# Adirondack Park Forest Preserve Carrying Capacity of Water Bodies Study: Phase 1 – Selecting Indicators for Monitoring Recreational Impacts

April McEwen, Chad Dawson, and Lisa Gerstenberger
SUNY College of Environmental Science and Forestry
320 Bray Hall
One Forestry Drive
Syracuse, NY 13210

August 31, 2011

Table of Contents

## List of Tables

## List of Figures

# INTRODUCTION

The Forest Preserve lands within the Adirondack Park are protected by Article 14 of the New York State Constitution. The Adirondack Park State Land Master Plan (APSLMP) provides the vision of how natural resource protection and human use should be balanced:

> "If there is a unifying theme to the master plan, it is that the protection and preservation of the natural resources of the state lands within the Park must be paramount. Human use and enjoyment of those lands should be permitted and encouraged, so long as the resources in their physical and biological context as well as their social or psychological aspects are not degraded" (Adirondack Park Agency and NYSDEC 2001, p.1).

Concerns have been raised about the current and future ecological integrity of Adirondack Park water bodies (Adirondack Park Agency and NYSDEC 2001; Adirondack Council 2010). Changes to freshwater ecosystems originate from many anthropogenic and natural causes. Some anthropogenic changes include: (1) terrestrial vegetation alteration and degradation in the riparian zone (e.g., soil loss, sedimentation, eutrophication); (2) aquatic vegetation alteration and degradation (e.g., aquatic species habitat loss, changes in biodiversity); (3) introduction of nuisance non-native plant and animal species (e.g., Eurasian watermilfoil, asian carp); (4) introduction of pollutants (e.g., pathogens, organic and inorganic compounds); and (5) other on site and external threats (e.g., acid rain, global climate change). The threats addressed in this report, including several of those mentioned above, are possible direct or indirect impacts due to recreational use, recreational facilities, and shoreline development for recreation and tourism uses.

In view of these threats to state and regional freshwater resources, the APSLMP proposed a research study to collect information about the quality of Adirondack Park water bodies:

> "A comprehensive study of Adirondack lakes and ponds should be conducted by the Department of Environmental Conservation to determine each water body's capacity to withstand various uses, particularly motorized uses and to maintain and enhance its biological, natural and aesthetic qualities. First emphasis should be given to major lakes and ponds totally surrounded by state land and to those on which state intensive use facilities exist or may be proposed. The importance of the quality of these resources

cannot be overemphasized." (Adirondack Park Agency and NYSDEC 2001, p.4)

The Adirondack Park Agency (2010) has mapped 1,838 bodies of water entirely within the Forest Preserve lands of the Adirondack Park (Figure 1) and most of those ponds and lakes (94%) are small and between one and 250 acres in size. Additionally, as many as 1,000 lakes and ponds in the Adirondack Park are on Forest Preserve lands **and** are partially or wholly on private lands (that is, they are not entirely on Forest Preserve lands). These water bodies are all considered to be impacted to varying degrees by human uses (Adirondack Council 2010).

The APSLMP requires that all units within the Adirondack Park on Forest Preserve lands be managed using a Unit Management Plan (UMP) that is developed and managed by the NYS Department of Environmental Conservation (NYSDEC). The APSLMP mandates the development of UMPs as a way to manage natural resources by location, physical features, ecological systems, and use patterns. A supporting statement in the APSLMP about the importance of addressing carrying capacity on all managed Forest Preserve land units is that "an assessment of the physical, biological and social carrying capacity of the area with particular attention to portions of the area threatened by overuse in light of its resource limitations and its classification under the master plan should be conducted" (APA and NYSDEC 2001, p.10).

The carrying capacity mandate of the APSLMP can be addressed through the Limits of Acceptable Change (LAC) planning framework (Dawson, Connelly, and Brown 2006b; McCool, Clark and Stankey 2007; Dawson and Hendee 2009). The LAC is a practical approach compared to the more complex and longer-term carrying capacity approach. The LAC framework is used to address the human use and resource impacts to recreational areas and compare them to acceptable resource and social conditions as required by the APSLMP. While NYS Environmental Conservation Law (6 NYCRR Part 703) has some quantitative water quality standards for several pollutants and some qualitative aquatic resource conditions, the NYS standards may not be stringent enough to represent the standards NYSDEC may decide to use for Adirondack Park water body resource protection under LAC, especially in wilderness and wild forest areas. This study does not set standards as those are a NYSDEC management responsibility and prerogative; rather **the focus of this study is on identifying the indicators of resource and social change to measure and how to take those measurements**.

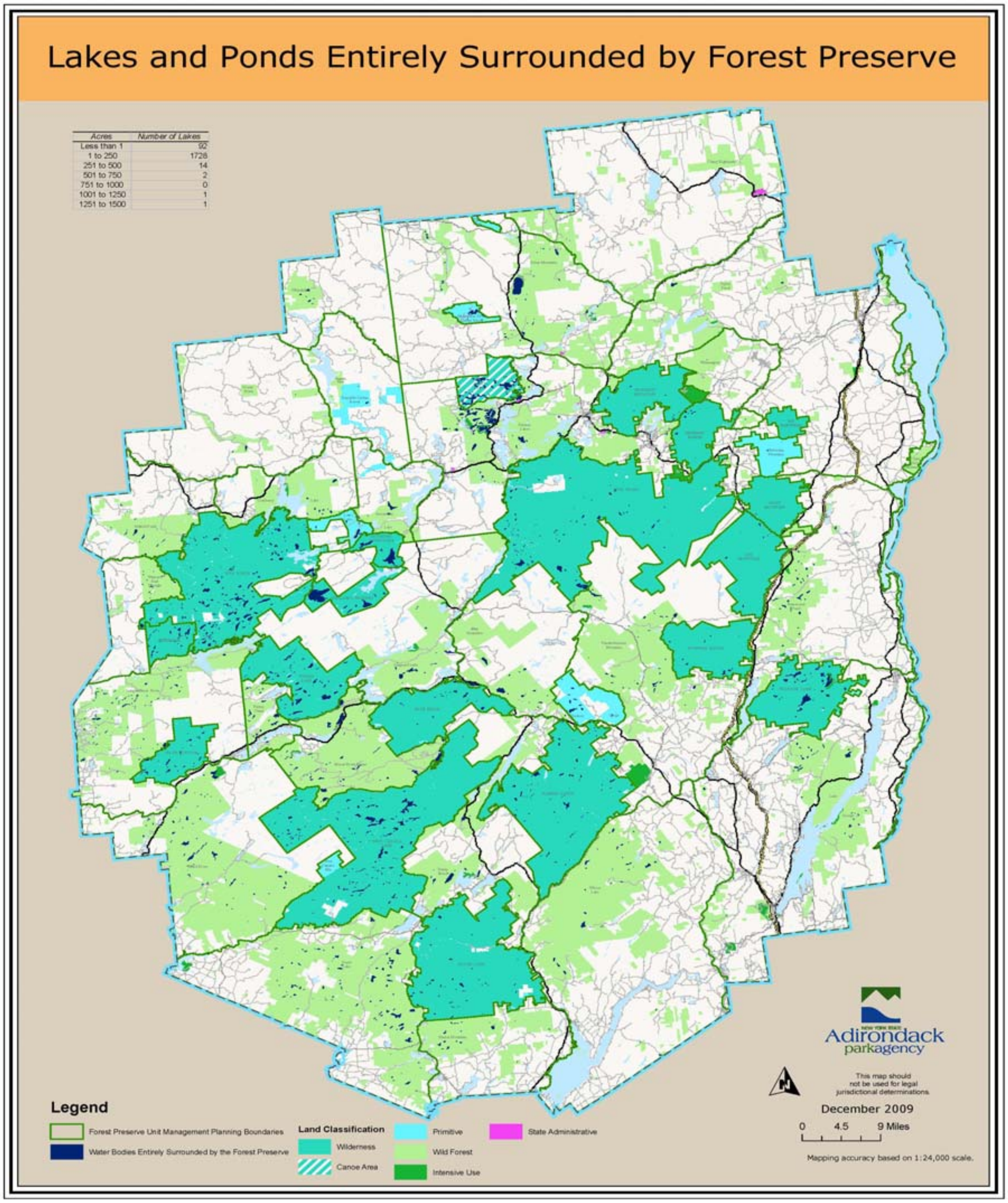


Figure 1. Ponds and lakes surrounded by Forest Preserve land within the Adirondack Park (APA 2010).

**The main objective of the study is to design a research protocol and select indicators that will comprehensively monitor the ecological and social impacts of recreational use on these water bodies and surrounding riparian lands (i.e., this type of study considers all recreation related impacts and is not a boating capacity study).** This project is the first phase of developing an overall carrying capacity analysis and subsequent phases will select water bodies to monitor, develop standards under the selected indicators, estimate recreational use, and develop management responses for locations that exceed acceptable standards. The intention of this research project is to support resource planning and management by the NYSDEC. Under the APSLMP, the main management goal of the NYSDEC is to protect and steward Forest Preserve lands and water bodies while managing visitor use for public enjoyment.

The information collected during this study was intended to produce four types of outputs: (1) an inventory and categorization of water bodies on Forest Preserve lands within the Adirondack Park; (2) a descriptive summary of the types of ecological and social impacts that result directly or indirectly from water-based recreational use on Forest Preserve lands within the Adirondack Park; (3) a descriptive profile of the types of recreational groups using water bodies on Forest Preserve lands within the Adirondack Park; and (4) a research protocol to assess the main ecological and social impacts of recreational use on water bodies on Forest Preserve lands within the Adirondack Park.

# RESEARCH METHODS

The methods used to gather data to develop the four study outputs were:

## (1) Water Body Inventory:

- The inventory of water bodies on Forest Preserve lands within the Adirondack Park was obtained with the GIS assistance of Steve Signell of the SUNY-ESF Adirondack Ecological Center at Newcomb, NY from the APA publicly available GIS dataset on Adirondack Park water resources.
- A categorization of Forest Preserve water bodies was developed to better understand the spatial frequencies of water body sizes and the proportion of public and private land surrounding the water body. Included within this categorization were water bodies that

- Nine representative Forest Preserve water bodies were selected from this inventory as pilot sites for an exploratory study and measurement of ecological and social indicators of recreational impacts occurring in and around Forest Preserve water bodies. These sites also allowed for the exploratory use of new protocols and equipment that were practical, feasible, portable, reliable, and cost-efficient.

## (2) Descriptive Profile of Recreational Users Groups Using Water Bodies:

- A descriptive summary profile of the types of recreation use and visitors using Forest Preserve water bodies within the Adirondack Park was compiled by Chad Dawson from over two decades of recreation use and visitor research in the Adirondack Park (see reference list) and from standard wilderness recreation references on the subject (e.g., Dawson and Hendee 2009; Leung and Marion 2000; Hammitt and Cole 1998).
- Guidebooks and standard recreation access information from public agencies, private sector businesses, and non-profit organizations were reviewed to assess public access issues and geographic location.

## (3) Descriptive Summary of Potential Ecological and Social Impacts:

- One output of this study was to provide a descriptive summary of potential recreation use and development related ecological and social impacts to aquatic and riparian (shoreline) areas. While all impacts within a watershed directly and indirectly affect water quality in water bodies, shoreline areas immediately adjacent to the water bodies were considered to be of utmost ecological importance and a focal area for water-based recreational use and development. Recreational activities are often more intense in proximity to the shoreline, can be more directly identified and measured as a result of recreational activities, and thus managed by the NYSDEC.
- Existing published literature and research reports on ecological and social recreational impacts (e.g., Liddle 1997) were reviewed to: (1) develop lists of recreational activities

- Potential ecological impacts to aquatic and terrestrial areas that occur as a result of water-based recreational use and development were extensively reviewed in a Master's thesis by April McEwen (McEwen 2010) during this study.
- Potential social impacts to people participating in water-based recreation were extensively reviewed from standard references on the subject (e.g., Dawson and Hendee 2009; Cole 1987; Hammitt and Cole 1998; Therrell et al. 2006) and by Chad Dawson from over two decades of recreation use and visitor research in the Adirondack Park.

## (4) Research Protocol to Assess Ecological & Social Impacts of Recreational Use:

- The Limits of Acceptable Change (LAC) planning process was used as a practical framework to implement the carrying capacity concept (Stankey et al. 1985; Dawson and Hendee 2009; McCool, Clark and Stankey 2007; Dawson, Connelly and Brown 2006b; Cole and McCool 1997). The LAC process identifies the critical agents of change in the bio-physical and social systems that need to be monitored. The LAC process identifies the desired biological and social conditions that management seeks to provide or maintain. The LAC indicators of change are the parameters that are monitored to detect changes in those desired conditions. The overall goals of the APSLMP (APA and NYSDEC 2001) were considered the general goals under the LAC framework.
- Potential aquatic and shoreline ecological impact indicators, the rationale for monitoring them, and protocols for their measurement were extensively discussed in a Master's thesis by April McEwen (McEwen 2010).
- Potential social impact indicators, the rationale for monitoring them, and protocols for their measurement were reviewed from standard wilderness recreation references on the subject (e.g., Dawson and Hendee 2009; Hammitt and Cole 1998) and specialized recreation ecology studies (e.g., Liddle 1997).

- A list of ecological and social impact variables to be monitored in and around water bodies on Forest Preserve lands was developed as a recommendation for further field testing and later implementation across the Adirondack Park.

# RESULTS

## Water Body Inventory

In conjunction with NYSDEC staff, an inventory of all Adirondack public access water bodies surrounded by any portion of Forest Preserve land was obtained. GIS analyses using several data layers created by the APA was conducted to: (1) identify the 1,195 total water bodies greater than five acres, and (2) estimate the amount of state-owned (public) shoreline from 1-100% [note: previous APA studies only identified the 1,838 water bodies of any size entirely surrounded by Forest Preserve lands]. GIS data were prepared for our analysis by Steve Signell, SUNY-ESF Adirondack Ecological Center. A categorical summary was made using Statistical Package for the Social Sciences (SPSS) Version 11.0. The majority of these water bodies (79%) are surrounded by 76-100% public shoreline. The complete inventory of water bodies greater than five acres surrounded by any amount of Forest Preserve shoreline, their size (surface area in acres), and percentage of state owned (public) shoreline are shown in Table 1.

Nine pilot sites within the Adirondack Park were selected based on the following criteria: state owned (% public) shoreline, size (surface area), surrounding land management classification, geographic distribution, and surrounding land management classification (Table 2). The criteria were chosen as this information was available for all sites and the selected criteria are major factors in dictating the types of use allowed (regulations), amount of use, and ecological (biological, physical, and chemical) factors that provide resistance or vulnerability to changes. These criteria were used to select pilot sites that collectively are characteristic of many water bodies on Forest Preserve lands across the Adirondack Park.

Table 1. The number of Forest Preserve public access water bodies by size and percent public shoreline ownership.

| Size Categories (acres) | Percent Public Shoreline | | | | Water Bodies Total |
|---|---|---|---|---|---|
| | 0-25% | 26-50% | 51-75% | 76-100% | |
| **1 (5-20)** | 23 | 27 | 35 | 575 | 660 |
| **2 (21-100)** | 26 | 32 | 27 | 282 | 367 |
| **3 (101-500)** | 20 | 10 | 14 | 77 | 121 |
| **4 (≥501)** | 14 | 15 | 7 | 11 | 47 |
| **Total** | 83 | 84 | 83 | 945 | 1195 |

Table 2. Nine pilot study water bodies selected by size and land management classification.

| Name of Water Body | Classification Size Category | Surface Area (acres) | UMP Name and Land Classification |
|---|---|---|---|
| Little Jabe Pond | 1 | 6 | Lake George Wild Forest |
| Chapel Pond | 1 | 18 | Dix Mountain Wilderness |
| Deep Lake | 2 | 29 | West Canada Lake Wilderness |
| Stewart Lake | 2 | 31 | Shaker Mountain Wild Forest |
| Lake Colden | 2 | 38 | High Peaks Wilderness |
| Fish Creek Pond/Square Pond | 3 | 135 | Campground Intensive Use Area |
| Putnam/North Pond | 3 | 185 | Pharoah Lake Wilderness and Campground Intensive Use Area |
| Meacham Lake | 4 | 1185 | Debar Mountain Wild Forest and Campground Intensive Use Area |
| Lake Lila | 4 | 1490 | William Whitney Wilderness |

The pilot sites were geographically distributed across the four major watersheds that drain the Adirondack Park including the Black River, Hudson River, St. Lawrence River, and Champlain River watersheds (Figure 2). Pilot sites were selected from land management units classified as wilderness, wild forest, and intensive use. As a result of the various land management classifications surrounding the pilot sites, water body shoreline conditions reflect a wide range of uses from almost no surrounding use (relatively pristine) to intensive use (developed for recreational purposes). Therefore, pilot sites have shoreline conditions ranging from pristine to highly developed for recreational purposes. Intensive use areas are highly developed for recreational purposes and are generally characterized as state campgrounds with more facilities, more recreational visitation, and more road and trail access (e.g., Fish Creek Pond, Meacham Lake, Putnam/North Pond) than other protected areas (wilderness, wild forest, primitive).

Two of the pilot sites, Meacham Lake and Putnam/North Pond (hereafter referred to as Putnam Pond), have a shoreline with a mix of land management classifications. Sites such as these highlight potential social and managerial conflicts that may occur at water bodies with shoreline consisting of more than one land management classification. For example, motorized boating is allowed in Putnam Pond although a percentage of the surrounding shoreline is classified as wilderness, and wilderness use regulations prohibit motorized use. However, motorized use is allowed in intensive use and some wild forest areas, which also make up a percentage of the Putnam Pond shoreline.

Pilot sites were mapped using ArcInfo 9.3 GIS software. Orthoimagery sets were previously captured in 2003-2008 and were obtained from the NYS GIS Clearinghouse. The recreational development at each site and locations where primary data was collected (sampling stations) were located on maps of each pilot study site. Points representing recreation attributes were added to each map using a combination of secondary information from NYSDEC campground maps, recreation maps and primary information collected at each site. Sampling station locations were geo-referenced using a GPS at the time of sampling for future mapping purposes. Site assessment and sampling occurred in the freshwater area and the critical riparian management zone (CMZ) (approximately 50 meters or 160 feet) (Abell, Allan, Lehner 2007). A critical management zone was drawn around the shoreline of each water body and around tributaries flowing into the water body. This zone represents the area where recreational use and development (if any) is concentrated and impacts to soil and vegetation potentially directly or indirectly influence changes in the water body. The freshwater area consists of the water body itself. The freshwater area is a focal point for water-based recreational use, serves as the medium for several recreational activities, and was the area where water quality indicators were measured.

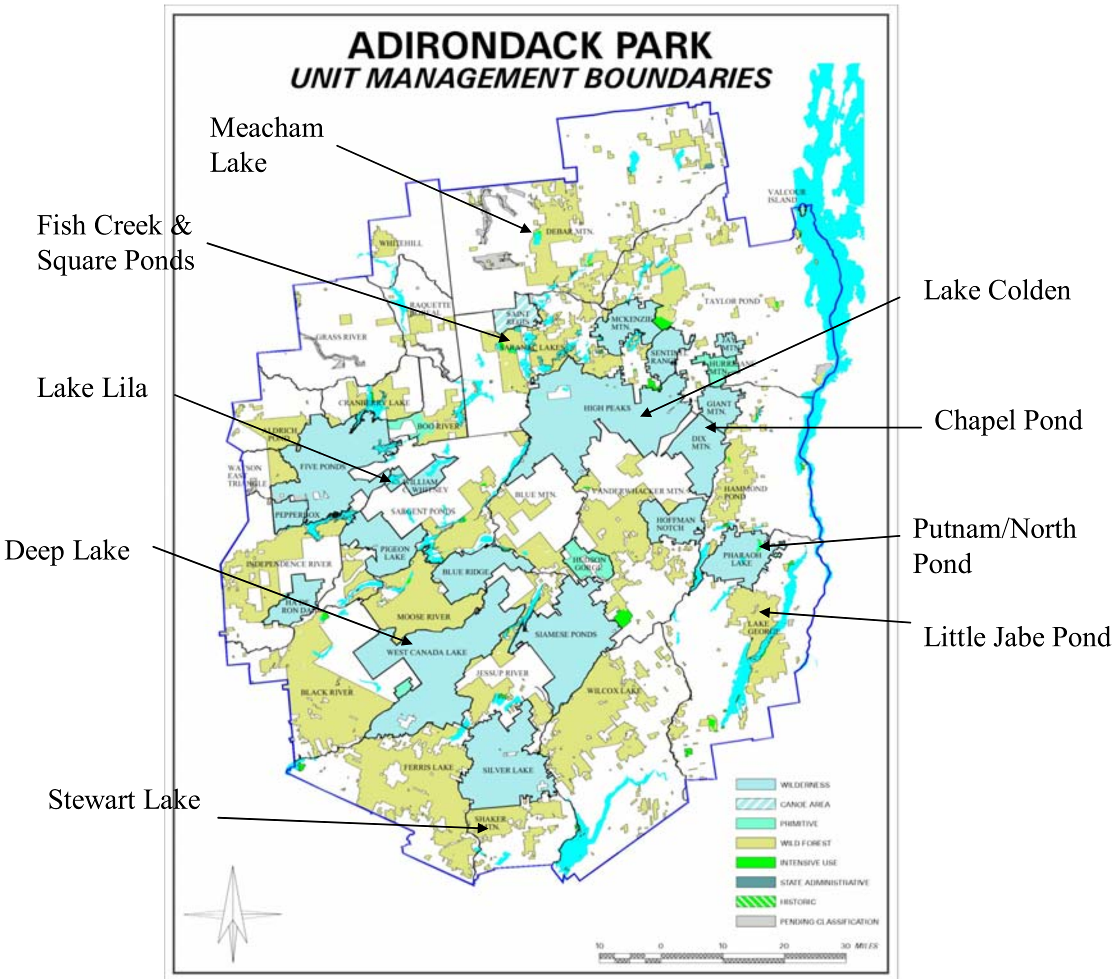


Figure 2. Pilot site geographic distribution within the Adirondack Park.

## Descriptive Profile of Recreational Users Groups Using Water Bodies:

Research conducted on the affects of recreational use focused mainly on activities such as hiking, fishing, camping, backpacking, canoeing/kayaking, and motor boating. These activities commonly occur at Adirondack water bodies and on Forest Preserve lands during the summer season while weather permits (May-August). Recreation activities occuring year round on Forest Preserve lands and water bodies include hunting, cross country skiing, snowshoeing, camping, snowmobiling and other activities.

Group activities such as angling, bird watching, swimming, camping, picnicking, and walking or hiking (common shore-based activities) reportedly produce similar impacts on the physical environment (e.g., trampling of vegetation, compaction/erosion of soils) (Liddle and Scorgie 1980). Jaakson (1970) places water-based recreational activities into three categories: (a) on-water activities that occur on the surface of the water (e.g., motor boating, waterskiing, canoeing/kayaking, fishing); (b) contact activities which require bodily contact with the water (e.g., swimming, wading); and (c) activities occurring in the near-shore area or within sight of the water (e.g., camping, hiking, fishing).

Recreational development is created to provide visitors with services or assist in providing recreational opportunities (Hammitt and Cole 1998). Development of the landscape for recreational purposes may include the removal and alteration of vegetation and soils for the construction of trails, campsites, buildings, access points, and impervious surfaces such as roads and parking lots. Impacts may occur during the construction, operation, and maintenance phases. Some impacts are similar to alterations caused by residential development around the shoreline (e.g., the grading of land and installation of on-site wastewater treatment systems) while others have characteristics unique to recreational use (e.g., a developed campground entirely surrounding a water body may have informal access points for each campsite in a close vicinity).

