, Houghton, MI.
906-487-1700

-Final Program-

Wednesday, April 24, 2002

9:00 a.m. Welcome, Introductions and Workshop Objectives Jack Oelfke, NPS - Isle Royale National Park; David Vana-Miller, NPS -Water Resource Division and Tom Crane, Great Lakes Commission

9:15 a.m. Introduction to National Park Service Water Resources Planning David Vana-Miller

9:30 a.m. Introduction to Isle Royale National Park, ISRO Water Resources and Water Resources Management Activities Jack Oelfke

10:00 a.m. Roundtable Discussion - Identification and Evaluation of Water Resources Issues at ISRO All Participants

10:50 a.m. Break

11:00 a.m. Roundtable Discussion - (continued)

12:00 Noon Break for Lunch Lunch on your own

1:15 p.m. Roundtable Discussion - (continued) All Participants

3:05 p.m. Break

3:15 p.m. Project Design and Implementation - Tom Crane and Jack Oelfke
1. Project Partner Roles and Responsibilities
2. Additional Stakeholder Groups to be Included in Process
3. Project Timeline and Schedule of Activities
3:45 p.m. Next Steps Tom Crane and Jack Oelfke

4:00 p.m. Adjourn