This study focused on Forest Preserve water bodies with shorelines that are classified by management on a spectrum as wilderness (most pristine), primitive, wild forest, canoe areas, to intensive developed areas like campgrounds (most developed). The profile of Adirondack Park visitor recreational activities (Table 3) on Forest Preserve lands is based on numerous visitor studies in areas throughout the Adirondack Park (Connelly, Dawson and Brown 2005; Dawson, Connelly, and Brown 2005; 2006a; Dawson, Schuster, Probst and Black 2008; Dawson and Schuster 2008; Dawson, Peters, Connelly and Brown 2005; Graefe, Dawson, and Gerstenberger 2010). However, parallel studies are not available for private landowners and leaseholders or renters on private riparian areas that share the shoreline of the Adirondack water bodies. Generally, the more private ownership and development there is around a lake, the more the recreational activity profile changes toward motorized aquatic and terrestrial use and access. Similarly, more remote water bodies that are surrounded by state Forest Preserve lands that prohibit motorized travel and road access will tend toward less activities and use. At these sites, “muscle powered” activities (if any) are more prevalent both on and around the water body.

Table 3. Recreation use and facility development around Adirondack Park water bodies on Forest Preserve lands depending on the surrounding land classification.

| **Wilderness** ⟸⟹ | **Intensive Development** |
|---|---|
| On-water activities that occur on the surface of the water | |
| • Canoeing/kayaking<br>• Fishing, hunting, nature study and photography from a boat<br>• Limited motorized access, if any<br>• Limited float plane landings | • Canoeing/kayaking<br>• Fishing, hunting, nature study and photography from a boat<br>• Motorboating<br>• Float plane landings |
| Water contact activities which require bodily contact with the water | |
| • Swimming<br>• Wading | • Swimming<br>• Wading<br>• Waterskiing |
| Shoreline activities occurring in close proximity to water bodies | |
| • Camping<br>• Hiking and backpacking<br>• Horseback riding<br>• Picnicking<br>• Nature study<br>• Photography<br>• Bird watching<br>• Fishing<br>• Hunting<br>• Cross country skiing<br>• Snowshoeing | • Camping<br>• Hiking<br>• Horseback riding<br>• Picnicking<br>• Nature study<br>• Photography<br>• Bird watching<br>• Fishing<br>• Hunting<br>• Cross country skiing<br>• Snowshoeing<br>• Mountain biking<br>• Motorized vehicles (ATV's, snowmobiling, etc.) |
| Recreation facilities on Forest Preserve lands | |
| • Trails<br>• Primitive campsites and lean-tos<br>• Pit privies<br>• Swimming beach<br>• Carry in access or boat launch<br>• Access roads | • Trails<br>• Primitive campsites and lean-tos<br>• Pit privies<br>• Swimming beach<br>• Carry in access or boat launch<br>• Access roads and parking lots<br>• Developed NYSDEC campground<br>• On-site wastewater treatment system for campground or other public waterfront facilities |

## Descriptive Summary of Potential Ecological and Social Impacts

Trends in recreational use over the past 30 years suggest visitation to protected areas such as the Adirondack Park and water-based recreation will continue to increase as population increases (Cordell et al. 1999, Dawson and Hendee 2009, Leung and Marion 2000). There are three basic premises that underline the impact recreational use has on the ecological and social environments: (1) changes in outdoor recreational settings are an inevitable result of recreation use and development (McCool et al. 2007) and using an outdoor setting for recreation purposes will result in some type of change to the environment (Frissell and Bayles 1996); (2) impacts to natural resources are not only a result of the actual number of people using the resource but also many other factors such as natural and managerial site characteristics, the types of recreational activity allowed, the intensity of use, and natural variability (Manning 1999; Hammitt and Cole 1998); and (3) the presence of recreationists and the evidence of their present and past use will have an effect on the recreational experiences of other visitors (Dawson and Hendee 2009).

Many regional and local government agencies have recognized the importance of preserving and restoring freshwater resources but increasingly have to make difficult decisions between balancing human demands for freshwater and protecting aquatic ecosystems to an extent where they can remain functionally intact (Poff et al. 2003). The Adirondack Park Agency (APA and NYSDEC 2001) recognized the need for freshwater resource protection when it included a policy directive in the APSLMP for the NYSDEC to conduct a study of Adirondack water bodies to determine their capacity to withstand various types of use while providing recreational opportunities for visitors to the Park. As an alternative to determining a subjective carrying capacity of Adirondack Forest Preserve water bodies, the design of a LAC type process used to monitor ecological and social impacts relies on research conducted on the effects of recreation use and development on Forest Preserve water bodies.

One step in the LAC process to monitor recreation use and development related impacts to water bodies is that indicators should be chosen to assess changes in freshwater resource conditions due to recreational uses and not other anthropogenic driving forces of change (e.g., acid deposition) or natural variation. In the LAC planning process, standards for acceptable conditions have to be created or chosen that meet management objectives and that are based on science and informed value judgments. Currently, New York State water quality standards exist that represents the legal limit for several pollutants and aquatic resource conditions (6 NYCRR

Part 703). However, these standards are legal limits for all water bodies in the state (including non-protected areas) that may or may not represent the limit of acceptable conditions that the NYSDEC wishes to maintain in Adirondack Park water bodies given policies in the APSLMP and the range of resource protection that is provided through classification of Forest Preserve units of land (APA and NYSDEC 2001). Standards will need to be defined for the aquatic ecosystem conditions the NYSDEC wishes to maintain in Forest Preserve water bodies. In this manner, the complete LAC process could be used to manage Forest Preserve water bodies so aquatic ecosystem (resource) conditions do not deviate from the acceptable conditions the defined standards represent. After standards have been created according to stakeholder input, management goals and land management classifications, monitoring of resource conditions must occur to ensure acceptable resource and social conditions are being maintained.

## Ecological Impacts

### Recreational Activities Can Cause Ecological Impacts

Leung and Marion (2000) define recreation ecology as “the field of study that examines, assesses and monitors visitor impacts, typically to protected natural areas, and their relationships to influential factors” (p. 23). While this definition denotes ‘visitor’ impacts as the target of investigation, the presence of visitors is often preceded by the recreational opportunities and facilities provided by managers and the natural setting (Manning 1979). Therefore, the basis for designing a process to monitor biological, physical, and chemical impacts caused by recreational uses of water bodies relies on research conducted on the impacts of: (1) visitors participating in water-based and shore-based recreational activities; and (2) related shoreline development that may occur near water bodies to provide visitors with services and recreational opportunities.

Recreation use and development related impacts to water bodies occur from activities that take place on or in the water body (e.g., boating, fishing, hiking, camping) and from activities and related development (e.g., trails, campsites, campfires, pit privies, septic tanks) that occur in the riparian and shoreline areas surrounding the water body (Hammitt and Cole 1998; Johnson and Carothers 1982; Liddle and Scorgie 1980; Liddle 1997; Manning 1979).

Impacts to Ecosystems

Ecological impacts caused by recreation use and development have been documented since the late 1800's (Liddle 1997). Most recreation ecology research has been conducted on the impact various recreational activities have on vegetation, soil, water, and wildlife (Leung and Marion 2000). Impacts to water has received the least attention and this maybe due to multiple reasons outlined by Hammitt and Cole (1998) including: (1) many impacts to water caused by recreational use and related development can be difficult to measure; (2) routine monitoring is needed to detect changes since changes are usually not visible or may be transient in nature; and (3) it is difficult to determine the significance of transient changes as many factors interact to intensify or mitigate impacts.

Impacts to vegetation and soil are commonly mentioned in recreation impact literature (Leung and Marion 2000; Liddle 1997; Zabinski and Gannon 1997). Recreation use and facilities (e.g., camping, hiking trails, ATV riding) may increase soil erosion processes through vegetation removal and soil compaction which influences overland runoff and sediment transport to receiving water bodies (Green 1998; Zabinski and Gannon 1997). Removal of overhanging canopy (e.g., cutting trees or clearing land) increases erosion potential as precipitation is not intercepted by vegetation (France et al. 1998; Sutherland et al. 2001). The amount of visitor use within the immediate riparian and more distant shoreline areas as well as the types of activities allowed are important factors as high-use recreational areas have shown significantly higher soil erosion rates than lower-use areas (Green 1998; Sutherland et al. 2001). Site-specific variables that have an impact on soil erosion include the slope of the area with steeper slopes having a greater potential for erosion (Rickard and Slaughter 1973), the erodibility of soils (Richter and Negendank 1977), vegetation cover (Kirkby 1980), and amount and type of litterfall (France et al. 1998).

Riparian areas are important ecological transitional zones between land and water. The vegetation in riparian areas serves as important habitat for animals, traps sediment, and improves water quality by filtering out nutrients and pollutants that have been transported to the water. Research has focused on the direct and indirect effects that canopy and ground vegetation removal has on environmental changes such as loss of litterfall, soil erosion, increases in the transport of nutrients and pollutants, and biotic effects (Dickman and Dorais 1977; France, Peters, McCabe 1998; Manning 1979; Pusey and Arthington 2003). Vegetation disturbance around Adirondack water bodies, especially in close proximity to the waterline where many recreational activities occur, can exacerbate natural processes since Adirondack water bodies receive a high amount of acidic deposition and are sensitive to atmospheric inputs due to their low acidic buffering capacity (Hunsaker et al. 1986; Ito et al. 2005). Understanding how the presence of vegetation in shoreline areas improves water quality is pertinent to understanding the effects of its removal.

- Tabacchi et al. (2000) summarize the impact riparian vegetation has on hydrological processes including: (1) the importance of living and dead vegetation in controlling runoff; (2) the impact of plant physiology on water storage and evapotranspiration; and (3) the effect riparian vegetation has on water quality.
- Sediment deposition occurring as a result of shoreline vegetation removal and soil erosion can smother habitat for aquatic animal species and have detrimental effects on aquatic macrophytes (Curry 2000). Increased transport of sediments to water bodies also may increase levels of nutrients such as phosphorous, the limiting nutrient to production in most Adirondack lakes (Dickman and Dorais 1977; Quinton 2001; Wetzel 2001). The reduction of nutrient-rich sediment inflows may play a significant role in slowing eutrophication processes. While deep lakes are less likely to respond quickly to sediment inputs, shallow lakes may change relatively fast in response to sedimentation depending on site characteristics such as slope, climate, and surface area of the lake (Wetzel 2001)
- Dense herbaceous vegetation and forest vegetation is very effective in retaining sediments (Magette et al. 1989; Daniels and Gilliam 1996). Riparian forest ground cover and grass have shown equal effectiveness in nutrient sequestration (Daniels and Gilliam 1996). Abu-Zreig et al. (2003) reported that the width of the vegetative barrier is the primary factor affecting retention of phosphorous while rate of inflow, type of vegetation, and density of vegetation coverage are important secondary factors.
- One biological impact recreational facilities have on riparian habitat is loss and fragmentation of habitat. A number of animal species are dependent upon riparian habitat for survival (Yamasaki 2000). Their displacement has been attributed in a number of studies to habitat loss (Doyle 1990; Knopf et al. 1988) and fragmentation

Impacts from Roads

Roads (i.e., any type of road used for motorized vehicle transport) are one of the most prominent alterations of the landscape and are important for recreational access. Forman and Alexander (1998) outline the ecological effect roads have on roadside vegetation, animals and their movement patterns, water, sediment, and chemicals.

- Roads may affect nearby water resources during 3-phases: construction, post-construction, and maintenance. Studies have varied in the reported amount of sediment transport and deposition caused by road construction to nearby waterways. Only in a few observances have existing erosion and sediment mitigation measures been effective in reducing impacts to waterways (Barrett et al. 1995; Howell, Nakao, Gidley 1979).
- Roadside vegetation that acts to remove pollutants from road runoff and detain sediments may be lost due to the toxic effects of high concentrations of sodium chloride (NaCl) from road salt application (Adirondack Council 2009; Langen et al. 2006). Soil erosion may also increase as de-icing agents (especially chloride) seep into soils, creating swelling and a reduction in the stability of vegetation (Adirondack Council 2009).
- Suspended solids in nearby water ways increase dramatically once road construction begins and then decrease when construction ends, although sediment contribution continues to some extent dependent upon sediment supply, transport capacity, road geometry, slope, length, width, surface, and maintenance, soil properties, and surrounding vegetation cover (Barrett et al. 1995; Forman and Alexander 1998).
- Several studies have shown chloride contamination and other effects from the road application of de-icing salts to be a major threat to northeastern water

- The incorporation of inorganic compounds (e.g. heavy metals) and organic compounds (e.g., PAHs) into surface runoff and subsequent deposition into receiving water bodies is of concern. These deleterious compounds found in oil and gas deposited on roads during vehicle operation persist in the environment and eventually flow off impervious road surface into tributaries or roadside soils (Forman and Alexander 1998).
- Biological impacts of roads on animals and aquatic biota are caused by: sediment deposition, the degradation of water quality due to nutrient and chemical inputs, and habitat fragmentation (Forman and Alexander 1998). The transport and deposition of fine sediments are felt in the aquatic community as habitat is smothered resulting in decreased species diversity (Cline, Short, Ward 1982; Suttle et al. 2004).

Bacterial Contamination

Bacterial contamination of freshwater resources and subsequent impacts on human health has been documented as a concern in wildlands and developed recreational areas (Hammitt and Cole 1998; Thompson 2004). Bacterial contamination of drinking water supplies and recreational swimming areas has led to federal and state regulations. Gastrointestinal illness is a concern in waters used for recreational purposes as recreational bathers have reported illness (Craun, Calderon, Craun 2005).

- Bacterial contamination may be introduced into the aquatic environment through a variety of human derived sources: (1) facilities used to dispose of human waste including on-site sewage treatment systems (Ahmed, Neller, Katouli 2005; Chen 1988; Scandura and Sobsey 1997), pit latrines commonly used in wilderness and back country areas (Nichols, Prettyman, Gross 1983), and wastewater treatment effluent; (2) direct bodily contact (Gerba 2000; Wade et al. 2006); and (3) re-suspension of sediments by various uses (e.g., recreational bathing and boat traffic) (Graczyk et al. 2007b).

- Other sources of fecal matter include dogs and birds (Graczyk, Majewska, Schwab 2008; Wright et al. 2009), wildlife (Graves et al. 2002), and agricultural runoff (Jamieson et al. 2002).
- Contamination of surface water can occur through contaminated groundwater, direct inputs, soil leaching, and overland runoff (e.g., during precipitation events or from contaminated tributaries) (Scandura and Sobsey 1997; Santamaria and Toranzos 2003).
- In forested watersheds with little agricultural or residential development, the occurrence of fecal bacteria indicators in water bodies may depend upon the amount, proximity, and maintenance of sewage treatment systems (e.g., septic systems, leach fields, outhouses); amount and type of recreational use; management actions to deter irresponsible actions; wildlife population species and density; and climate.
- Wildlife can be the biggest source of fecal matter inflow to a remote water body that shows high concentrations of bacteria if there is minimal recreation activity and associated human waste (Hammitt and Cole 1998).

Although fecal indicator bacteria (e.g., fecal coliforms) are not pathogens, they are often found in association with bacterial and protozoan pathogens. Therefore, fecal indicator bacteria including fecal coliforms, Enterococcus, faecal streptococci, and Escherichia (E.) coli have been widely used as indicators of bacterial contamination. However, existing indicator bacteria are unable to correctly determine all types and amounts of pathogens (Graczyk et al. 2007b; Schwab 2007), although they have been found to exist in correlation with gastrointestinal illness (Wade and others 2006). Existing indicators and criteria to protect swimmers from illness due to pathogens are more than 20 years old. Existing indicator accuracy and new methods for detecting pathogens are being investigated by the EPA and are the subject of many scientific studies (USEPA 2009).

<u>Water Quality Impacts</u>

Water quality parameters (e.g., water temperature, dissolved oxygen, turbidity, nutrients) may change due to recreational impacts to surrounding land or direct disturbance within the water body (Hammitt and Cole 1998). For example, phosphorous concentrations in water bodies have been found to increase with on-site wastewater treatment at developed campgrounds (Robertson, Schiff, Ptacek 1998), removal of shoreline vegetation and trail use can increase soil erosion and result in tributary and water body sedimentation and increased nutrients (Dickman and Dorais 1977, Wilkerson and Whitman 2010). A typical water body response to increased levels of phosphorous is increased productivity as plants acquire the macro-nutrient that under natural processes only enters water bodies in small amounts (Schindler 1974). Increased productivity can lead to decreased dissolved oxygen levels as the increased amount of organic matter requires oxygen for decomposition, subsequently reducing the amount of available oxygen required by aquatic organisms for respiration (Wetzel 2001). Although it is generally accepted that shoreline erosion and vegetation removal in the riparian area can have an adverse impact on water quality through such mechanisms as increases in nutrients (e.g., nitrogen, phosphorous, carbon), the significance of the impacts vary as determined by factors such as type, intensity, and extent of use; vegetation and soil characteristics (e.g., high impact-soils that are highly erodible and well drained); and water body characteristics (e.g., high elevation, low flushing rate, shallow, small) (Hammitt and Cole 1998; Liddle and Scorgie 1980).

Primary impacts to the physical aquatic environment can have either direct (e.g., pollution of water), indirect (e.g., the suspension of sediment), or cumulative effects on biological activity within the water. These impacts, when combined with each other or when interacting with alternative sources of impact (e.g., natural or anthropogenic) to reach a certain level of magnitude may cause human health and ecological integrity concerns (Hammitt and Cole 1998).

Motorized boating has been a social and ecological concern since the 1950's, spurring a substantial amount of research into its direct and indirect effects on freshwater plants and animals (Asplund 2000; LaBelle 1990; Liddle and Scorgie 1980; Mosisch and Arthington 1998). Of the water-based activities reviewed, motorized craft are capable of having the most significant impact on aquatic ecosystems due to the direct and indirect physical, chemical, and biological impacts the activity can create. However, non-motorized boating also can create physical and biological impacts on the aquatic ecosystem depending on site-specific characteristics (Liddle 1997). Impacts vary depending on the productivity (e.g., increases in algae and plants) and physical characteristics (e.g., depth, volume) of the lake. Shallow lakes are more susceptible to motorized boat propulsion-induced turbidity and lakes with steeper shorelines maybe more susceptible to erosion caused by motorized boat caused waves (Asplund 2000). Water bodies with extensive shore-based uses and water-based motorized uses may see greater impacts due to removal of riparian and emergent vegetation from trampling coupled with the erosion action of the waves from wind and motorized use.

Non-motorized boats are small and mobile so they are capable of traveling in shallow water areas larger motorized craft cannot reach. Shoreline impacts have been noted from boats being pulled up on shore, which can damage vegetation and increase erosion processes (Hammitt and Cole 1997). Additionally, boats capable of traveling in shallow waters may cause physical damage to emergent and submerged aquatic macrophytes, which create subsequent biological impacts as habitat is altered or damaged (Asplund and Cook 1997; Liddle and Scorgie 1980).

Physical impacts of water-based recreational use include: (1) wave action, (2) turbidity, (3) direct boat contact, and (4) noise and visual disturbance (Asplund 2000; Liddle and Scorgie 1980; Mosisch and Arthington 1998).

- Wave action from the operation of motorized craft can create stress on aquatic ecosystem by eroding soil (Johnson 1994; Liddle 1997; Nanson et al. 1994), damaging aquatic macrophytes through abrasion or uprooting (Asplund and Cook 1997; Sukopp 1971), and re-suspending sediments (Bussmann 2005; Garrad and Hey 1987).
- Turbidity from motorized boating occurs when boats operate in relatively shallow waters, although studies have documented direct turbidity impacts from motorboats operating in water up to 15 feet deep (Asplund 2000). Notably, jet/wave skis or jet-propelled craft have been the focus of recent research due to their ability to go into very shallow areas and cause turbidity, suspended sediments, and water pressure gradients (Mosisch and Arthington 2004).
- Non-motorized craft disturb sediments and cause some plant damage when operating in extremely shallow areas where oars or paddles may come into contact with benthic sediments and submerged or emergent macrophytes (Liddle and Scorgie 1980). Wading or walking in the near shore zone causes some re-suspension of sediments; similar effects occur from dragging boats or pushing off the bottom with paddles (Liddle 1997). Comparisons between the impacts of non-motorized and motorized boats were not available.

- Increased turbidity in an aquatic ecosystem may have a negative effect on macrophyte growth due to decreased light penetration (Hammitt and Cole 1998). However, Asplund and Cook (1997) conclude impacts such as direct contact and sediment scouring from motorboat propulsion is a greater source of plant growth limitation. Sediment suspension as a result of water-based uses is relatively short-term but can cause changes in water quality (Asplund 2000).
- Chemical contaminants from the release of unburned gasoline and oil into the water column can be broken down into gasoline compounds such as benzene, toluene, ethyl benzene, xylene (collectively called BTEX), methyl tertiary butyl ether (MTBE), and polycyclic aromatic hydrocarbons (PAHs). Higher levels of BTEX and MTBE have been found to exist in water bodies used for motorized water-based recreation with the highest concentrations found in the uppermost water layer in shallow lakes (Avallone 2003; Schmidt et al. 2004). Higher concentrations of MTBE have been measured in water bodies with higher amounts of motorized use (Reuter et al. 1998; VanMouwerik and Hagemann 1999). A small amount of PAHs are present in unburned fuel, but the majority is released as exhaust from the engine combustion process (VanMouwerik and Hagemann 1999). PAHs bind to organic and inorganic particulate matter in the water column, sink to the bottom, and are deposited in bottom sediments where they remain unless returned to the water column via biological and/or anthropogenic activity and leaching (Mosisch and Arthington 2001; Neff 1979). PAHs persist in the environment for long amounts of time. Without some form of remediation of the sediments, their degradation in the aquatic environment is dependent upon microbial processes that operate most efficiently under aerobic conditions.
- PAHs and BTEX represent the most toxic of gas and oil components to aquatic life. En route and after deposition in sediments, these compounds can be accumulated by aquatic biota and transferred up the food web (USEPA 2007b). Studies have documented genetic differences, mutations, decreased growth rates, and mortality in fish and other aquatic biota as a result of bio-accumulation (Clements, Oris, Wissing 1994; Mosisch and Arthington 2001). Due to the

- Two-stroke engines release more chemical inputs into the water than four-stroke engines. In a 2-stroke engine, oil is added directly to the fuel for lubrication purposes instead of being sent separately to the crankcase for lubrication. Additionally, 2-stroke intake and exhaust systems are fairly inefficient as exhaust valves expel exhaust and unburned fuel simultaneously (Jackivicz and Kuzminski 1973).
- Recreational boating impacts to waterfowl and fish include nest disturbance and related flight distances and avoidance caused by increased physiological responses (Asplund 2000; Graham and Cooke 2008; Mosisch and Arthington 2004; Mueller 1980; Stalmaster and Kaiser 1998; York 1994). Several studies have concluded that walking and canoeing may cause greater disturbances (e.g., greater flushing response, flight distances, and increased time of nest absence) than motorized use, although motorized boating may disturb a larger area and population (Rodgers and Smith 1995 and 1997; Stalmaster and Kaiser 1998).
- Dispersion of exotic species (plants and animals) at landscape scales is evident on water bodies that accommodate large amounts of recreational use including fishing and motorized boating (Pimentel 2000). Introductions due to fishing have occurred as non-native species have been introduced initially to enhance sports fishing; however, this usually proves detrimental to the overall success of the fishery (Mills 1993; Whittier 1999). Other introductions due to fishing occur as non-native species are used as bait and escape into the water.
- Recreational boating has been pin-pointed as a major mode of exotic species transport including exotic macrophytes (plants) and animals (Johnson and Carlton 1996; Johnstone, Coffey, Howard-Williams 1985; Muirhead and MacIsaac 2005). While all types of recreational boating are potential pathways of exotic species transport, motorized boating has been largely implicated in the introduction of exotic aquatic plant species (Johnson and Padilla 1996). Motorboat trailers, boat hulls, engines, and the vegetation remaining on engines all act as vectors of

While physical, chemical, and biological impacts can be categorized into different groups, they often interact with each other to amplify particular impacts or to form additional impacts. Many primary physical and chemical impacts result in cumulative and long-term biological impacts. For example, gas and oil released into the water column may attach to particles and be retained in sediments without instantly having a detrimental biological consequence. Over a period of time, however, biota bio-accumulate persistent toxic compounds, which can then be transferred up the food web resulting in ecological and human health effects (Metcalfe et al. 2000).

A wide variety of recreational activities and related facility development were reviewed that may create pressures to directly, indirectly, or synergistically impact water bodies by decreasing water quality or having some adverse effect on aquatic ecosystems. A summary of recreation related ecological impacts to water bodies is listed in Table 4 (McEwen 2010) and is based on the foregoing review of the literature and general summaries of the ecological impacts of recreational activities.

Table 4. Summary of recreation related ecological impacts to water bodies.

| Activity | Primary Action | Associated Impacts |
|---|---|---|
| **Water-Based** | | |
| Motorized Boating | Wave action | Sediment re-suspension/turbidity/erosion – may smother macrophytes, cause re-suspension of pollutants/macronutrients buried in sediments |
| | Direct contact | Damage to macrophytes, mortality of aquatic organisms |
| | Chemical introduction | PAH accumulation in sediment, bio-accumulation of toxic compounds up the food web, acute toxicity to aquatic biota, human health concerns |
| | Noise | Disturbance to waterfowl and aquatic species including physiological impacts, absence and avoidance of nests |
| | Transportation | Dispersal and introduction of exotic macrophytes and animals, affects aquatic ecosystem function and integrity by altering structure |
| Non-motorized boating (paddled craft) | Energy from oar propulsion | Damage to or uprooting of submerged macrophytes, localized turbidity from contact with sediments in shallow areas, may cause re-suspension of pollutants or macro-nutrients |
| Recreational Bathing (swimming/wading) | Bacterial contamination | Human health concerns for other swimmers, drinking water contamination |
| | Suspension of sediments | Localized turbidity, suspension of bacteria buried in sediments, re-suspension of macro-nutrients buried in sediments |
| Fishing | Removal of Fish | Decrease in recreational opportunities/ecosystem services, may have food web impacts |
| | Introduction of exotic species | See 'Motorized Boating-Transportation' |
| **Shore-Based** | | |
| Hiking, Camping | Trampling | Land (Direct/Indirect) - Cutting and damage to woody vegetation, removal of coarse woody debris, woody and herbaceous vegetation removal, soil compaction, reduced infiltration and soil porosity, increased soil density, decreased ability of plant roots to receive moisture, reduction in organic litterfall, soil erosion<br>Water (As a result) – Reduction in allocthonous inputs, increased sedimentation, increased transport of macronutrients (mainly N and P), increased productivity, habitat impairment |
| Littoral structures | Permanent shading | Water - Reduces primary productivity, predatory species advantage |
| | Construction | Water - Habitat loss, possible chemical impacts from treated wood, increased sedimentation |
| Roads/ Parking lots | Impervious surface | Land/Water - Lack of infiltration increases overland runoff, increased soil erosion, gas and oil compounds enter runoff, nearby vegetation effects |
| | Winter management | Water - Direct NaCl contamination of water resources via overland transport (overland runoff, tributaries), NaCl contamination of groundwater through soil saturation, increases mobility of other metals to surface waters, favors aquatic species with higher salt tolerances, acutely toxic at some levels, toxic to roadside vegetation, human health concerns from drinking water contamination |
| | Operation | Land - Habitat fragmentation, Reduces mobility of animals (especially wetland species such as amphibians), causes avoidance/disturbance |
| Facilities | Impervious surface | Land/Water - Creates a space with no infiltration and precipitation absorbance capacity, increases runoff, increases likelihood of surrounding impacts from visitor concentration |
| | On-site wastewater treatment | Water - Bacterial contamination, increased macronutrients |

## Social Impacts

The overall experience of visitors while on their trips in wilderness is affected both by the natural environment and the social setting (Dawson, Hendee and Schuster 2009). The social setting is influenced by the visitor's behavior (e.g., crowding, conflict) and effects of their past and present behavior on the natural environment (e.g., litter, vegetation trampling). The behavior of one visitor or visitor group affects other visitors in a variety of ways. Visitor interactions within a group affect visitor experiences, but are generally not subject to management action compared to interaction between groups while on a recreation trip. Visitors seek some level of satisfaction with their overall trip and will accommodate or cope with various interferences towards that goal to arrive at some level of overall trip satisfaction.

Managers need to be aware of how management decisions modify both the resource setting and also the social setting (Dawson and Hendee 2009). In particular, managers need to understand how visitor experiences must be managed as part of a social setting (Dawson, Connelly and Brown 2006b). Visitors have experiences on the site during their visit; however, they also have experiences before they arrived at the site and after they leave the site. Visitor experiences are affected and shaped by all aspects of the trip from website trail condition reports to information and education programs to direction signage and trail blazes to public access conditions. The following sections outline the most important visitor experience issues that must be understood for measuring and managing visitor experiences, much of which was outlined by Dawson, Hendee and Schuster (2009).

### Visitor Satisfactions and Benefits

Measuring visitor satisfactions with an overall wilderness trip and the various components that make up that trip have been well documented in the literature (Manning 1999; Dawson, Hendee and Schuster 2009). However, multiple variables must be measured to understand both satisfaction and dissatisfaction during a recreation experience. The combination of satisfying and dissatisfying experiences results in overall trip satisfaction that should be considered together as a combined overview of visitor experiences. Visitor experiences partially arise from their interaction and observation of resource conditions that management can control, such as on trails, at campsite, directional signage, public access, and other factors. The social experience for visitors is also made up of various individual and group experiences and interactions with other visitors such as the visitor's perception of their solitude, encounters with other visitors, and the possibility of crowding during the wilderness experience.

Visitors engage in recreational trips to satisfy various needs and personal outcomes that they wish to experience. A visitor chooses a trip area and destination (i.e., resource and a social setting) with the expectation that the experiences on that trip will result in an overall satisfying trip. The desire to fill those social needs is what motivates people to engage in recreation experiences. Benefits are the aggregate satisfactions or outcomes from recreational experiences that accrue to the individual and, ultimately, to society at large through healthier individuals, family cohesion, preserving cultural heritage, and other benefits. Visitor motivations for continued recreational experiences arise both from their past trip satisfactions and the benefits they individually achieved from previous recreational experiences (Driver and Brown 1983; Driver et al. 1987; McCool et al. 2007). The three most often measured concepts (Manning 1999; Dawson, Hendee and Schuster 2009) are:

- The multiple attributes of a resource setting and visitor behavior that lead to satisfying or dissatisfying experiences for visitors, such as campsite conditions, perceptions of crowding, evidence of visitor impacts on the setting. These are most often measured for a specific trip and management area to better understand overall trip satisfaction and visitor experiences to a specific setting (Newman and Dawson 1999; Dawson, Newman and Fuller 2000; Johnson and Dawson 2002; Pfaffenback, Zinn and Dawson 2003; Dawson, Connelly, and Brown 2005; Dawson, Peters, Connelly and Brown 2005; Watson et al. 2007; Dawson, Schuster, Propst and Black 2008; Dawson and Schuster 2008; Graefe, Dawson, and Gerstenberger 2010).
- Overall trip satisfaction is measured for a specific identified trip and area; however, this should be measured in conjunction with the multiple attributes noted above since overall trip satisfaction may remain high in spite of dissatisfying experiences with certain conditions (i.e., visitor coping is a component of achieving overall satisfaction that also needs to be measured) (Manning 1999).

- Visitor motivations for taking trips to wildlands and wilderness areas can be measured as more generic reasons for travel to wild forests and wilderness areas and arise from previous experiences or information obtained from outside sources (Manning 1999; Johnson and Dawson 2002). Motivations are often described as the same in kind as satisfactions but different in time (i.e., either following from a previous trip or preceding a planned trip).

Visitor Relationships with Wilderness as a Place

Visitors become attached to wildlands and wilderness areas, or specific facilities and locations within an area, to the extent that the individual values and identifies with that specific place (Brooks et al. 2006; Farnum et al. 2005). Visitors become attached to a particular place and select it repeatedly because it may provide the conditions necessary for them to have their preferred recreational and social experiences. The identification with place and dependence upon place -- to have that valued and satisfying experience -- is related to visitors' subjective experiences, beliefs, values, attitudes and preferences. Visitor attachment to place is influenced by the visitor's perception of acceptable resource, social, and management conditions. The two concepts that can be measured and have the most relevance to planning and management are:

- Place attachment can be measured by type and strength of attachment, which is influenced by the visitor's perception of what are desirable and acceptable conditions for the resource and social setting (Choi and Dawson 2002; Graefe, Dawson, and Gerstenberger 2010).
- Visitor dependence on place can be measured by type and strength of dependence and is often related to how visitors respond to management plans and actions (Dawson and Schuster 2008; Graefe, Dawson, and Gerstenberger 2010).

Normative Behavior in Visitors

The concept of using normative behavior to manage visitor experiences is based on the concepts of social norms and social standards for behavior. Social norms are the shared beliefs about how people ought to act in certain situations and settings (Heywood 1996). Social standards are defined as what behaviors are acceptable to people in certain settings and activities (Hall and Shelby 1996). For example, in wilderness visitors expect appropriate camping practices and how those campers interact within their group and with other groups. Social norms and standards evolve over time and are learned from other visitors as well as from information and education programs, printed literature, and social interactions with other recreational visitors both on site and off site. Social norms are used to judge the behavior of other visitors as well as the social setting created by management. Visitors use social norms to judge management plans and activities in view of the way they affect the visitor experiences.

Visitors affect each other's behavior through learning and observation of the behavior and activities of other visitors. In particular, new visitors observe and learn from other visitors as they enter a new experience. Additionally, all visitors are affected by information and education programs that describe acceptable actions and behaviors within a recreational and natural setting. Managers can strongly affect the visitor behavior through information and education programs that influence their normative behavior (i.e., norms and standards).

Three concepts related to normative behavior are of particular importance in measuring, understanding, and managing visitor experiences:

- Perceived Crowding -- the number of visitors can be measured as well as the density of visitor use. Additionally, visitor perceptions of density and perceptions of crowding need to be measured since different visitors will have different perceptions. Visitors expect relatively low densities of use within wildland and wilderness settings. The question for managers is at what level of density do visitors perceive crowding and experience dissatisfaction with their experience of solitude. Visitor perception is based both on past experiences by the visitor, normative standards shared within a group of visitors, and the actual number of other visitors present and their behavior (Dawson, Newman and Fuller 2000; Dawson and Alberga 2004; Dawson 2005; Peters and Dawson 2005; Vaske and Shelby 2008).
- Visitor Coping with Dissatisfying Experiences -- When visitors experience dissatisfying experiences and situations, such as the unacceptable behavior of other visitors, these visitors will employ coping mechanisms that allow them to experience less dissatisfaction with the situation. However, coping by visitors tends to reduce the overall trip satisfaction that a visitor experiences in that setting. Such dissatisfactions can lead to behavioral change by visitors such that they do not want to experience that situation again, or they changed locations for their activities, or they choose a different activity to

- Visitor Conflict -- Conflict between recreation visitors can be defined in four categories: (1) intra-activity conflicts such as between different types of hikers; (2) inter-activity conflicts, such as between backpackers and hikers; (3) conflict between recreation visitors and other wilderness users such as landowners with lands within public land areas (i.e., in-holdings); and (4) conflict between recreation visitors and management activities such as trail closures (Jacob and Schreyer 1980; Schreyer 1990). Conflict between visitors is often more of a perception then it is an actual physical crowding. Conflict most often is between different types of users or the objectionable behavior of other users. Sometimes conflicts are asymmetrical or one directional, meaning cross country skiers may be more affected by snowmobilers than snowmobilers are affected by cross-country skiers, or between different types of water-based recreational users (Wang and Dawson 2001 and 2005).

  Perceived conflict can be measured through surveys of visitors and their experiences and help managers to anticipate potential problems between visitors and the reaction of visitors to management plans and actions (Connelly, Brown and Dawson 2005; Dawson, Schuster, Propst and Black 2008; Dawson and Schuster 2008). When assessing visitor conflicts, it is best to understand that visitors may have conflicts due to actions of others that interfere with their goals and satisfactions. Additionally, visitors may have conflicts in values such as between hunters and non-hunters or between motorized users and non-motorized users (Cole, Watson and Roggenbuck 1995; Vaske et al. 1995; Schuster, Hammitt, Moore and Schneider 2006). Conflict may also arise between visitors due to the use of technology and equipment that suggests visitors hold different values about what a

Developing the list of important concepts is necessary prior to developing a specific series of indicator variables that can measure wildland and wilderness visitor experiences. Research and practical management experience can result in a list of indicator variables that can be measured and used in the LAC planning framework. Table 5 outlines the categories of indicator variables that can be measured regarding different types of potential social impacts on visitor experiences caused by recreation activities in and around water bodies (i.e., water-based and shore-based) on Adirondack Forest Preserve lands.

Table 5. Summary of recreation related social impacts to visitor experiences.

| **Social Theories** | **Measurable Concepts** | **Potential Impacts** |
|---|---|---|
| Visitor Satisfactions and Benefits | Attributes of resource setting | Satisfying and dissatisfying experiences such as campsite separation in sight and sound, screening from sight of others, evidence or absence of other visitor impacts on the setting, and naturalness of resource conditions. |
| | Attributes of behavior of other visitors | Satisfying and dissatisfying experiences such as perceptions of solitude, crowding, proximity of other campers, depreciative behavior, litter evident, and non-normative behavior of others. |
| | Overall trip satisfaction | The general impression that a visitor has of a specific trip based on the collective experiences that were either satisfying or dissatisfying and level of coping they may have had to use to reach an overall satisfying trip experience. |
| | Visitor motivations for recreation trip | The degree of actualization by visitor of their reasons for taking a trip based on past satisfactions or hoped for satisfactions they may experience; the disparity or congruity of motivations and satisfactions that impacts the overall trip satisfaction. |
| Visitor Relationship with Place | Place Attachment | The type and strength of attachment which is perceived by visitor's as desirable and acceptable conditions for their recreation experience. |
| | Place Dependence | The type and strength of dependence on place that is required by visitors to have a satisfying recreation experience. |
| Normative Behavior in Visitors | Perceived Crowding | Visitor perceptions of the number and density of other visitors; physical, sight and sound proximity of other visitors; and perception of crowding based on past experience or motivations. |
| | Visitor Coping with Dissatisfying Experiences | Stress and coping with dissatisfying conditions from non-normative behavior or depreciative behavior of other visitors, conditions of facilities and management, and conditions of resource setting. |
| | Visitor Conflict | Perceived or real conflicts such as (1) intra-activity conflicts, (2) inter-activity conflicts, (3) conflict between recreation visitors and other types of users, (4), conflict between recreation visitors & management, and (5) conflicts in values between different types of users. |

**Recreation Facilities and Visitor Use**

Measurement of visitor use across time and space, the number and type of recreation facilities and their capacities, and the carrying capacity of the resources are all necessary to understand the context of the visitor experience (APA and NYSDEC 2001). Some of the variables that can be measured related to visitor use include (table 6) daily access by visitors, the total number visitors staying overnight in a recreational area, and the number and type of visitors traveling through an area by land or water (Dawson, Connelly and Brown 2006a; Dawson and Hendee 2009). Additionally, knowing the activities engaged in by the visitors and that type of equipment used can help managers to understand the potential conflicts that might arise between different types of visitors and their activities.

Knowledge of visitor use can lead to better understanding of visitor experiences by being able to calculate visitor densities and the physical capacity of recreation facilities (Table 7). Measurement of enforcement activities within a given area also helps managers to understand visitor conflicts, non-normative behavior, depreciative behavior, and potential damage to the recreation experiences of others as well as to the physical facilities themselves.

Table 6. Summary of recreation activity use information needed for understanding the context of visitor experiences.

| **No Use** ◄——► **Heavily Used** |
|---|
| Hiking and backpacking |
| Horseback riding and mountain bike riding |
| Camping |
| Public Campground |
| Roadside camping |
| Primitive campsites or lean-tos |
| Motorized vehicle use |
| Snowmobile use |
| Boating access |
| Motorized boats |
| Non-motorized boats |
| Swimming |
| Picnicking and nature study |
| Fishing |
| Boat fishing |
| Shore fishing and tributary fishing |
| Ice fishing |
| Hunting |

Table 7. Summary of recreation related facilities and public access information needed for measurement of the recreation setting.

| **Undeveloped** ⟷ **Highly Developed** |
|---|
| Public road for vehicle access |
| Designated hiking or riding trails |
| Parking area at trailhead |
| Physical and visual access to water body |
| Designated trails to and along shoreline and portage trails |
| Horseback riding trails |
| Mountain bike riding trails |
| Camping |
| State Campground |
| Designated roadside camping |
| Designated primitive campsites or lean-tos |
| Human waste treatment – septic systems and pit privies |
| User created campsites |
| Boating access |
| Motorized boats |
| Non-motorized boats |
| Swimming beaches |
| Picnicking and interpretative nature study areas |
| Public fishing access |
| Boat fishing |
| Shore fishing and tributary stream fishing |
| Winter recreation |
| Snowmobile trails |
| Cross country skiing and snowshoeing trails |

## *Research Protocol to Assess Ecological and Social Impacts of Recreational Use*

The LAC planning process requires the identification of indicator variables and standards as the basis of determining if the desired ecological and social conditions are present and whether to continue the present management direction or to change management actions to achieve the desired conditions. The indicator selection process for ecological indicators has been widely published (Ahuja, Sharpley, Lehman 1982; Daniels and Gilliam 1996; Quinton 2001) and there are tradeoffs and compromises that must be made when selecting ecological indictors (Dale and Beyeler 2001; Kurtz, Jackson, Fisher 2001; Murtaugh and Pooler 2006; Niemeijer and de Groot 2008; Niemi and McDonald 2004; Whittier and others 2002). Indicators of change are the variables that can accurately represent a change in broader conditions in the water bodies, which would require management action to maintain the quality of these resources.

Similarly, criteria for selecting social, ecological and managerial indicators for the LAC process have been described in wilderness management literature (Dawson and Hendee 2009). While many indicator selection criteria exist, there are several fundamental criteria used by all who are involved in the monitoring of water resources. For example, an indicator must be feasible, sensitive, and conceptually relevant in a variety of settings (e.g., a remote wilderness area and an accessible recreation management setting. Tradeoffs in indicator selection result in compromises that should be carefully evaluated to best meet management objectives (Niemi and McDonald 2004).

Recreation facilities (i.e., development) and visitor use types and intensity must be measured to understand the relationships between recreational use and impacts on ecological and social conditions. The LAC indicators of change are the variables that are monitored to detect changes in those desired conditions. The overall goals of the APSLMP (APA and NYSDEC 2001) were considered the general goals under this LAC framework.

We developed an appropriate list of indicators to measure as indicators of change caused by recreational impacts in the nine case study water bodies (Table 8 and 9). These indicators were then measured in the field at nine pilot sites, which allowed some assessment of whether the selection criteria were met as anticipated or needed to be adjusted.

The development of this field protocol was meant to be brief and highly focused to measure very carefully selected variables that were indicators of change in ecological systems and the social experiences of visitors. We were not designing an inventory; rather we were interested in only 25-30 indicators of change that could be measured from primary field data collection or secondary data analysis from existing sources.

Indicators were chosen based on the variability in recreational intensity and took into consideration several factors: (1) certain types of recreational activity and development will have different types of impact on the pilot sites; (2) the extent of recreational development or the proportion of water body (shoreline) used for recreational purposes will increase the area that is subjected to recreational impacts; and (3) the intensity of recreational impacts caused by shore and water-based use will increase as the amount of recreational development increases to provide more access and facilities, subsequently providing more visitors with recreational opportunities.

Indicators of water quality were chosen that were reported in the literature review to be a result of common shore and water-based recreational activities that take place at Adirondack water bodies. The indicators represent: (1) conditions that are a possible result of recreational activities and development (e.g., increased levels of pollutants or contaminants, introductions of non-native species) and (2) changes in the condition of the aquatic ecosystem that are affected by impacts on shore and changing conditions within the water (e.g., dissolved oxygen, temperature). All of the selected water quality parameters have been linked to impacts created by recreational use of land and/or water and are recommended by the USEPA (2003) for use as indicators for aquatic life and recreational use. While management actions should be developed in response to changing aquatic ecosystem conditions, several of the condition indicators currently have NYS standards or guidance values (6 NYCRR Part 703) and some (e.g., water temperature) may be important for monitoring ecosystem conditions, but fluctuate daily and seasonally in response to natural variation. Interpretation and utility of the indicators are also based upon the sampling strategy including spatial, temporal, and data collection considerations.

Table 8. Aquatic ecosystem condition indicators measured in pilot study of nine Adirondack water bodies.

| Indicators | Purpose | Application | NYS Standard or Guidance? |
|---|---|---|---|
| Non-native Aquatic Plant Species | To detect presence of non-native aquatic plant species that may alter the aquatic ecosystem's ecological integrity and have adverse synergistic effects when accompanied by other recreation impacts. | All sites | No |
| Gasoline Compounds | To assess concentration of toxic (or otherwise harmful to aquatic biota) gasoline compounds released into water bodies from motorized boating. | Sites with motorized boating | Yes |
| Fecal Coliforms | To measure bacterial contamination that may result from: overland runoff of improperly disposed human feces and wildlife feces, direct release of sewage/bacteria, and improperly functioning on-site wastewater treatment (e.g. septic systems). | All sites | Yes |
| Chloride | To assess increases in chloride concentration that are detrimental to aquatic biota…related to winter management of nearby roads used for recreational purposes. | All sites | Yes |
| Total Phosphorous | To determine levels of phosphorous concentrations. | All sites | Yes |
| Total Dissolved Solids | To use TDS as one water quality parameter that may show aquatic response to recreation related pressures. | All sites | Yes |
| Dissolved Oxygen | To use dissolved oxygen as one water quality parameter that may show aquatic response to recreation related pressures but is useful in determining stresses to aquatic biota. | All sites | Yes |
| Water Temp | To use water temperature as one water quality parameter that may show aquatic response to recreation related pressures but is useful in determining stresses to aquatic biota. | All sites | No |

Table 9. Recreation impact indicators measured in pilot study of nine Adirondack water bodies.

| Indicators | Purpose | Application | NYS Standard or Guidance? |
|---|---|---|---|
| Recreation Impact Score | To identify the recreational activities and development that exist at the pilot sites and score them according to the types of potential impacts they create. | All sites | No |
| Proportion of Shoreline Disturbance | To estimate the proportion of the shoreline area with some known or visible amount of recreation related disturbance including vegetation, soil, and habitat fragmentation impacts. | All sites | No |
| Number of Campsites | To identify the potential for the water body to be used for extended recreational purposes (overnight use) or more intensively; the amount of shoreline use; and associated impacts. | All sites | No |
| Roads (length) | To identify access that allows certain types of recreational use, the amount of disturbance, and additional impacts created by impervious surfaces. | All sites | No |
| Trails (length) | To identify access, the amount of shoreline use, and associated impacts. | All sites | No |

**Data Collection**

Primary data and secondary data were used to obtain information on the indicators. Secondary data was collected for phosphorous, chloride, and non-native aquatic plant species at all pilot sites where secondary data could be found. Data collection considerations included how data were collected, transported, and stored (method used), where sampling occurred (sampling station), and analyses or calculations involved in formulating final indicator values. The location of each sampling station at individual pilot sites (see Figures 3 to 11) was recorded using a Geographic Positioning System (GPS).

All indicators were measured in all lakes unless time, funding, or equipment constraints prohibited primary data from being collected, in which case secondary data were used. Secondary data included information collected from maps (e.g., topographic, campground, contour) and online sources such as the DEC (http://www.dec.ny.gov) and Adirondack Lake Survey Corporation (ALSC) (http://www.adirondacklakessurvey.org) websites. Gasoline compounds were included as supplemental indicators and were measured in pilot sites with motorized boating.

Pilot sites were each visited two times. Pilot sites were initially visited in May - June of 2009 to verify secondary data needed to conduct a risk assessment and to aid in identifying constraints associated with measuring indicators at each pilot site. A second visit during August through October 2009 was used to collect primary data on condition (water quality) indicators since use of water bodies in the Adirondacks is most intense in the summer months between May and September and on weekends and holidays.

Values obtained for water quality indicators were based on collecting measurements at several locations within the freshwater area to get an overall representation of the water body. At least four sampling stations were chosen on four sides of the lake and in the deepest section (generally close to the middle) to get a representation of the entire lake. If recreation occurred on only one side of the water body, an additional sampling station was chosen near such shoreline use for targeted sampling. If a water body was located a far distance from a parking lot and a boat could not be carried in to sample, then only one or two sampling stations were utilized as access points allowed. Stations for gasoline compound data collection were selected according to points where sampling devices could be attached (e.g., docks, buoys) and near areas of observed frequent motorized use (e.g., boat launches). If a tributary stream into the water body was surrounded by recreational use, fecal coliforms were collected in the tributary if access allowed.

Figures 3 to 11 show the recreational development at each site and locations (sampling stations) where primary data was collected. Sampling station locations were geo-referenced using a GPS at the time of sampling. Recreation attributes were added to each map using a combination of secondary information from NYSDEC campground maps, recreation maps and field information collected at each site. The shoreline management area (i.e., critical management zone) was drawn around the shoreline of each water body and around tributaries flowing into the water body. This zone represents the area (approximately 50 meters or 160 feet) where recreational use and development (if any) is concentrated and impacts to soil and vegetation potentially directly or indirectly influence changes in the water body. The freshwater area consists of the water body itself and was the area where water quality indicators were measured.

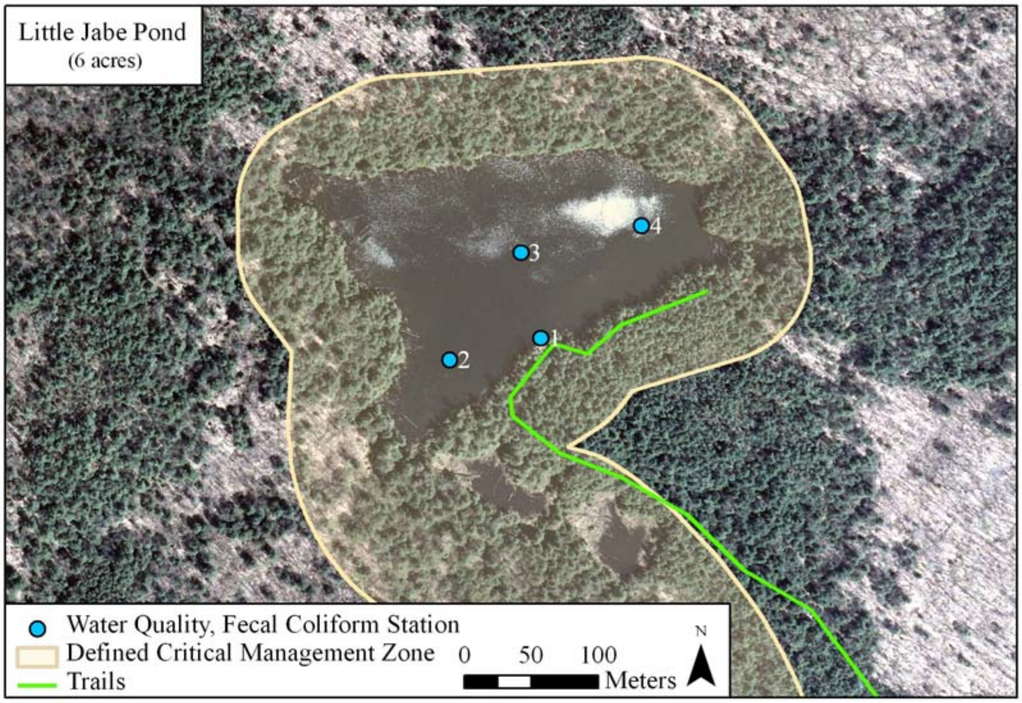


Figure 3. Little Jabe Pond in Lake George Wild Forest.

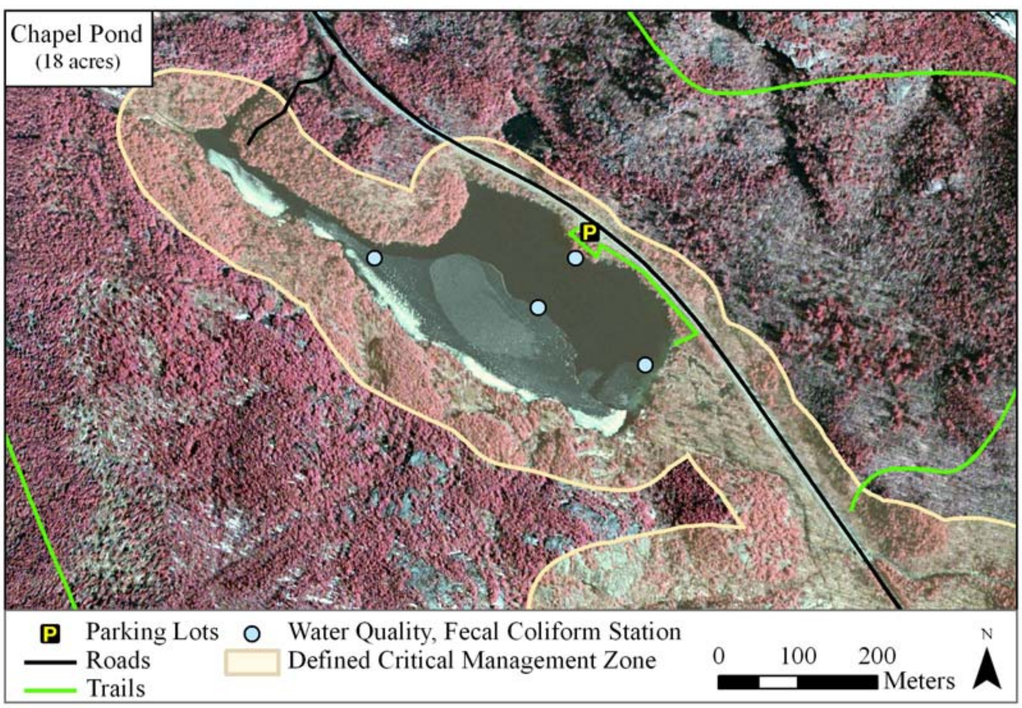


Figure 4. Chapel Pond in Dix Mountain Wilderness.

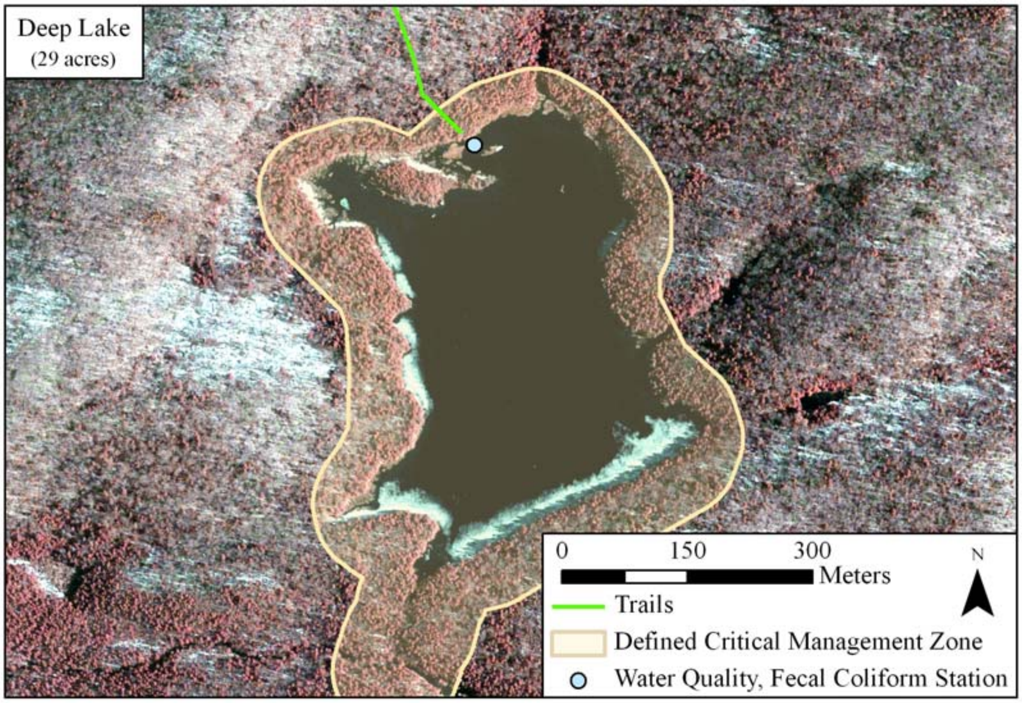


Figure 5. Deep Lake in the West Canada Lake Wilderness.

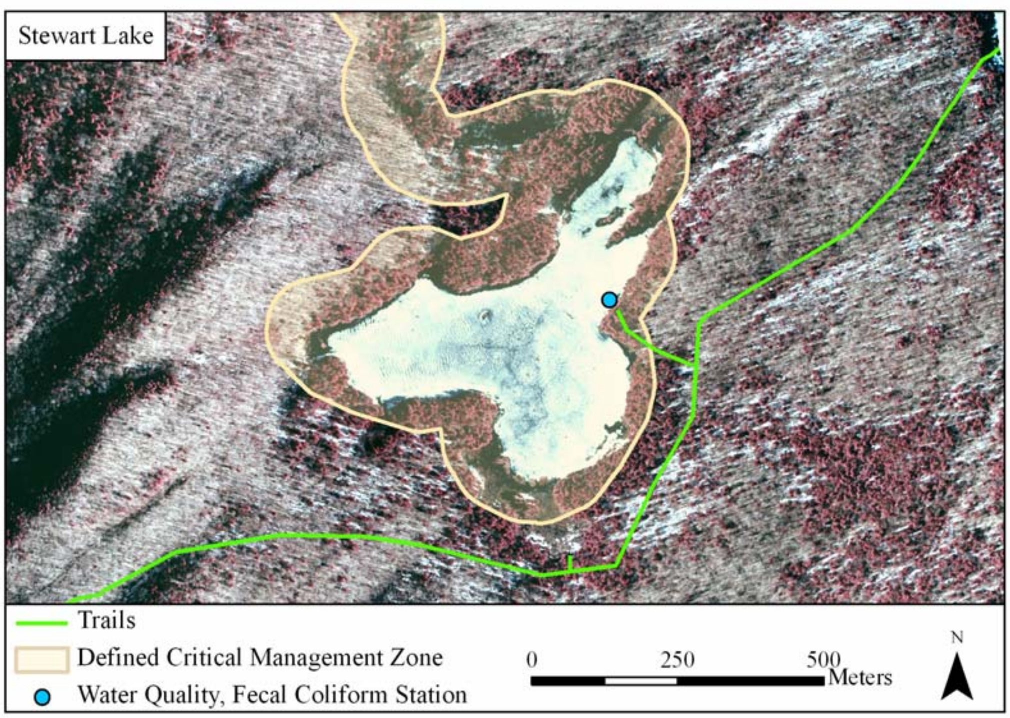


Figure 6. Stewart Lake in Shaker Mountain Wild Forest.

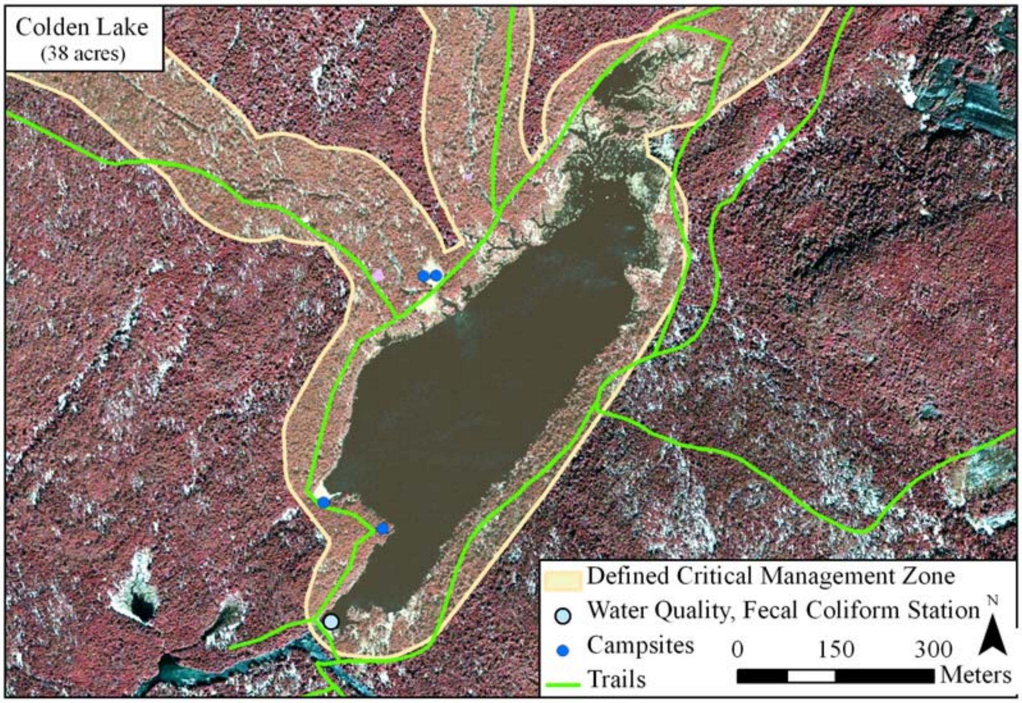


Figure 7. Lake Colden in the High Peaks Wilderness.

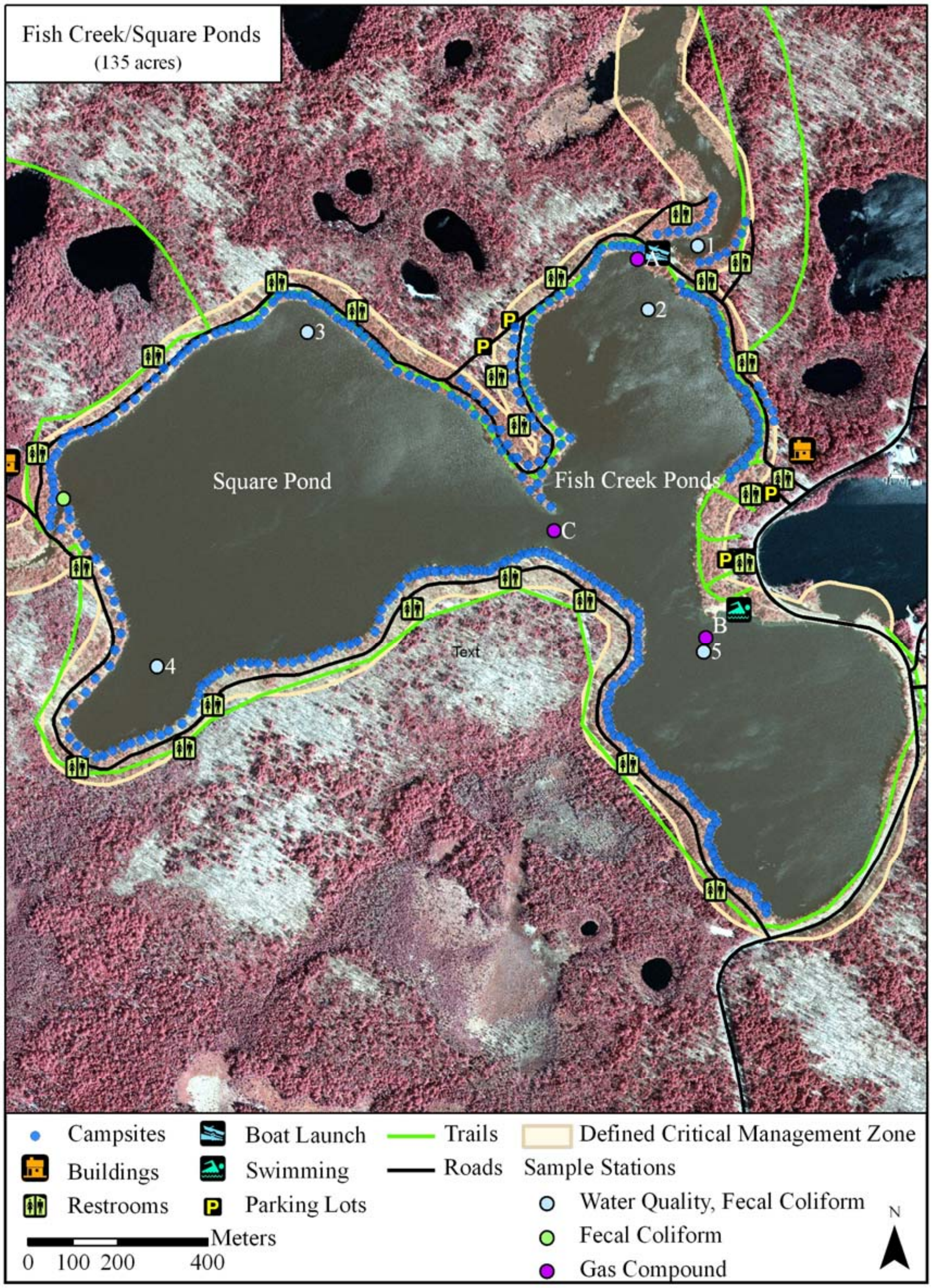


Figure 8. Fish Creek/Square Pond and Campground Area in the Saranac Lake Wild Forest.

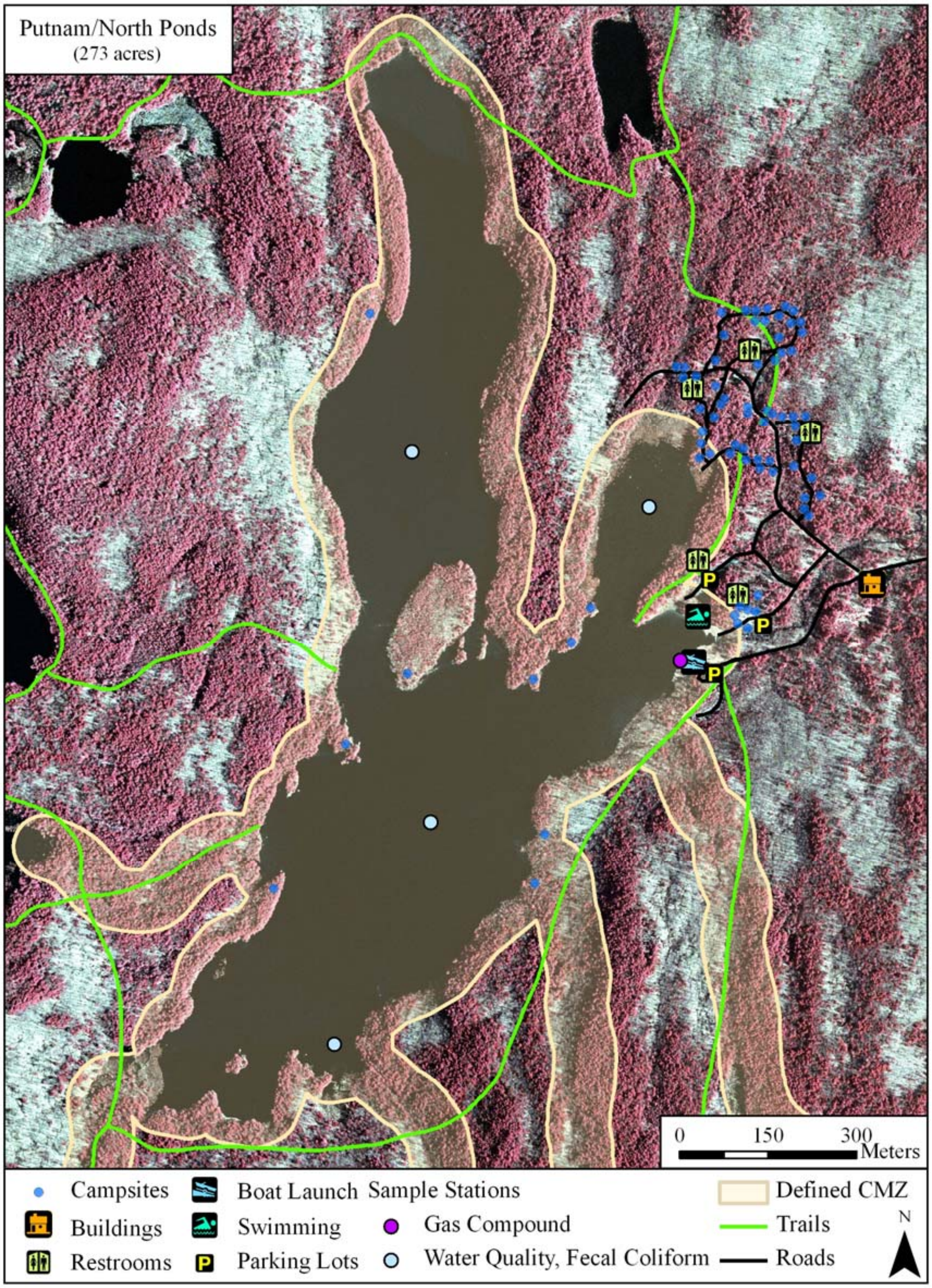


Figure 9. Putnam/North Pond and Campground Area and a portion of the Pharaoh Lake Wilderness.

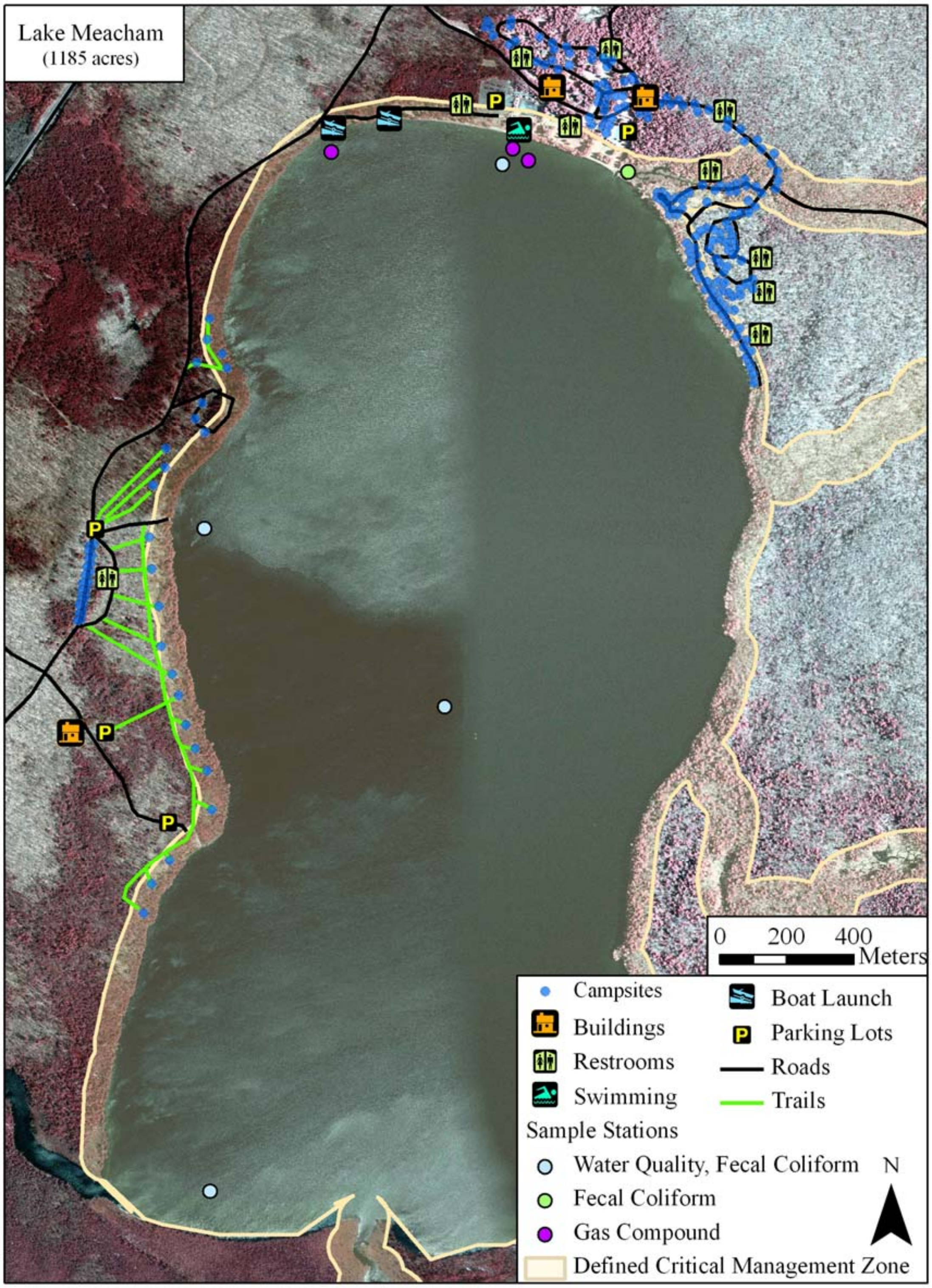


Figure 10. Meacham Lake and Campground Area in the Debar Mountain Wild Forest.

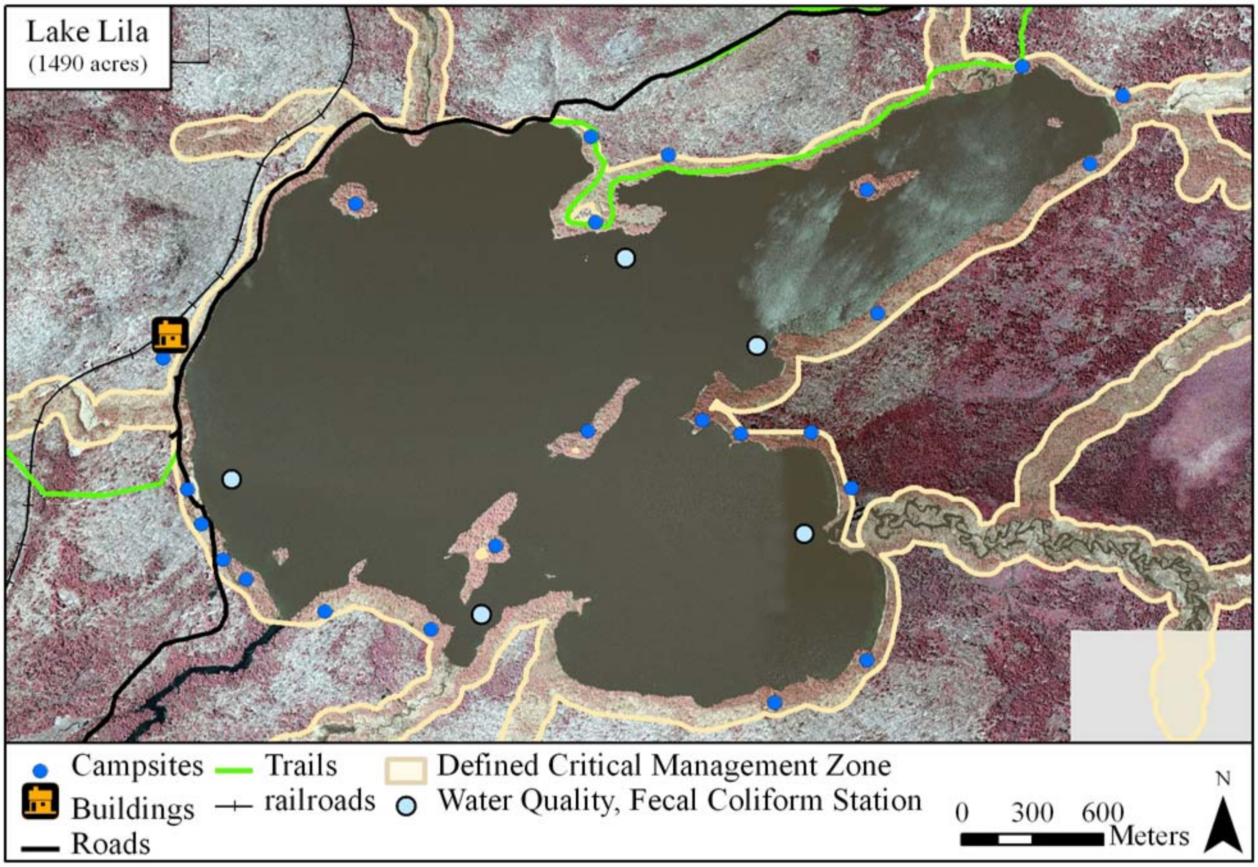


Figure 11. Lake Lila in the William Whitney Wilderness.

**Ecological indicators**

**Chloride** was chosen as a core indicator because it is typically not present in high concentrations in open lake systems (Wetzel 2001), but high concentrations have been found in several Adirondack lakes due to winter maintenance of roads (USEPA 2003, Langen and others 2006). Plants are affected by salt inhibiting water absorption, reduced root growth, uptake of nutrients, and other damage. Measurement of actual chloride concentration in natural waters can be conducted using several standardized methods in the 2005 edition of Standard Methods for the Measurement of Water and Wastewater (Eaton and others 2005). Chloride data for all of the pilot sites except for Lake Lila and Meacham Lake were collected from the 1984-1987 Adirondack Lake Survey Corporation (ALSC) (1987) survey in order to understand chloride differences in lakes that may be affected by winter road management (de-icing salt). Anions such as chloride also increase the conductivity of surface waters and total dissolved solids were measured at all of the pilot sites.

Increasing chloride concentrations in Adirondack water bodies primarily due to winter maintenance of nearby roads is an important human health and ecological concern (Adirondack Council 2009; Langen et al. 2006). According to NYS water quality standards, chloride concentrations in any state waters should not exceed 250 ppm (250 mg/L) (6 NYCRR Part 703.5), although the EPA recommends chloride concentrations should not exceed 25 ppm (Kedell 2009). Of the pilot sites, the highest chloride concentrations were .55 ppm (Fish Creek Pond) and .86 ppm (Chapel Pond). Both water bodies have state highways that receive winter maintenance located within a portion of their immediate riparian area. The state highway near Chapel Pond receives regular road salt in winter maintenance and chloride concentrations in Chapel Pond have increased since the ALSC data was collected (Langen et al. 2006). Generally, pilot sites without roads located nearby had a chloride concentration of .37ppm or lower (Little Jabe, Stewart, Deep, Colden).

While primary data was not collected on this water quality indicator at each pilot site, standardized methods and recommendations are given by Eaton et al. (2005) regarding standardized methods used to measure chloride concentration in surface waters. The method used depends upon the clarity of water being sampled and management objectives, although measurement of chloride by ion chromatography is preferred (Eaton et al. 2005). More rapid assessment methods taken to detect increases in sodium chloride added by de-icing agents may require the direct measurement of electrical conductivity or total dissolved solids (TDS). TDS can increase due to a number of factors including a large watershed to water body surface area ratio (WA:SA) as there is more runoff and in watersheds with higher amounts of development and agricultural use (Wetzel 2001). Therefore, while rapidly assessed measurements such as TDS may not be completely sensitive or representative of chloride concentrations, there is a positive statistical correlation between increases in sodium chloride from application of de-icing salts and increases in conductance and total dissolved solids or salts (Langen et al. 2006). An easily measured indicator such as conductivity or TDS is a cost-effective indicator to help detect increases or high levels in salts but chloride should be measured directly at sites where managers wish to pinpoint the periodic increases in chloride content or have discriminative evidence to back management actions.

In order to increase efficiency, water samples should be collected for chloride concentration analysis when other water sampling takes place at the site, preferably before summer use at water bodies. Springtime sampling is recommended to capture increases in chloride concentration that may occur with spring runoff. However, increased chloride concentrations in groundwater and from soil contamination may take years to reach surface water bodies (Langen et al. 2006). As a result, managers may decide to monitor chloride annually at some sites but analyze results to detect spikes or trends over longer periods of time. Chloride concentrations are generally uniform spatially and seasonally throughout water bodies (Eaton et al. 2005, Wetzel 2001). Therefore, it is recommended a set of samples be taken at each water body inlet and at the water body outlet at a depth of one to five meters. Standard protocols for the collection and handling of water samples should be followed (Eaton et al. 2005).

**Total phosphorous** was chosen as a core indicator because it is considered the primary limiting macronutrient to productivity within many water bodies (Wetzel 2001) and is recommended by the USEPA (2003) as an indicator for aquatic life. Recreational activities that increase external or internal phosphorous loading to water bodies may alter the productivity levels within the water subsequently affecting the rate of eutrophication (Yousef et al. 1980, Dickman and Dorais 1977). Secondary data were obtained from a water chemistry survey conducted by the ALSC (1987).

Internal (e.g., re-suspension of sediments) and external loading (e.g., campfire ash inputs) of phosphorous from recreational uses of surface waters could cause undesirable algal growth, increase eutrophication rates, and have important implications for resource conditions and natural resource managers (Abell, Allan, Lehner 2007; Dickman and Dorais 1977; McEwen 2010; Yousef, McLellon, Zebuth 1980). NYS standards for phosphorous are qualitative and phosphorous inputs should not be such that they result in algal growth, slime, or weeds, or impair the water for its intended use (6 NYCRR Part 703.2). Ecoregion 58 (Adirondack Park) phosphorous guidance values based on aesthetic effects for primary and secondary contact recreation are 20µg/L (.02mg/L) (NYSDEC 2008). Although primary sampling of phosphorous concentration at pilot sites was not conducted in 2009, secondary data was collected from the Adirondack Lake Survey Corporation (1987). Colden, Deep and Stewart Lakes had the lowest phosphorous ratings and were three of the pilot sites with the lowest recreation use and development of facilities.

Phosphorous is the primary limiting nutrient for many Adirondack water bodies making the monitoring of phosphorous concentrations important, especially in water bodies with many types of uses and high use intensity such as Fish Creek Pond and sensitive oligotrophic (low productivity) lakes in remote areas such as Lake Colden. Natural site-specific risk factors such as elevation, the position of the water body within the watershed, depth, and volume may contribute to the amount of phosphorous contributed by external sources and the response of the aquatic ecosystem to increases in phosphorous concentration (Wetzel 2001).

Standardized methods and recommendations are given by Eaton et al. (2005) regarding measurement of phosphorous concentration in surface waters. Eaton et al. (2005) suggest the persulfate oxidation method be used to analyze water samples as it is simple, cost-effective, and total nitrogen as well as total phosphorous can be analyzed from the same sample. Total nitrogen is also an important measure of lake productivity as it often becomes the limiting nutrient in highly productive (eutrophic) water bodies or high elevation water bodies where phosphorous levels are naturally low (Wetzel 2001).

Similar to the sampling design discussed for chloride measurement, a set of water samples should be collected at the main water body inlet and tributaries. Monitoring phosphorous concentration in tributaries is useful to determine if sources of external P are originating from the greater catchment area outside the critical management zone or if internal loading (e.g., re-suspension of sediments from motorized boating) is the main source of elevated P levels. Routine targeted sampling near areas of high use at developed campgrounds would help managers identify elevated P levels in that area perhaps from sources such as leaching from wastewater or soil erosion from access points (Chen 1988).

Phosphorous may not be distributed uniformly throughout water bodies, especially in deeper water bodies, which thermally stratify in the summer (Wetzel 2001). Therefore, water samples collected within the water body should be taken from the upper and bottom water layers using a water collection device (e.g., Van Dorn sampler). It is recommended that standard protocols for the collection and handling of water samples be followed (Eaton et al. 2005).

**Total Dissolved Solids, Dissolved Oxygen, Temperature --** The USEPA (2003) recommends the use of several indicators for aquatic life including dissolved oxygen, temperature, conductivity, pH, and nutrients. Dissolved oxygen, temperature, and total dissolved solids (TDS) were chosen as core water quality indicators in this study because they also may change as a result of pressures created by shore and water based recreation activities and development (Hammitt and Cole 1998). Also, pH and oxidation-reduction potential were measured as supplemental indicators.

These indicators collectively represent several important aquatic conditions that are important in sustaining aquatic life. Dissolved oxygen content in water is important in regulating biotic functions as it is required for aquatic organism metabolism and affects the growth, distribution, and behavior of aquatic organisms (Wetzel 2001). Temperature affects the solubility of gases (including dissolved oxygen) in water and several coldwater species require lower temperatures to survive. Dissolved oxygen content and water temperature naturally fluctuate throughout the season as a result of changes in atmospheric temperature, photosynthesis, elevation, salinity, depth, decomposition of organic material, and respiration of aquatic organisms (Wetzel 2001). Therefore, pressures caused by anthropogenic activity on land and in the water including effects of recreation activities and development can affect dissolved oxygen content and temperature directly or indirectly (e.g., added macro-nutrients increases the amount of decomposing organic matter and lowers dissolved oxygen levels).

TDS levels increase with increases in ionic concentration from salts and sediments. While TDS is a way to express ionic concentration (electrical conductivity), it is not a discriminative measure of suspended solids, which studies have shown to be a result of water-based recreational use, especially in shallow water bodies. Measurements of turbidity or total suspended solids (TSS) should be used to quantify fluctuations in important parameters related to the disturbance of sediments before and after use as well as before use begins/ends.

Levels of TDS and TSS may also be determined or fluctuate in response to natural variation such as windy conditions as sediments are stirred up and on site characteristics such as the geology of the basin and watershed characteristics (Wetzel 2001). TDS concentrations and especially total suspended solids (TSS) are also affected by activities that induce turbidity (e.g., swimming, boating, shoreline erosion) (Hammitt and Cole 1998; Mosisch and Arthington 1998). Generally, the purer the water, the lower the TDS and TSS levels (Wetzel 2001).

These water quality parameters were measured using a multi-parameter waterproof handheld meter (Hanna Instruments 9828, Woonsocket, RI). The meter was calibrated at the site according to manufacturer's instructions. Measurements were taken at four different depths (1-4 meters) at various sampling stations. Generally, measurements were spaced to gather a water quality representation of the entire water body and to determine changes that might occur at different depths. In deeper lakes that potentially thermally stratify (e.g., Meacham Lake), there may have been minimal variation in parameters across depth due to the relatively shallow depth of measurement. A sampling station was chosen on each side of the lake and in the middle of the lake depending on the size. Deep Lake, Stewart Lake, and Lake Colden were located in remote areas that required an extended hike. Therefore, a kayak could not be carried in and a single measurement was taken at the most convenient access point.

NYS water quality standards differ depending on the water quality parameter according to intended use classification. Descriptions of use classifications were found in 6 NYCRR Part 701. Water quality standards according to various use classifications were found in 6 NYCRR Parts 805, 830, and 941. The daily average dissolved oxygen concentration in Fish Creek Pond (classified as AA waters) at a depth of 4 meters were lower than the NYS AA use standards at 3.2ppm. Class AA and C standards require the daily average of dissolved oxygen to not be less than 6 mg/L (6 ppm) and at no time less than 4 mg/L (6 NYCRR Part 703.3).

Dissolved oxygen levels in the uppermost layer of water in Fish Creek Pond met NYS criteria while anoxic (low dissolved oxygen levels) conditions existed at the average FCP depth (3.7m). Under the conditions detected in Fish Creek Pond at the time of measurement, fish would not be sustained at the average depth where the cooler water temperatures are and where they might escape to avoid heavy motorized boating traffic. Furthermore, anoxic conditions cause sediments to release P (Wetzel 2001). This process is known as internal loading and can be the largest source of P input to a water body (Mehner et al. 2008). Anoxic conditions in the hypolimnetic (deepest) layer have important implications for aquatic organisms.

Deeper lakes that thermally stratify in the summer or dimictic lakes may require measurements be drawn from multiple water layers including the epilimnion, metalimnion, and hypolimnion. At the minimum in shallow lakes, measurements should be taken above and below the thermocline. When possible, measurements should also be taken at all tributaries to target external sources of sediment (turbidity, TSS) and ionic contributions (conductivity, TDS).

Tributaries are affected by changes in the watershed and may be a major source of pollutants to water bodies, especially those located in relatively developed watersheds.

Interpretation of actual physical water quality parameter values was limited because the parameters were only measured one day at each pilot study site. Primary measurements taken at pilot sites were meant to explore feasibility and sampling design concerns, but not to determine accurate estimations of each indicator value or predict recreational impacts.

**Non-Native Aquatic Plant Species --** Secondary data collected from Adirondack Park Invasive Plant Program (APIPP) (2004) surveys was used to identify nuisance aquatic plant species at pilot sites. Aquatic surveys conducted by the APIPP aim to identify the following aquatic nuisance aquatic plant species: Eurasian watermilfoil, water chestnut, curlyleaf pondweed, and fanwort. Use of secondary data from an established program that trains personnel to identify aquatic nuisance plant species made this data collection easy and cost-effective.

Surveys conducted by the APIPP (Griffin and others 2001) identified Eurasian water milfoil as a non-native aquatic plant found in Fish Creek Pond, Meacham Lake, and Putnam/North Pond. These three pilot sites are intensive use areas, which allow motorized boating and have state highways leading to them. Wash stations for boat trailers were not present at the pilot site boat launches, although management signage was placed at the Fish Creek Pond and Meacham Lake boat launches to prompt visitors to remove plant materials from boat trailers.

Routine monitoring of waters should be surveyed with protocols used by the Adirondack Park Invasive Plant Program (APIPP) (2004). Since the APIPP uses volunteers to conduct surveys, they are capable of conducting more detailed surveys at more locations. Therefore, use of the APIPP as a secondary data source is recommended as a cost-effective and reliable way to obtain data.

No standards currently exist for this indicator. Unfortunately, many non-native nuisance species are difficult to eradicate after introduction. However, this indicator was included as the presence of non-native aquatic plant species is a major concern for recreational area managers due to the implications nuisance species have for the ecological integrity and structure of water bodies (Johnson, Ricciardi, Carlton 2001) and the socio-economic (e.g., decreased recreational opportunities and costs to taxpayers) impacts these nuisance species create (Pimentel 2000). The spread and productivity of non-native aquatic species can adversely affect aquatic ecosystem condition by reducing the amount of light that can penetrate the water to be used in photosynthesis by other native aquatic plants as well as reduce dissolved oxygen concentrations needed for respiration by aquatic organisms and plants (Wetzel 2001).

**Gasoline Compounds --** Benzene, toluene, ethylbenzene, and xylene compounds, were measured in situ at the three pilot sites that allowed motorized boating (Fish Creek Pond, Meacham Lake, Putnam/North Pond) through deployment of Passive In-Situ Concentration/Extraction Samplers (PISCES) in several sampling locations. PISCES are capable of collecting gasoline compounds introduced into the water column. PISCES can be used fairly discriminatively to detect gasoline compounds introduced from motorized boating, especially in mainly forested watersheds (Adirondack Lake Survey Corporation 1985). There are other ways to measure gasoline compounds in the water column but PISCES were cost effective and easy to use in the field with appropriate preparation of materials and adherence to sampling guidelines. Obtaining indicator values for gasoline compounds required preparing and cleaning equipment in a laboratory, deployment of PISCES at three sampling locations, collection of PISCES, and laboratory analysis at SUNY-ESF.

Methods used to complete these tasks replicated methods detailed by Avallone (2003). Individual PISCES bodies were washed with soap and water, dried, and solvent rinsed with acetone and hexane prior to use. Materials used in PISCES, including membranes, filters, and o-rings, were cleaned through Soxhlet extraction then assembled. Assembled PISCES were wrapped in aluminum foil to avoid contamination until deployment at the site. Glass sampling bottles (250mL) with Teflon lids were washed with soap and water, solvent rinsed, dried, and tightly capped to prevent contamination until PISCES contents were collected in the field.

After preparation of PISCES and collection of needed materials (e.g., hexane), two PISCES were deployed at a 1-1.5m depth at each sampling station in Fish Creek Pond, Putnam Pond, and Meacham Lake. PISCES duplicates were used for quality assurance and as a backup in case of sample loss at a particular sampling station. At each site, one set of PISCES was placed at the main boat launch access point, and the other two sets were attached to existing buoys.

PISCES were left at each site for seven days including two weekend days when use generally intensifies. A kayak was used to deploy and collect PISCES. Upon collection, PISCES contents were emptied into pre-cleaned 250mL glass bottles, and placed on ice until they could be returned to the laboratory for analysis. The content collection bottles were pre-labeled with the date, unique site, and sampling station ID for later identification.

A chemistry laboratory at SUNY-ESF was used to analyze the gasoline compounds following developed and standardized procedures (Avallone 2003). Samples taken in the field were concentrated down to 10mL using a Kuderna-Danish apparatus. Nitrogen was then bubbled through the sample in order to further concentrate it down to approximately 1mL. A gas chromatography-mass spectrometry instrument (GC-MS) was used to analyze the following gasoline compounds: ethylbenzene, isopropylbenzene, propylbenzene, 1,2,4- trimethylbenzene, 1,3,5- trimethylbenzene, and sec-butyl benzene, xylenes (o-, m-, p-), and p-isopropyl toluene (1-methylethyl benzene). Avallone (2003) should be referred to detailed methods used in analyzing gasoline compound concentrations.

PISCES were left at each site for seven days including two weekend days when motorized use is generally higher. The reported concentrations represent the average compound concentration in the water as sampled by two PISCES at each sampling station (the average of concentrations analyzed from two samplers) over the seven days the sampler was in the water. Peak compound concentrations were obtained as NYS water quality standards should never be exceeded for these toxic compounds. The PISCES sampled approximately 40mL of water per day at Fish Creek Pond, Putnam Pond, and Meacham Lake. Fish Creek Pond had the highest concentrations of gasoline compounds out of the three pilot sites with motorized boating use. Fish Creek Pond was observed to have a much higher level of motorized use than the other pilot sites, although the exact difference in use intensity was not evaluated. The highest concentrations of o+m+p- xylene, carcinogenic compounds known to have adverse impacts on human health and cause toxicity in organisms (Adirondack Lake Survey Corporation 1987), were detected at no-wake zone between Fish Creek Pond and Square Ponds. NYS standards exist for all of the gasoline compounds (6 NYCRR Part 703). Concentration of o+m+p- xylene was the highest compound detected but far below the state standard of 5 μg/L (5,000 ng/L).

**Fecal Coliforms --** A kayak was used to collect water samples in all locations except at sites where boating access was remote and not feasible (i.e., Deep Lake, Stewart Lake, Lake Colden). At these remote sites, samples were collected at the most accessible point. For all other sites where a boat was able to be carried in, sampling stations were selected to obtain an accurate representation of the entire water body. Sampling stations were at least 2 meters from the shoreline in all locations except remote locations. The total amount of samples at each site varied with the size of the water body. Three samples were taken at each sampling station but the amount of sampling stations varied between lakes. Generally, the most samples were selected at larger water bodies or water bodies with more intensive use.

Water grab samples were collected in 100mL Whirl-pak bags at each sampling station by inverting and plunging the bag approximately 30 cm below the surface. The sample was collected according to standard protocol to avoid inclusion of surface water, which contains more bacteria (Eaton et al. 2005). Samples were transported on ice and processed within 6 to 24 hours.

Coliform Count Plates of 3M Petri-film (3M Corporation, St. Paul, MN) were used to identify and enumerate coliforms. 3M Petri-film Coliform Count Plates have been tested in a study to determine their reliability in detecting fecal coliforms in water (Schraft and Watterworth 2005). A Hach Portable Incubator (Hach Laboratories, Loveland, CO) was used to incubate Petri-film plates at $44 \pm 1^{o}C$ (temperature recommended for enumeration of therotolerant (fecal) coliforms) for $24 \pm 2$ hours. Coliform counts were enumerated within 1-2 hours of incubation according to manufacturer's instructions.

Quantitative NYS standards exist for total and fecal coliforms (6 NYCRR Part 703.4). Fecal coliforms should not exceed an average of 200 CFU/100mL according to standards for class C waters at any sampling occasion (6 NYCRR Part 703.4). Class AA waters do not have a fecal coliform standard but a total coliform standard: monthly median value (50 CFU/100 mL) and 20% of monthly samples must not exceed 240 CFU/100mL.

Although bacteria indicators are widely used in monitoring by managers, their use as an indicator related to recreation use and development is clouded with uncertainty regarding the source of the bacteria (e.g., wildlife or humans), the amount of time bacteria remains in the water column before it is diluted, the ability of bacteria indicators to be indicative of harmful pathogens, and the number of samples that should be taken (Bennear, Jessoe, Olmstead 2009; Griffin et al. 2001; Schwab 2007). While this indicator can be rapidly assessed, the source of bacterial contamination cannot be rapidly analyzed and may take extensive experiments to determine.

At several remote pilot sites (i.e., Stewart Lake and Little Jabe Pond), a large quantity of wildlife feces was observed along the shoreline. Both of these lakes had minimal signs of visitor use at one or two points along the shoreline and no recreationists were observed at either water body when they were visited on a sunny summer day. As part of a suite of indicators designed to represent recreation use and development related adverse impacts to water bodies, a high fecal coliform count in both of these lakes was likely partially caused both by wildlife and by recreational use add lack of any restroom facilities (that is, wildlife and humans are both sources of contamination). Therefore, it is recommended that bacteria indicators be used as an indicator of the suitability of the waters to sustain recreational uses for human health concerns in accordance with USEPA (2003) recommendations.

In areas with heavy use, Hammitt and Cole (1998) suggest use levels may decrease the amount of wildlife using the area. Therefore, in areas with heavy use, increased levels of bacteria indicators may be associated with an increase in visitor usage. Macronutrients such as phosphorous are also associated with the introduction of waste and fecal effluent. Therefore, increases in bacteria indicators (e.g., fecal coliforms, E.coli) and macronutrients at water bodies that receive higher levels of seasonal use may be a good indication of visitor related fecal contamination. Cost-effective rapid assessment methods (e.g., Coliscan Easygel method, Micrology Labs, LLC) for assessing fecal coliforms or E.coli may cause these bacterial indicators to be the most cost-effective indicators until advanced indicators for pathogen contamination is developed in the future (Griffin et al. 2001; Schwab 2007).

Of the water quality indicators, measurement of fecal coliforms proved to be the most difficult. The lack of strict adherence to handling considerations such as the way water samples should be collected and the time in which samples should be transported and analyzed may create data quality and issues when comparing samples collected at different times, especially in remote water bodies where such considerations may not be as controllable. Eaton et al. (2005) recommends analyzing water samples within six hours of the time they are collected. Therefore, fecal coliform counts should be interpreted cautiously, especially if the time between water sample collection and enumeration of fecal coliforms varies. It is also useful to collect water samples for fecal coliform analysis using a water sampling device (e.g., Van Dorn sampling bottle) to avoid contamination of the sample. Standardized protocols should be referred to for other handling considerations (Eaton et al. 2005).

All water-based indicators need to be collected using the same standardized procedure so that results can be compared between lakes. There are many standardized USEPA approved procedures utilized in state water monitoring programs (Eaton et al. 2005). Selection of standardized protocols may depend on the level of accuracy monitoring objectives requires, cost effectiveness, and other constraints (e.g., remote lakes may require some water-based indicators to be measured in the field).

E. coli is becoming an increasingly popular bacterial indicator used to detect fecal contamination in surface waters (Eaton et al. 2005). While E. coli levels receives regulatory monitoring in some states, NYS only uses fecal and total coliforms as bacteria indicators for the suitability of state waters for drinking or recreational bathing (Eaton et al. 2005; Griffin et al. 2001).

**Social Indicators**

The nine types of social indicators are based on past use in numerous studies of visitors to Adirondack Forest Preserve lands over the last two decades and on extensive literature on monitoring social conditions and visitor experiences, as reviewed previously in this report and summarized in Table 5. All data on these measures were collected in the various Adirondack studies through interviews or surveys (on site or mail surveys) with visitors.

**All exhibits in this section are examples of the types of questions that can be asked to measure social indicators.** The recreation activities and resource and management situations present at each waterbody may require modification of the social questions asked of visitors.

**Attributes of resource setting** --Satisfying and dissatisfying experiences such as campsite separation in sight and sound, screening from sight of others, evidence or absence of other visitor impacts on the setting, and naturalness of resource conditions. An example of that approach is shown below and it was used in the St. Regis Canoe Area Visitor and Campsite Study (Dawson, Schuster, Propst and Black 2008):

Example: A series of situations that may have detracted from your experience today in your campsite area are listed below. *If you did not encounter a situation then circle zero. Otherwise, rank the seriousness of the situation by circling the appropriate number.*

| Detracting Situations | Not A Problem | Slight Problem | → | | | Serious Problem |
|---|---|---|---|---|---|---|
| **Resource** | | | | | | |
| Human impacts to campsite (litter, tree damage, etc.) | 0 | 1 | 2 | 3 | 4 | 5 |
| Campsite attractiveness (site does not look nice) | 0 | 1 | 2 | 3 | 4 | 5 |

**Attributes of behavior of other visitors** -- Satisfying and dissatisfying experiences such as perceptions of solitude, proximity of other campers, depreciative behavior, litter evident, and non-normative behavior of others. An example of that approach is shown below and it was used in the St. Regis Canoe Area Visitor and Campsite Study (Dawson, Schuster, Propst and Black 2008):

Example: A series of situations that may have detracted from your experience today in your campsite area are listed below. *If you did not encounter a situation then circle zero. Otherwise, rank the seriousness of the situation by circling the appropriate number.*

| Detracting Situations | Not A Problem | Slight Problem | → | | | Serious Problem |
|---|---|---|---|---|---|---|
| Too many people camping in this area | 0 | 1 | 2 | 3 | 4 | 5 |
| Difficulty finding place to camp | 0 | 1 | 2 | 3 | 4 | 5 |
| Designated sites too close together | 0 | 1 | 2 | 3 | 4 | 5 |
| Behavior of other visitors near campsite | 0 | 1 | 2 | 3 | 4 | 5 |

**Overall trip satisfaction** -- The general impression that a visitor has regarding a specific trip based on the collective experiences that were either satisfying or dissatisfying and level of coping they may have had to use to reach an overall satisfying trip experience. An example of that approach is shown below and it was used in the Bog River Management Unit Study (Dawson, Peters, Connelly and Brown 2005):

Example: Overall how satisfied or dissatisfied were you with your trip to the Bog River Management Unit?

- ❑ Very dissatisfied
- ❑ Dissatisfied
- ❑ Neutral
- ❑ Satisfied
- ❑ Very satisfied

**Visitor motivations for recreation trip** -- The degree of actualization by visitor of their reasons for taking a trip based on past satisfactions or hoped for satisfactions they may experience and can be measured by the disparity or congruity of motivations and satisfactions that impacted the overall trip satisfaction. General motivations are used here as it is not possible to list all types of activities and whether it was a primary or secondary rwason for being at or near a particular body of water. An example of that approach is shown below and it was used in the Adirondack Park Forest Preserve Roadside Camping Study (Graefe, Dawson and Gerstenberger 2010):

Example: For each motivation, please first indicate its importance in selecting your camping setting, then indicate how satisfied you were with each motivation during your roadside camping trip.

| How important was this motivation in selecting your camping setting? | | | | | | To what extent were your motivations satisfied during your camping trip? | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Very Unimportant | Unimportant | Neutral | Important | Very Important | Motivation | Very Dissatisfied | Dissatisfied | Neutral | Satisfied | Very Satisfied |
| ❑ | ❑ | ❑ | ❑ | ❑ | To experience natural environment and scenic beauty. | ❑ | ❑ | ❑ | ❑ | ❑ |
| ❑ | ❑ | ❑ | ❑ | ❑ | To feel a connection with nature and a natural environment. | ❑ | ❑ | ❑ | ❑ | ❑ |
| ❑ | ❑ | ❑ | ❑ | ❑ | To experience a remote area away from sight and sound of cities and people. | ❑ | ❑ | ❑ | ❑ | ❑ |
| ❑ | ❑ | ❑ | ❑ | ❑ | To feel a connection with wilderness and wild forests as important places. | ❑ | ❑ | ❑ | ❑ | ❑ |
| ❑ | ❑ | ❑ | ❑ | ❑ | To experience an environment free of litter, human waste, and impacts. | ❑ | ❑ | ❑ | ❑ | ❑ |
| ❑ | ❑ | ❑ | ❑ | ❑ | To experience solitude and being isolated from other groups and having a personal experience within my group. | ❑ | ❑ | ❑ | ❑ | ❑ |
| ❑ | ❑ | ❑ | ❑ | ❑ | To practice travel skills through a remote wild environment. | ❑ | ❑ | ❑ | ❑ | ❑ |
| ❑ | ❑ | ❑ | ❑ | ❑ | To enjoy physical activity, challenge, and exercise. | ❑ | ❑ | ❑ | ❑ | ❑ |

**Place Attachment** -- The type and strength of attachment which is perceived by visitor's as desirable and acceptable conditions for their recreation experience. An example of that approach is shown below and it was used in the Adirondack Park Forest Preserve Roadside Camping Study (Graefe, Dawson and Gerstenberger 2010):

Example: Overall, how would you characterize your feelings of attachment to **the roadside camping area that you visited during the time of your interview**? *(please check one box only))*

- ❑ No attachment
- ❑ Very weak attachment
- ❑ Weak attachment
- ❑ Mild attachment
- ❑ Strong attachment
- ❑ Very strong attachment

**Place Dependence** -- The type and strength of dependence on place that is required by visitors to have a satisfying recreation experience. An example of that approach is shown below and it was used in the Adirondack Park Forest Preserve Roadside Camping Study (Graefe, Dawson and Gerstenberger 2010):

Example: Please indicate how often you would go camping in other settings if **the roadside camping area that you visited during the time of your interview** was no longer available. *(Please check one box only)*

- ❑ I would camp much less often
- ❑ I would camp slightly less often
- ❑ I would camp about the same amount
- ❑ I would camp slightly more often
- ❑ I would camp much more often

**Perceived Crowding** – Crowding is measured by self reported visitor perceptions of the number and density of other visitors; physical, sight and sound proximity of other visitors; and perception of crowding based on past experience or motivations. An example of that approach is shown below and it was used in several Adirondack Park wilderness visitor studies (Dawson, Newman and Fuller 2000):

Example: Overall, did you feel physically crowded by other visitors during your trip to the [name] wilderness?

- ❑ Not crowded
- ❑ Slightly crowded
- ❑ Moderately crowded
- ❑ Very crowded
- ❑ Extremely crowded

**Visitor Coping with Dissatisfying Experiences** -- Stress and coping with dissatisfying conditions from non-normative behavior or depreciative behavior of other visitors, conditions of facilities and management, and conditions of resource setting. An example of that approach is shown below and is based on studies of visitors to Adirondack wilderness areas and the St. Regis Canoe Area (Johnson and Dawson 2004; Dawson, Schuster, Propst and Black 2008; Propst, Schuster and Dawson 2009):

Example: If you encountered dissatisfying experiences on your trip in the [name] management unit, what were you likely to do or did you do?

| **Actions taken or to be taken:** | **No dissatisfying experiences** | **Very Unlikely** | **Unlikely** | **Neutral** | **Likely** | **Very Likely** |
|---|---|---|---|---|---|---|
| Ignored the problem or tried not to think about it | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Confronted the people responsible to attempt to change their behavior | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Accepted the dissatisfying experience as part of that management area experience | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Avoided the dissatisfying experience during the trip as much as possible | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Changed travel plans (location or length of stay) during the trip in that management area to get away from the dissatisfying experience | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Visitor Conflict** -- Perceived or real conflicts such as (1) intra-activity conflicts, (2) inter-activity conflicts, (3) conflict between recreation visitors and other types of users, (4), conflict between recreation visitors and management, and (5) conflicts in values between different types of users. An example of that approach is shown below and it was based on a study of recreation conflict along the Great Lakes coastline of New York State (Wang and Dawson 2004):

Example: If you encountered interference in enjoying or carrying out your recreation activities in the [name] management unit, who or what caused that conflict in achieving your motivations for having a satisfying trip experience?

| **Conflict caused by:** | **No problem encountered** | **Slight interference** | **Moderate interference** | **Extreme interference** |
|---|---|---|---|---|
| Recreational users engaged in the same activities as mine **on shore** | ☐ | ☐ | ☐ | ☐ |
| Recreational users engaged in the same activities as mine **on the water** | ☐ | ☐ | ☐ | ☐ |
| Recreational users engaged in different activities from mine **on shore** | ☐ | ☐ | ☐ | ☐ |
| Recreational users engaged in different activities from mine **on the water** | ☐ | ☐ | ☐ | ☐ |

Data Collection

Visitor surveys were done either on site to measure immediate reactions of visitors to existing conditions and experiences, or conducted by mail survey of users known to use the management unit (i.e., on site contacts, trailhead registers) when the information collected was not specific to a trip, but was specific to a management unit (Newman and Dawson 1999; Dawson, Newman and Fuller 2000; Johnson and Dawson 2002; Pfaffenback, Zinn and Dawson 2003; Dawson, Connelly, and Brown 2005; Dawson, Schuster, Propst and Black 2008; Dawson and Schuster 2008; Dawson, Peters, Connelly and Brown 2005; Graefe, Dawson, and Gerstenberger 2010).

## Recreation Use Estimation

The estimation of recreational use by activity, location, and date is necessary to provide an understanding of the relationship between the recreational use and impacts. Thus, a manager can understand what level and types of recreational use are contributing which impacts and, thereby, have some rationale for developing a management response if LAC standards are exceeded for an area.

Many recreation use estimation approaches have been developed and require varying amounts of effort, time, and expenses to conduct; however, this study only considered those techniques for estimating use that characterized use consistently over time and locations with repeated application of that technique and met the other criteria for good indicators (e.g., low cost) (Major et al. 1992; Hollenhorst et al. 1992; Yuan et al. 1995; Watson et al. 2000; Lynch et al. 2002; Haas 2002; Haas et al. 2004; Dawson et al. 2006a; Fay et al. 2010).

Recreational use estimation needs to be in standardized units by activity and waterbody so that the relationships between use and level of impact can be understood and support management decision-making. Estimation is recommended by three general types of use (i.e., boating, hiking, and camping) and not specific activities (e.g., swimming, fishing, mountain biking) because of the extended on-site observation necessary to classify visitors and the fact that they can change quickly from one activity to another (e.g., anglers in motorboats can stop fishing and start their motor and become a motor boater). The general types of activities and units of measurement suggested for recreational use estimation are:

- Boating is most often estimated using visual counts of **boats-at-one-time (BAOT)** using: observation or photography from a boat traveling on the water, aircraft during an over flight, or observers along the shoreline – these are sometimes called "instantaneous counts" because of the need to count boats quickly as they may move or be moving when counted. The alternate approach is counts of vehicles in public boat launch parking lots; however, this method is not a good indicator when access to a water body can be achieved from commercial marina facilities and waterfront residences, or when access can be via a connected body of water. Visual counts of motorized and non-motorized boats should be made several times each day to account for various uses at different times of the day (usually between mid-morning and late afternoon). The BAOT average and range per day then is used as the indicator and is broken down into estimates of motorized and nonmotorized watercraft by weekend day and week day. NOTE: this indicator approach is meant to characterize boating use and be used over time for comparative purposes; it is not intended to estimate population parameters such as an angling catch and effort creel census or roving interviewer surveys which are more intensive and comprehensive.

- Hiking, including backpacking and mountain biking, on trails is most often estimated using self-reported counts of **persons-at-one-time (PAOT)** or Visitor Days using trailhead registers that are checked for compliance by electronic trail counters or by staff observation or electronic photography along a trail. The unit of measure is individual visitors per day and not groups per day.
- Camping at designated campsites on public lands or in state campgrounds is most often estimated by camper self registration or campground entry registrations. Estimation is in **Visitor-Nights** and the unit of measure is individual visitors per night and not groups per night. Some roadside camping areas and sites in the backcountry or wilderness are dispersed and must be counted by observation; counting camper occupancy at these during boater counts is a cost effective approach.

**Recreation Use and Development Indicators**

Based on possible direct physical, chemical, or biological impacts, categories of recreational use and development were scored (Table 10). Each type of possible impact was given an equivalent point value (e.g., physical = 1, chemical = 1, biological = 1) and then each activity or type of development was given an impact score based on the number of possible impacts. For example, if an activity creates physical impacts and biological impacts, it would receive an aggregated score of two. The highest impact score is three, which means an activity or type of development is capable of having physical, chemical, and biological impacts. The score for each type of impact at a pilot site was summed to produce an overall impact score for each pilot site. For example, overall impact scores were highest for developed campgrounds around Meacham Lake, Fish Creek Pond, and Putnam Pond that had on-site wastewater treatment systems, roads leading to them, concentrated or widespread visible shoreline disturbance (e.g., soil erosion and vegetation impacts), and had facilities to accommodate a greater number of visitors than the other sites. In contrast, primitive campsites around pilot sites with camping (Lake Lila, Lake Colden) were only accessible by trails and had setback requirements for pit privies as mandated in the APSLMP (APA and NYSDEC 2001) so they had lower overall impact scores.

Table 10. Recreational use and development impact scores.

| Activities | Direct Impacts (B=Biological, P=Physical, C=Chemical) | Impact Score |
|---|---|---|
| Fishing | B | 1 |
| Hiking | P | 1 |
| Primitive Camping/Campsites | P | 1 |
| Recreational Bathing/Swimming | P | 1 |
| Non-motorized Boating | B,P | 2 |
| Motorized Boating | B,P,C | 3 |
| **Development** | | |
| Designated campgrounds | B,P,C | 3 |
| Buildings (e.g., bathrooms, cabins, picnic shelters) | P | 1 |
| Impervious surfaces (e.g., roads, paved parking lots) | B,P,C | 3 |

To illustrate the use of this indicator approach, impact scores were determined at each pilot site based on the impact they were capable of producing: physical, chemical, and biological impacts. Overall impact scores were calculated by aggregating the sum of individual impact scores at each pilot site (Table 11).

Table 11. Pilot study area recreation use and development impact scores.

| Pilot Study Water Body | Type of Recreation Impacts | | | | | | | | | Study Area Impact Score | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fishing | Hiking | Rec Bathing | Motor Boating | Non-motorized Boating | Developed Campground | Primitive Camping | Buildings | Impervious Surfaces | | |
| **Stewart** | | | | | | | | | | **0** | **Low** |
| **Deep** | 1 | | | | | | | | | **1** | |
| **Little Jabe** | 1 | 1 | | | | | | | | **2** | |
| **Colden** | | 1 | | | | | 1 | | | **2** | |
| **Lila** | 1 | 1 | | | 2 | | 1 | | | **5** | **Med** |
| **Chapel** | 1 | 1 | 1 | | 2 | | | | 3 | **8** | |
| **Fish Creek Ponds** | 1 | 1 | 1 | 3 | | 3 | | 1 | 3 | **13** | **High** |
| **Meacham** | 1 | 1 | 1 | 3 | | 3 | 1 | 1 | 3 | **14** | |
| **Putnam** | 1 | 1 | 1 | 3 | | 3 | 1 | 1 | 3 | **14** | |

Shoreline disturbance has been used as an indicator of increasing ecological stress in Northeastern water bodies (Whittier et al. 2002). As shore-based recreational use and development can have a tremendous impact on the vegetation, soils, and water body near-shore areas, an indicator of shoreline disturbance was developed to represent the following multiple recreation related impacts: removal of riparian vegetation, soil compaction, and habitat fragmentation. An indicator for recreation related shoreline disturbance was developed based on types of recreational development surrounding Forest Preserve water bodies known to cause vegetation removal, soil impacts (e.g., erosion), and hydrological impacts (e.g., less infiltration and more overland runoff). Five factors were assessed to gain information on the proportion of shoreline disturbance at each study site including the area taken up by: (1) campsites, (2) trails, (3) roads, (4) parking lots, and (5) buildings (Green 1998; Whittier 2002).

This indicator is based on research conducted by recreation ecologists on impacts to soil and vegetation caused by shore-based recreational activities such as camping, hiking, and development of facilities for recreational use (Cole 1982; Cole and Spildie 1998; Cole 1987; Leung and Marion 2000; Liddle 1997; Manning 1979; Marion and Cole 1996). Impacts associated with vegetation removal by recreational use and alteration of natural surfaces by recreational development can affect the ability of the shoreline area to provide shade, habitat, and nutrients as well as retain runoff, sediment, and excessive nutrients (Manning 1979; Johnson and Carother 1982). While detailed vegetation loss and soil impact assessments (e.g., Cole 1989) could be used to estimate the impacts in each pilot site and may fulfill other management objectives, they would be time consuming, more expensive, and would not meet the objectives of this study to explore feasible and cost-effecient methods given funding, personnel, and time constraints.

Secondary and primary data were entered into a GIS or used in calculations for analysis of the five types of disturbance indicators within the CMZ (McEwen 2010). Each of the five indicators was estimated using GIS information and ground estimates of the total area impacted. The CMZ area for each pilot site was determined by obtaining the area within the 50 meter buffer of each pilot site. Since polygon data needed correction, this CMZ area was verified by taking the shoreline length (meters) and multiplying it by the 50 meter (160 ft) buffer from the shoreline.

The recreational development in the critical management zone (CMZ) represented the extent of recreational development or the proportion of area within 50 meters of the shoreline that was used for recreational purposes. While recreational disturbance may have also impacted the area beyond the CMZ, the most recreational bio-physical impacts were noted in the area nearest the water's edge including vegetation removal, soil compaction, soil erosion, and impervious surfaces. This area of utmost hydrological and biological importance (Naiman and Decamps 1997) likely receives the most impact as visitors wish to have views of the water while camping or hiking, and roads provide access to the water and campsites.

The proportion of recreational development in the critical shoreline management zone for the nine study area water bodies is shown in table 12. For example, Fish Creek/Square Pond had a high proportion (97%) of shoreline disturbance, the majority of which was impervious road surfaces and campsites such that an intensive use area (Fish Creek Campground) completely surrounds the water body. Two other pilot sites (Meacham Lake, Putnam/North Pond) have intensive use areas located on their shoreline as well. However, these lakes are much larger and the intensive use areas are generally located in a concentrated area along the shoreline. Generally, the campgrounds at Meacham Lake and Putnam/North Pond extend along the shoreline for a relatively short distance and extend away from the shore into the upland area. Therefore, the proportion of disturbed shoreline within the CMZ is much lower at these sites.

Table 12. The proportion of physical area impacted by recreation development in the critical coastal management zone.

| Pilot Site Water Bodies | Critical Management Zone ($m^2$) | Proportion of Critical Management Zone Disturbance ($m^2$) |
|---|---|---|
| Little Jabe | 34,991 | 12 |
| Chapel | 844,978 | 15 |
| Deep | 89,977 | 0.2 |
| Stewart | 109,972 | 0.2 |
| Colden | 109,972 | 10 |
| Fish Creek Ponds | 194,950 | 97 |
| Putnam | 299,923 | 6 |
| Meacham | 449,885 | 11 |
| Lila | 914,766 | 6 |

It is widely accepted that the riparian area (critical management zone) plays an important role in improving water quality (Naiman and Decamps 1997). Higher levels of shoreline disturbance have been associated with decreased water quality (Whittier 2002). Although degradation and assessment of water quality in relation to recreational use of land has received relatively little attention (Hammitt & Cole 1998), attention has been given the amount of watershed land-use and have related higher levels of watershed disturbance to decreased water quality (Murtaugh & Pooler 2006). Shoreline buffer areas beyond 50 meters should be considered when high levels of recreation related facilities and use are evident beyond that critical zone.

## RECOMMENDATIONS AND DISCUSSION

Selected indicators that met feasibility and other criteria and were related to Adirondack water bodies were selected and evaluated at nine pilot study water body sites. Following an extensive review of the literature, review of other Adirondack research, and testing in the pilot study, we recommend measurement of eight types of ecological indicators (table 13), nine types of social impact indicators (table 14), the three types of recreation use estimation indicators (table 15), and five types of recreation use and development indicators (table 16).

Table 13. Recommended ecological impact indicators for use in Adirondack water bodies.

- Non-native aquatic plant species
- Gasoline compounds
- Fecal coliforms and E.coli
- Chloride
- Total phosphorous
- Total dissolved solids
- Total suspended solids or turbidity
- Dissolved oxygen
- Water temperature

Table 14. Recommended social impact indicators for use in Adirondack water bodies.

- Attributes of resource setting
- Attributes of behavior of other visitors
- Overall trip satisfaction
- Visitor motivations for recreation trip
- Place attachment
- Place dependence
- Perceived crowding
- Visitor coping with dissatisfying experiences
- Visitor conflict

Table 15. Recommended recreation use estimation indicators for use in Adirondack water bodies.

- Boating (Boats-at-one-time)
- Hiking (People-at-one-time)
- Camping (Visitor-nights)

Table 16. Recommended recreation development and use indicators for use in Adirondack water bodies.

- Recreation development and use impact score
- No of Campsites
- Roads (meters)
- Trails (meters)
- Proportion of shoreline disturbance

These three sets of indicators are recommended as part of a monitoring process to help the NYSDEC fulfill APSLMP mandates taking into consideration the limitations imposed in determining the Limits of Acceptable Change (i.e., carrying capacity) of a resource area and the primary and secondary constraints that often face natural resource management agencies when implementing regional-scale aquatic surveys and monitoring programs (Hughes and Peck 2008).

**Sampling Considerations for Ecological Measurements**

Water quality indicators can fluctuate throughout the season and may differ drastically between lakes as a result of current trophic status, position in the watershed, volume, depth, and a multitude of other factors (Wetzel 2001). Therefore, it is recommended that the sampling design take these important fluctuations into consideration and analyze physical water quality parameters (e.g., dissolved oxygen, temperature) to assess the state of the water body and identify degradation of these parameters as a possible indirect effect of shore and water based uses. Generally, these parameters will fluctuate in response to fluctuations in other condition indicators (e.g., increases in phosphorous increase productivity which eventually will decrease dissolved oxygen). Physical water quality parameters are best used as a way to characterize the state of the ecosystem considering impacts that have already occurred and may occur in the future.

The physical water quality parameters (i.e., dissolved oxygen, conductivity, temperature, TDS, TSS) can be measured continuously throughout the season with a data logger with regular scheduled maintenance and downloading of data. At least once before recreation use begins (April), during use (July) and after most recreation use ends (October), a vertical profile of physical water quality parameters should be collected from several depths so changes in gradients can be observed. The additional number of vertical profiles collected throughout the season will depend upon management and research objectives. It is suggested that physical water quality parameters that are affected by other chemical water quality parameters be taken at the same time (e.g., an increase in gasoline compounds may correlate with an increase in motorized boating activity and an increase in total suspended solids at shallow water bodies). In deep stratified water bodies, measurements should be taken from the epilimnion, metalimnion, and hypolimnion. In shallow unstratified water bodies, measurements should be distributed throughout the vertical water column.

The chemical water quality parameters that require collection of water samples and laboratory analysis (i.e., gasoline compounds, phosphorous, chloride, bacteria indicators) should be measured multiple days per month (April – October) or at a rate that has been pre-determined to represent a reliable estimate of fluctuations throughout the season. Frequent sampling at the site being assessed, accurate estimates of types and amounts of use, and inventory of managerial factors (e.g., type of wastewater treatment) is needed in order to establish trends in water quality fluctuations in relation to increases or decreases in use and in relation to fluctuations in natural variability (e.g., seasonal changes).

Spatial determination of sampling locations is dependent on the purposes of monitoring or the question being asked. In the pilot study, a defined critical management zone of 50 meters (160 ft) from the shoreline was not always large enough to capture shoreline recreation use and development that may cause adverse impacts on water bodies, especially in intensive use areas. The critical management zone can be determined by visiting the site to assess the proximity of recreational use and development to the water body (i.e., a CMZ wider than 50 meters may be necessary). If a GIS has been created for the site, it can be used to assess, analyze, and compare the types and extent of development at the site. Determination of amounts and types of use throughout the season is dependent upon surveys, registration areas, and inclusion of use-related questions on check-in forms and data collection materials.

**Sampling Considerations for Social Measurements**

Visitor surveys can be conducted on site to measure visitors experiences: (1) as they leave the management unit at the conclusion of their trip for trip specific and management specific information; (2) conducted by mail survey of users contacted on site to acquire their names and addresses for trip specific and management specific information; and (3) conducted by mail survey of users known to use the management unit (i.e., names and addresses from trailhead registers) when the information to be collected is not specific to a trip, but is specific to a management unit. All visitor interview and survey data collection should follow appropriate social science protocols (e.g., Salant and Dillman 1994; Dillman, Smyth and Christian 2009).

Estimates of visitor use (e.g., number of anglers, boats, campers, hikers) should be taken seasonally as well as on weekends and weekdays to capture the variability in use and better estimate annual recreational use. Recreational use estimates need to be related to the geographic area in which they occur to provide some understanding of the relationship between use and impacts.

**Recommended Next Phases of Monitoring Recreational Impacts**

This report is the completion of the Phase One process of selecting the indicators that need to be used to monitor recreational impacts to water bodies and the riparian CMZ. Three other phases are recommended to fully develop a systematic approach to impact monitoring.

**Phase Two – Monitoring:**

Monitoring of Adirondack water bodies involves planning and data collection that could be conducted in four steps.

1. The APSLMP states that priority of a comprehensive study should be given to "major lakes and ponds totally surrounded by state land and to those on which state intensive use facilities exist or may be proposed" (APA and NYSDEC 2001, p. 4). Therefore, we recommend that the overall monitoring process begin with an assessment of Adirondack water bodies regarding each water body's recreation development and use indicator scores and the natural characteristics of the water body and CMZ. Such an assessment of potential recreation impact would focus limited NYSDEC funding, time, and personnel on water bodies most in need of monitoring by prioritizing water bodies with the highest risk of having impacts related to recreation development and use. It is recommended that the NYSDEC work together with the Adirondack Lake Survey Corporation (ALSC) and the Adirondack Park Agency (APA) to integrate existing knowledge of site-specific characteristics (e.g., water body depth and volume, shoreline substrate) and available geospatial data (e.g., roads and trails) to develop a map of Adirondack water bodies that have a higher likelihood of being impacted by recreation development and use. This assessment should not be the only basis for management actions and mainly serves the purpose of informing managers and setting priorities for monitoring the water bodies on Forest Preserve lands.
2. Preparations for monitoring should begin before data collection in the field. In addition to information already obtained when conducting a risk assessment, information should be collected on the land classification the water body is located within and any special UMP rules that may apply as well as the NYS designated use classification and state water quality standards for the water body (New York State Codes, Rules, and Regulations, Title 6, Chapter X, Parts 700-705).
3. Data collection will involve both primary and secondary data. Secondary data obtained before a trip into the field should be verified and geo-referenced. Data collected at sampling stations should be geo-referenced to locations where measurements are taken. If sampling is conducted using a data logger, it is preferable a built-in GPS system be used to associate sampling stations with data. Data forms should be developed and used to verify the site, date, time of

4. After monitoring is completed, laboratory analyses and survey data has been returned, and all calculations and analyses have been made, information should be entered into a database in spreadsheet form for easier statistical analyses and integration into a GIS geodatabase. Data collection, assimilation of information using a standardized protocol, and sharing of that data with other state (e.g., water quality division) and federal agencies (e.g., EPA STORET database) will assist managers in making informed decisions and will also assist future integration of site-specific data into an Adirondack water body monitoring program.

**Phase Three -- Setting LAC Standards:**

Standards have to be created for each recommended indicator so that the recommended monitoring process can be fully integrated into UMPs and management planning under the LAC framework used by the NYSDEC to assess recreational impacts. Standards represent the bottom line of resource conditions as "LAC standards are statements of minimally acceptable conditions" (Cole & Stankey 1997, p. 7). Standards link the assessment of aquatic ecological conditions and visitor experience conditions to management actions that occur when minimally acceptable conditions (standards) have been exceeded. If standards are exceeded, management actions are taken to bring resource conditions back within acceptable limits. Management actions taken in response to exceeded standards may include evaluation of the site to assess appropriateness for specific types and amounts of recreational use and development, education, restorative actions, zoning, capacities associated with amount of development and use (e.g., campsites, buildings, trails, impervious surface, etc.) allowed in the shoreline area, use permits, and restrictions on the type of motorized engine allowed and/or speed, etc., depending on the indicator whose standard has been surpassed and the scientific basis for taking such an action (Dawson and Hendee 2009).

While NYS water quality standards exist for some water quality indicators, these standards may or may not refer to the resource conditions the NYSDEC wishes to maintain in Forest Preserve water bodies of the Adirondack Park. NYS standards apply to all state waters including those located in highly developed non-protected watersheds and are legal limits for dissolved oxygen, TDS, fecal coliforms, chloride, and phosphorous (although the qualitative standards for phosphorous are not easy to interpret or measure). To ensure Forest Preserve water resources in their physical and biological context are not degraded as mandated by the APSLMP, standards for these protected waters may need to be more stringent than statewide standards.

Standards for social impact indicators are most often expressed in either: (1) percentages of survey respondents self reporting that they perceive crowding, such as the majority of visitors reporting perceptions of crowding (USDA Forest Service 2005) or more than 66% of visitors reporting perceptions of crowding during a season may indicate that a carrying capacity has been exceeded (Vaske and Shelby 2008); or (2) probabilistic statements such as 80 percent probability of five or fewer encounters with other groups on the water body.

Standards for recreation development and use indicators are sometimes expressed in percentage change per year or multi-year period, such as less than 5% change in total area of campsite per year or less than 5% change in total area of shoreline disturbance per five year monitoring interval. They can also be expressed in terms of the management prescription for recreation facilities on each type of land classification (e.g., wilderness areas will not have primitive campsites with an impact area of vegetation loss greater than 300 sq ft)

**Phase Four – Implement Monitoring:**

Following the development of standards, the results of the monitoring phase can be compared with the standards, then management decisions can be made regarding whether the standard has been exceeded or not and whether management action is required. Particular consideration must be given to the relationship between amount and type of recreation use that is estimated to be causing the impacts in a given area. Following the comparison of standards and actual conditions in the water bodies areas monitored, it will be possible for some management approaches to be developed that address some of the more widespread impacts identified. Thus, coherent and generalized management approaches can be used, where appropriate, to address corrective actions needed to return areas to their desired and prescribed conditions. In other site specific situations, management approaches may need to be developed that are unique to that situation.

**Conclusion**

Conceptually relevant indicators were selected for measurement; rapid and cost-effective methods were chosen or developed for measurement of selected indicators; and spatial and temporal guidelines were created based on an extensive literature review and pilot study. A monitoring process was recommended to assist the NYSDEC in making management decisions and meeting APSLMP mandates. Full integration of the monitoring process into a LAC framework requires development of standards for each indicator and an investigation into cause and effect relationships that may vary given each site's specific management and natural characteristics. Application of the recommended monitoring process may be used to increase sustainable recreational opportunities and to maintain and enhance the social, biological, and aesthetic qualities of the water bodies on Forest Preserve lands within the Adirondack Park.

**Acknowledgements**

Technical aspects of this project could not have been completed without the assistance of many of SUNY-ESF's faculty and students. The guidance and expertise of Dr. John Hassett and Jennifer Croskey as well as the use of the chemistry laboratory and PISCES equipment was invaluable to the measurement and analysis of gasoline compounds. The inventory of water bodies on Forest Preserve lands within the Adirondack Park was carried out with the GIS assistance of Steve Signell of the SUNY-ESF Adirondack Ecological Center at Newcomb, NY.

# REFERENCES

Abell, R, Allan J, Lehner B. 2007. Unlocking the potential of protected areas for freshwaters. Biological Conservation 134(1):48-63.

Abu-Zreig, M, Rudra R, Whiteley H, Lalonde M, Kaushik N. 2003. Phosphorus removal in vegetated filter strips. J Environ Qual 32(2):613-9.

Adirondack Council. 2009. Low sodium diet: Curbing New York's appetite for damaging road salt. [Internet]. [cited 2009 Feb 10]. Available from: http://www.adirondackcouncil.org/Road%20Salt%20Report209.pdf

Adirondack Council. 2010. Adirondacks Waters: Resource at Risk. (accessed August 1, 2010) http://www.adirondackcouncil.org/Water%20Pub%20-%20Final.pdf

Adirondack Lake Survey Corporation (ALSC). 1985. Standard operating procedures: Field operations. 2nd ed. Ray Brook (NY). p. 1-200.

Adirondack Lake Survey Corporation (ALSC). 1987. Adirondack lakes survey: Summer surface chemistry data, 1984-87. [Internet]. [cited 2009 Sept 13]. Available from: http://adirondacklakessurvey.org.

Adirondack Park Agency and NYS Department of Environmental Conservation. 2001. State of New York Adirondack Park State Land Master Plan. New York: Ray Brook.

Adirondack Park Agency. 2010. Lakes and Ponds Entirely Surrounded by Forest Preserve. (accessed August 1, 2010) http://www.apa.state.ny.us/_assets/ForestPreserveWater/ForestPreserveLakeMap.pdf

Adirondack Park Invasive Plant Program (APIPP). 2004. Aquatic invasive plant project regional coordinated monitoring 2004 report. [Internet]. [cited 2010 Jan 12]. Available from: http://www.adkinvasives.com/documents/2004ProjectReport_000.pdf

Ahmed, W, Neller R, Katouli M. 2005. Evidence of septic system failure determined by a bacterial biochemical fingerprinting method. Journal of Applied Microbiology 98:910-20.

Ahuja, L, Sharpley A, Lehman O. 1982. Effect of soil slope and rainfall characteristics on phosphorous in runoff. Journal of Environmental Quality 11(1):9-13.

Anderson, D. H. and P. J. Brown. 1984. The Displacement Process in Recreation. Journal of Leisure Research 16: 61-73.

Asplund, TR and Cook CM. 1997. Effects of motor boats on submerged aquatic macrophytes. Lake and Reservoir Management 13(1):1-12.

Asplund, TR. 2000. The effects of motorized watercraft on aquatic ecosystems. Madison (WI): Wisconsin Department of Natural Resources, Bureau of Integrated Science Services; University of Wisconsin. Report No. PUBL-SS-948-00.

Avallone, AD. 2003. Temporal and spatial dynamics of gasoline pollution in new york state lakes and rivers and their relationship to motorboat activity [thesis]. [Syracuse (NY)]: State University of New York College of Environmental Science and Forestry. p.1-131.

Barrett, ME, Malina Jr JF, Charbeneau RJ, Ward GH. 1995. Effects of highway construction and operation on water quality and quantity in an ephemeral stream in the austin, texas area. Austin (TX): Center for Research in Water Resources. Report No. CRWR 262.

Bennear, L, Jessoe K, Olmstead S. 2009. Sampling out: Regulatory avoidance and the total coliform rule. Environmental Science and Technology 43(14):5176-82.

Brooks, J. J., G. N. Wallace and D. R. Williams. 2006. Place as Relationship Partner: An Alternative Metaphor for Understanding the Quality of Visitor Experience in a Backcountry Setting. Leisure Sciences 28: 331-349.

Bussmann, I. 2005. Methane release through resuspension of littoral sediment. Biogeochemistry 74:283-302.

Chen, M. 1988. Pollution of ground water by nutrients and fecal coliforms from lakeshore septic tank systems. Water, Air, and Soil Pollution 37(3-4):407-17.

Choi, Kye Young and Chad Dawson. 2002. Attributes Affecting Campsite Selection at Two Types of Campgrounds in the Adirondack Park. In Schuster, Rudolph (editor), Proceedings of the 2002 Northeastern Recreation Research Symposium. Gen. Tech. Report NE (in press). Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station.

Christensen, D, Herwig B, Schindler D, Carpenter S. 1996. Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. Ecol Appl 6(4):1143-9.

Clements, W, Oris J, Wissing T. 1994. Accumulation and food chain transfer of fluoranthene and benzo[a]pyrene in chironomus riparius and lepomis macrochirus. Arch Environ Contam Toxicol 26(3):261-6.

Cline, LD, Short RA, Ward JV. 1982. Influence of highway construction on the macroinvertebrates and epilithic algae of a high mountain stream. Hydrobiologia 96(2):149-59.

Cole, D. and Carlson, T. 2010. Numerical Visitor Capacity: A Guide to its Use in Wilderness. Fort Collins, CO: USDA Forest Service Rocky Mountain Research Station. General Technical Report RMRS-GTR-247.

Cole, D and McCool S. 1997. Limits of acceptable change and related planning processes: A workshop. In: McCool, S., Cole, D., & comps. 1998. Conference Proceedings: Limits of Acceptable Change and Related Planning Processes: Progress and Future Directions. Ogden, UT: USDA Forest Service Rocky Mountain Research Station. General Technical Report No. INT-GTR-371. p. 1-2.

Cole, D and Stankey G. 1997. Historical development of limits of acceptable change: Conceptual clarifications and possible extensions. In: McCool, S., Cole, D., & comps. 1998. Conference Proceedings: Limits of Acceptable Change and Related Planning Processes: Progress and Future Directions. Ogden, UT: USDA Forest Service Rocky Mountain Research Station. General Technical Report No. INT-GTR-371. p. 5-9.

Cole, D. 1989. Area of vegetation loss: A new index of campsite impact. Missoula (MT): USDA Forest Service Intermountain Research Station. Report No. INT-389.

Cole, D. N., A. E. Watson and J. W. Roggenbuck. 1995. Trends in Wilderness Visitors and Visits: Boundary Waters Canoe Area, Shining Rock, and Desolation Wilderness. Research Paper INT-RP-483. Ogden, Utah: U.S. Forest Service, Intermountain Research Station.

Cole, DN and Spildie DR. 1998. Hiker, horse, and llama trampling effects on native vegetation in montana, USA. Journal of Environmental Management 53:61-71.

Cole, DN. 1982. Wilderness campsite impacts: Effect of amount of use. Missoula, (MT): USDA Forest Service Intermountain Forest and Range Experiment Station . Report No. INT-284.

Cole, DN. 1987. Research on soil and vegetation in wilderness: A state-of-knowledge review. In: National wilderness research conference proceedings: Issues, state-of-knowledge, future directions; 1987; Fort Collins. Ogden (UT): USDA Forest Service Intermountain Research Station. p. 135-177.

Connelly, N.A.; Dawson, C.P.; Brown, T.L. 2005. Comparative analysis of visitor attitudes and preferences in three Adirondack management areas. In K. Bricker (editor), Proceedings of the 2004 Northeastern Recreation Research Symposium, March 28-30, 2004 at Bolton Landing, NY. USDA Forest Service Gen. Tech. Rep. NE-326. Newton Square, PA. Pp 231-239.

Cordell, K, McDonald B, Teasley J, Bergstrom J, Martin J, Bason J, Leeworthy V. 1999. Outdoor recreation participation trends. In: Cordell, H. Ken; Betz, Carter ; Bowker, J.M.; et al. Outdoor Recreation in American Life: A National Assessment of Demand and Supply Trends. Champaign (IL): Sagamore Publishing. p. 219-321.

Craun, G, Calderon R, Craun M. 2005. Outbreaks associated with recreational water in the united states. International Journal of Environmental Health Research 15(4):243-62.

Curry, R. A. 2000. Forestry and the biodiversity of fishes in eastern north america. In: Wagner, RG, Hagan, JM, editors. Forestry and the riparian zone conference proceedings; 2000 October 26; Orono (ME). p. 27-30.

Dale, V and Beyeler S. 2001. Challenges in the development and use of ecological indicators. Ecol Ind 1(1):3-10.

Daniels, RB and Gilliam JW. 1996. Sediment and chemical load reduction by grass and riparian filters. Soil Sci Soc Am J 60:246-51.

Dawson, C.P. 2005. Monitoring Outstanding Opportunities for Solitude. International Journal of Wilderness 10(3): 12-14.

Dawson, C.P., Connelly, N.A. and Brown, T.L. 2005. Adirondack Visitor Studies Conducted in Support of NYSDEC Unit Management Planning: Lake George Wild Forest (North) and William C. Whitney Wilderness. Human Dimensions Research Unit report HDRU Series No. 05-7, Cornell University, Ithaca, NY. 87 pages.

Dawson, C.P., Connelly, N.A. and Brown, T.L. 2006a. Adirondack Visitor Studies Conducted in Support of NYSDEC Unit Management Planning: Recommendations for Research. Human Dimensions Research Unit report HDRU Series No. 06-9, Cornell University, Ithaca, NY. 26 pages.

Dawson, C.P.; Connelly, N.A.; Brown, T.L. 2006b. Developing a Research Process To Monitor Social Conditions In Five Adirondack Park Protected Areas. In J. Peden and R. Schuster (editors), Proceedings of the 2005 Northeastern Recreation Research Symposium, April

10-12, 2005 at Bolton Landing, NY. USDA Forest Service Gen. Tech. Rep. NE-341. Newton Square, PA. pp 70-77.

Dawson, Chad P. and John C. Hendee. 2009. Wilderness Management: Stewardship and Protection of Resources and Values (4th edition). Fulcrum Publishing, Golden, CO.

Dawson, Chad P. and Kristofer A. Alberga. 2004. Acceptable Number of User Encounters: A Study of Adirondack and Great Gulf Wilderness Hikers. In: Murdy, Jim (editor), Proceedings of the 2003 Northeastern Recreation Research Symposium, April 6-8, 2003 at Bolton Landing, NY. USDA Forest Service Gen. Tech. Rep. NE-317. Newton Square, PA. Pp 380-385.

Dawson, Chad P., J. Baker, L. Barker and C. Williams. 2011. Southeastern Adirondack Forest Preserve Visitor Study. Research report to the NYS Department of Environmental Conservation. Syracuse, NY: SUNY-ESF. 47 pages.

Dawson, Chad P., John C. Hendee and Rudy M. Schuster. 2009. Wilderness Visitor Management: Stewardship for Quality Experiences. In: Dawson, Chad P. and John C. Hendee. 2009. Wilderness Management: Stewardship and Protection of Resources and Values (4th edition). Fulcrum Publishing, Golden, CO. pp. 439-486.

Dawson, Chad P., Peter Newman and Cathy Fuller. 2000. User Satisfactions and Perceptions of Crowding in Four Adirondack Wilderness Areas. In: G. Kyle (editor), Proceedings of the 1999 Northeastern Recreation Research Symposium, April 11-13, 1999 at Bolton Landing, NY. USDA Forest Service Gen. Tech. Rep. NE-269. Radnor, PA, pp. 120-126.

Dawson, Chad P., Rudy Schuster, Blake Propst and Corenne Black. 2008. St. Regis Canoe Area Visitor and Campsite Study. Research report to the NYS Department of Environmental Conservation. Syracuse, NY: SUNY-ESF. 69 pages.

Dawson, Chad P.and Rudy Schuster. 2008. Lows Lake Primitive Area Visitor Study. Research report to the NYS Department of Environmental Conservation. Syracuse, NY: SUNY-ESF. 35 pages.

Dawson. C.P., Peters, N., Connelly, N.A. and Brown, T.L. 2005. Adirondack Visitor Studies Conducted in Support of NYSDEC Unit Management Planning: Bog River Unit, Mc Kenzie Mountain Wilderness, and West Canada Lake Wilderness Human Dimensions Research Unit report HDRU Series No. 06-6, Cornell University, Ithaca, NY. 121 pages.

Dickman, M and Dorais M. 1977. The impact of human trampling on phosphorous loading to a small lake in Gatineau Park, Quebec, Canada. Journal of Environmental Management 5(4):335-44.

Dillman, D. A., J. D. Smyth and L. M. Christian. 2009. Internet, Mail and Mixed-Mode Surveys: The Tailored Design Method (3rd edition). Hoboken, NJ: John Wiley and Sons, Inc.

Dixit, SS, Smol JP, Charles DF, Hughes RM, Paulsen SG, Collins GB. 1999. Assessing water quality changes in the lakes of the northeastern United States using sediment diatoms. Can J Fish Aquat Sci 56(1):131-52.

Doyle, AT. 1990. Use of riparian and upland habitats by small mammals. Journal of Mammalogy 71(1):14-23.

Driver, B. and P. Brown. 1983. Contributions of behavioral scientists to recreation resource management. New York: Plenum.

Driver, B., R. Hash, and G. Haas. 1987. Wilderness Benefits: A State of Knowledge Review. In: National Wilderness Research Conference: Issues, State of Knowledge, Future Directions. GTR-INT-220. Ogden, Utah: U.S. Forest Service, Intermountain Research Station. pp. 294-319.

Eaton, A, Clesceri L, Rice E, Greenberg A, Franson M, editors. 2005. Standard methods for the examination of water and wastewater: Centennial edition. 21st ed. Washington (DC): American Public Health Association.

Farnum, J., T. Hall and L. E. Kruger. 2005. Sense of Place in Natural Resource Recreation and Tourism: An Evaluation and Assessment of Research Findings. General Technical Report PNW-GTR-660. Portland, OR: U.S. Forest Service, Pacific Northwest Research Station.

Fay, G; Colt, S.; White, E. 2010. Data survey and sampling procedures to quantify recreation use of national forests in Alaska. Gen. Tech. Report PNW-GTR-808. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest research Station.

Forman, RT and Alexander LE. 1998. Roads and their major ecological effects. Annu Rev Ecol Syst 29:207-31.

France, R, Peters R, McCabe L. 1998a. Spatial relationships among boreal riparian trees, litterfall, and soil erosion potential with reference to buffer strip management and coldwater fisheries. Ann Bot Fennici 35:1-9.

Frissell, C and Bayles D. 1996. Ecosystem management and the conservation of aquatic biodiversity and ecological integrity. Water Resources Bulletin 32(2):229-240.

Garrad, P and Hey R. 1987. Boat traffic, sediment resuspension, and turbidity in a broadland river. Journal of Hydrology 95:289-97.

Gerba, C. 2000. Assessment of enteric pathogen shedding by bathers during recreational activity and its impact on water quality. Quantitative Microbiology 2(1):55-68.

Graczyk, T, Majewska A, Schwab K. 2008. The role of birds in dissemination of human waterborne enteropathogens. Trends Parasitol 24(2):55-9.

Graczyk, TK, Sunderland D, Tamang L, Shields TM, Lucy FE, Breysse PN. 2007b. Quantitative evaluation of the impact of bather density on levels of human-virulent microsporidian spores in recreational water. Applied and Environmental Microbiology 73(13):4095-9.

Graefe, David, Chad P. Dawson, and Lisa Gerstenberger. 2010. Adirondack Park Forest Preserve Roadside Camping Study. Research report to the NYS Department of Environmental Conservation. Syracuse, NY: SUNY-ESF. 100 pages.

Graham, AL and Cooke SJ. 2008. The effects of noise disturbance from various recreational boating activities common to inland waters on the cardiace physiology of a freshwater fish, the largemouth bass (micropterus salmoides). Aquatic Conserv: Mar Freshw Ecosyst 18:1315-24.

Graves, AK, Hagedorn C, Teetor A, Mahal M, Booth, A.M. Reneau Jr, R.B. 2002. Antibiotic resistance profiles to determine sources of fecal contamination in a rural virginia watershed. Journal of Environmental Quality 31:1300-8.

Green, DM. 1998. Recreational impacts on erosion and runoff in a central arizona riparian area. J Soil Water Conserv 53(1):38-42.

Griffin, D, Lipp E, McLaughlin M, Rose J. 2001. Marine recreation and public health microbiology: Quest for the ideal indicator. Bioscience 51(10):817-26.

Hall, T. and B. Shelby. 1996. Who Cares About Encounters? Differences Between Those With and Without Norms. Leisure Sciences 18: 7-22.

Hammitt,W and Cole DN. 1998. Wildland recreation: Ecology and management. 2nd ed. New York (NY): John Wiley & Sons, 361pp.

Haas, G.; Aukerman, R.; Lovejoy, V. and Welch, D. 2004. Water Recreation Opportunity Spectrum (WROS) users' guidebook. Lakewood, CO: US Dept. of Interior, Bureau of Reclamation, Office of Program and Policy Services, Denver Service Center.

Haas, G. 2002. Visitor capacity on public lands and waters: Making better decisions. A report of the Federal Interagency Task Force on Visitor Capacity on Public Lands. Ashburn, VA: National Recreation and Park Association.

Heywood, J. L. 1996. Social Regularities in Outdoor Recreation. Leisure Sciences 18: 23-37.

Hollenhorst, S.J.; Whisman, S.A.; Ewert, A. W. 1992. Monitoring visitor use in backcountry and wilderness: A review of methods. Gen. Tech. report PSW-GTR-134. Albany, CA: USDA, Forest Service, Pacific Southwest Research Station.

Howell, RB, Nakao DI, Gidley JL. 1979. Analysis of short and long-term effects on water quality for selected highway projects. Sacramento (CA): California State Department of Transportation. Report No. NTIS PB 80-196165.

Hughes, R and Peck D. 2008. Acquiring data for large aquatic resource surveys: The art of compromise among science, logistics, and reality. J N Am Benthol Soc 27(4):837-59.

Hunsaker, CT, Christensen SW, Beauchamp JJ, Olson RJ, Turner RS, Malanchuk JL. 1986. Empirical relationships between watershed attributes and headwater lake chemistry in the adirondack region. Oak Ridge (TN): Oak Ridge National Laboratory Environmental Sciences Division. Report No. ORNL/TM-9838.

Ito, M, Mitchell M, Driscoll C, Roy KM. 2005. Nitrogen input-output budgets for lake-containing watersheds in the adirondack region of new york. Biogeochemistry 72(3):283-314.

Jaakson, R. 1970. Planning for the capacity of lakes to accommodate water-oriented recreation. Plan Canada 10:29-40.

Jackivicz, J, T.P. and Kuzminski LN. 1973. A review of outboard motor effects on the aquatic environment. J Wat Poll Contr Fed 45:1759-70.

Jacob, G. R. and R. Schreyer. 1980. Conflict in Outdoor Recreation: A Theoretical Perspective. Journal of Leisure Research 12 (4): 368-380.

Jamieson, R, Gordon R, Sharples K, Stratton G, Madani A. 2002. Movement and persistence of fecal bacteria in agricultural soils and subsurface drainage water: A review. Canadian Biosystems Engineering 44:1.1-1.9.

Jennings, MJ, Bozek MA, Hatzenbeler GR, Emmons EE, Staggs MD. 1999. Cumulative effects of incremental shoreline habitat modification on fish assemblages in north temperate lakes. North American Journal of Fisheries Management 19:18-27.

Jennings, MJ, Emmons EE, Hatzenbeler GR, Edwards C, Bozek MA. 2003. Is littoral habitat affected by residential development and land use in watersheds of wisconsin lakes? Lake and Reservoir Management 19(3):272-9.

Johnson, Andrew and Chad P. Dawson. 2004. An exploratory study of the complexities of coping behavior in Adirondack Wilderness. Leisure Sciences 26:281-293.

Johnson, Andrew K. and Chad P. Dawson. 2002. Coping, Crowding and Satisfaction: A Study of Adirondack Wilderness Hikers. In: S. Todd (editor), Proceedings of the 2001 Northeastern Recreation Research Symposium, April 1-3, 2001 at Bolton Landing, NY. USDA Forest Service Gen. Tech. Rep. NE-289. Radnor, PA. Pp. 25-31.

Johnson, L and Padilla D. 1996. Geographic spread of exotic species: Ecological lessons and opportunities from the invasion of the zebra mussel dreissena polymorpha. Biol Conserv 78(1-2):23-33.

Johnson, L, Ricciardi A, Carlton J. 2001. Overland dispersal of aquatic invasive species: A risk assessment of transient recreational boating. Ecol Appl 11(6):1789-99.

Johnson, LE and Carlton JT. 1996. Post-establishment spread in large-scale invasions: Dispersal mechanisms of the zebra mussel dreissena polymorpha. Ecology 77(6):1686-90.

Johnson, R and Carothers S. 1982. Riparian habitats and recreation: Interrelationships and impacts in the southwest and rocky mountain region. Fort Collins (CO): USDA Forest Service Rocky Mountain Forest and Range Experiment Station. Report No. 12. p. 1-27.

Johnson, S. 1994. Recreational boating impact investigations-upper mississippi river system, pool 4, red wing, minnesota. Lake City (MN): Minnesota Department of Natural Resources. Report No. EMTC 94-S004. 48 p.

Johnstone, IM, Coffey BT, Howard-Williams C. 1985. The role of recreational boat traffic in interlake dispersal of macrophytes: A new zealand case study. Journal of Environmental Management 20:263-79.

Kaushal, S, Groffman P, Likens G, Belt K, Stack W, Kelly V, Band L, Fisher G. 2005. Increased salinization of fresh water in the northeastern united states. Proceedings of the National Academy of Sciences of the United States of America 102(38):13517-20.

Kedell, A. 2009. Testimony of the adirondack council at the clean water hearing. Albany (NY). [Internet]. [cited 2010 Feb 10]. Retrieved from: http://www.adirondackcouncil.org/WaterTestimony1009.pdf

Kirkby, MJ, editor. 1980. Soil erosion. Chichester: Wiley Publishing.

Knopf, FL, Johnson RR, Rich T, Samson FB, Szaro RC. 1988. Conservation of riparian ecosystems in the united states. The Wilson Bulletin 100(2):272-84.

Kurtz, J, Jackson L, Fisher W. 2001. Strategies for evaluating indicators based on guidelines from the environmental protection Agency's office of research and development. Ecol Ind 1(1):49-60.

LaBelle, JM. 1990. Conflicts among water-based recreational uses. (NY): The Commission on the Adirondacks in the Twenty-First Century. Report No. TR-10, Volume 1. p. 246-257.

Landrum, P. F., Geisy J. P., Oris J. T. and Allred P. M. 1987. Photoinduced toxicity of polycyclic aromatic hydrocarbons to aquatic organisms. In: Oil in Freshwater: Chemistry, Biology, Countermeasure Technology: Symposium on oil pollution in freshwater; 1984 October 15; Alberta (CA). Oxford: Pergamon. p. 314-328.

Langen, TA, Twiss M, Young T, Janoyan K, Stager JC, Jr O, J., Prutzman H, Green B. 2006. Environmental impacts of winter road management at the cascade lakes and chapel pond: The final report. New York State Department of Transportation. Report No. 1. 335p.

Leung, Y. and Marion J. 2000. Recreation impacts and management in wilderness: A state of knowledge review. In. Wilderness science in a time of change conference proceedings - Wilderness ecosystems, threats, and management; 1999 May 23-27; Missoula (MT). Ogden (UT): USDA Forest Service Rocky Mountain Research Station. p. 23-48.

Liddle, M and Scorgie H. 1980. The effects of recreation on freshwater plants and animals: A review. Biological Conservation 17(3):183-206.

Liddle, M. 1997. Recreation ecology: The ecological impact of recreation and ecotourism. London: Chapman & Hall. 664pp.

Lynch, J.; Vogt, C.; Cindrity, S.; Nelsom, C. 2002. Measuring and monitoring trail use: A nationwide survey of state and federal trail managers. East Lansing, MI: Department of Park, Recreation and Tourism resources, Michigan State University.

Magette, WL, Brinsfield RB, Palmer RE, Wood JD. 1989. Nutrient and sediment removal by vegetated filter strips. Transactions of the American Society of Agricultural Engineering 32:6663-7.

Major, J.T.; Gann, M.C.; Reinhardt, R.W.; Bartlett, W.; Soloman, G. 1992. 1990 statewide survey of boating use at public waterway access sites in New York State. Albany, NY: Bureau of Fisheries, NYS Department of Environmental Conservation and Bureau of Planning, Office of Parks, Recreation, and Historic Preservation.

Manning, R. 1979. Impacts of recreation on riparian soils and vegetation. Water Resources Bulletin 15(1):30-43.

Manning, R. 1999. Studies in outdoor recreation: Search and research for satisfaction. 2nd ed. Corvallis: Oregon State University Press. 374pp.

Marion, J and Cole D. 1996. Spatial and temporal variation in soil and vegetation impacts on campsites. Ecol Appl 6(2):520-30.

McCool, S, Clark R, Stankey G. 2007. An assessment of frameworks useful for public land recreation planning. Portland (OR): USDA Forest Service Pacific Northwest Research Station. General Technical Report No. PNW-GTR-705. p. 1-125.

McEwen, April L. 2010. An Exploratory Process for Monitoring Recreation Use Impacts to Water bodies within Adirondack Forest Preserve Lands. M.S. Thesis, SUNY College of Environmental Science and Forestry, Syracuse, NY. 146 p.

Metcalfe, T, Metcalfe C, Bennett E, Haffner G. 2000. Distribution of toxic organic contaminants in water and sediments in the detroit river. J Great Lakes Res 26(1):55-64.

Mills, E. L., J. H. Leach, J.T. Carlton and C.L. Secor. 1993. Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions. Journal of Great Lakes research 19(1): 1-54.

Moles, A and Marty GD. 2005. Physiological changes in prickly sculpin (cottus asper) inhabiting a lake used by jet-propelled watercraft. Bulletin of Environmental Contamination and Toxicology 74(6):1151-8.

Mosisch, TD and Arthington AH. 1998. The impacts of power boating and water skiing on lakes and reservoirs. Lakes & Reservoirs: Research and Management 3:1-17.

Mosisch, TD and Arthington AH. 2001. Polycyclic aromatic hydrocarbon residues in the sediments of a dune lake as a result of power boating. Lakes & Reservoirs: Research and Management 6:21-32.

Mosisch, TD and Arthington AH. 2004. Impacts of recreational power-boating on freshwater ecosystems. In: Buckley R, editor. Environmental impacts of ecotourism. Cambridge (MA): CAB International. p. 125-154.

Mueller, G. 1980. Effects of recreational river traffic on nest defense by longear sunfish. Transactions of the American Fisheries Society 109:248-51.

Muirhead, JR and MacIsaac HJ. 2005. Development of inland lakes as hubs in an invasion network. Journal of Applied Ecology 42:80-90.

Murtaugh, P and Pooler P. 2006. Evaluating ecological indicators: Lakes in the northeastern United States. Environ Monit Assess 119(1):83-96.

Naiman, R and Décamps H. 1997. The ecology of interfaces: Riparian zones. Annu Rev Ecol Syst 28(1):621-58.

Nanson, G, von Krusenstierna A, Bryant E, Renilson M. 1994. Experimental measurements of river-bank erosion caused by boat-generated waves on the gordon river, tasmania. Regulated Rivers: Research and Management 9:1-15.

Neff, J. 1979. Polycyclic aromatic hydrocarbons in the aquatic environment: Sources, fates and biological effects. London: Applied Science Publishers Ltd. 274pp.

New York State Department of Environmental Conservation (NYSDEC). 2008. New York State Nutrient Standards Plan [Internet]. [cited 2010 march 1]. Available from: http://www.dec.ny.gov/docs/water_pdf/nutrstdplan2.pdf

New York State. 2010. 6 NYCRR Parts 701-941. New York Codes, Rules and Regulations, Title 6, Environmental Conservation Law [Internet]. [cited 2010 march 2]. Available from: http://www.dec.ny.gov/regs/2485.html or http://westlaw.com.

Newman, Peter and C. P. Dawson. 1999. The Human Dimensions of the Wilderness Experience in the High Peaks Wilderness Area. In: H. Vogelsong (editor), Proceedings of the 1998 Northeastern Recreation Research Symposium, April 5-7, 1998 at Bolton Landing, NY. USDA Forest Service Gen. Tech. Rep. NE-255. Radnor, PA, pp. 122-129.

Nichols, DS, Prettyman D, Gross M. 1983. Movement of bacteria and nutrients from pit latrines in the boundary waters canoe area wilderness. Water, Air, and Soil Pollution 20(2):171-80.

Niemeijer, D and de Groot R. 2008. A conceptual framework for selecting environmental indicator sets. Ecological Indicators 8:14-25.

Niemi, G and McDonald M. 2004. Application of ecological indicators. Ann Rev Ecol Evol Syst 35:89-111.

Peters, N.; Dawson, C.P. 2005. Estimating visitor use and distribution in two Adirondack wilderness areas. In K. Bricker (editor), Proceedings of the 2004 Northeastern Recreation Research Symposium, March 28-30, 2004 at Bolton Landing, NY. USDA Forest Service Gen. Tech. Rep. NE-326. Newton Square, PA. Pp 164-171.

Pfaffenback, Becky, Harry Zinn and Chad Dawson. 2003.Exploring and Understanding Visitor Satisfaction Among Non-Motorized Watercraft Users in Two Adirondack Canoeing Areas. In: Schuster, Rudolph (editor), Proceedings of the 2002 Northeastern Recreation Research Symposium. USDA Forest Service Gen. Tech. Rep. NE-302. Newtown Square, PA. Pp. 222-228.

Pimentel, D. 2000. Environmental and economic costs of nonindigenous species in the United States. Bioscience 50(1):53-65.

Poff, NL, Allan JD, Palmer MA, Hart DD, Richter BD, Arthington AH, Rogers KH, Meyer JL, Stanford JA. 2003. River flows and water wars: Emerging science for environmental decision making. Frontiers in Ecology and the Environment 1(6):298-306.

Pusey, BJ and Arthington AH. 2003. Importance of the riparian zone to the conservation and management of freshwater fish: A review. Marine and Freshwater Research 54:1-16.

Quinton, J. 2001. The selective removal of phosphorus from soil: Is event size important? J Environ Qual 30(2):538-45.

Reuter, JE, Allen BC, Richards RC, Pankow JF, Goldman CR, Scholl RL, Seyfried JS. 1998. Concentrations, sources, and fate of the gasoline oxygenate methyl tert-butyl ether (MTBE) in a multiple-use lake. Environ Sci Technol 32:3666-72.

Richter, G and Negendank J. 1977. Soil erosion processes and their measurement in the german area of the moselle river. Earth Surface Processes 2:261-78.

Rickard, WE and Slaughter CW. 1973. Thaw and erosion on vehicular trails in perma frost landscapes. J Soil Water Conserv 28:263-6.

Robertson, WD, Schiff SL, Ptacek CJ. 1998. Review of phosphate mobility and persistence in 10 septic system plumes. Ground Water 36(6):1000-10.

Rodgers, JA and Smith HT. 1995. Set-back distances to protect nesting bird colonies from human disturbance in florida. Conservation Biology 9(1):89-99.

Rodgers, JA and Smith HT. 1997. Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in florida. Wild Soc Bull 25(1):139-45.

Salant, P. and D. A. Dillman. 1994. How to Conduct Your Own Survey. Hoboken, NJ: John Wiley and Sons, Inc.

Santamaria, J and Toranzos G. 2003. Enteric pathogens and soil: A short review. International Microbiology 6(1):5-9.

Scandura, JE and Sobsey MD. 1997. Viral and bacterial contamination of groundwater from on-site sewage treatment systems. Water Science and Technology 35(11-12):141-6.

Schindler, DW. 1974. Eutrophication and recovery in experimental lakes: Implications for lake management. Science 184(4139):897-9.

Schmidt, T, Haderlein S, Pfister R, Forster R. 2004. Occurrence and fate modeling of MTBE and BTEX compounds in a swiss lake used as drinking water supply. Water Res 38(6):1520-9.

Schraft, H and Watterworth L. 2005. Enumeration of heterotrophs, fecal coliforms and escherichia coli in water: Comparison of 3M petrifilm plates with standard plating procedures. Journal of Microbiological Methods 60:335-42.

Schreyer, R. 1990. Conflict in Outdoor Recreation: The Scope of the Challenge to Resource Planning and Management. In: Vining, J. ed. Social Science and Natural Resources Management. Boulder, CO: Westview Press. pp. 13-31.

Schuster, R. M., W. E. Hammitt and D. Moore. 2006. Stress Appraisal and Coping Response to Hassles Experienced in Outdoor Recreation Settings. Leisure Sciences 28: 97-113.

Schuster, R. M., W. E. Hammitt, D. Moore and I. E. Schneider. 2006. Coping with Stress Resulting from Social Value Conflict: Nonhunters' Response to Anticipated Social Interaction with Hunters. Human Dimensions of Wildlife Management 11: 101-113.

Schwab, K. 2007. Are existing bacterial indicators adequate for determining recreational water illness in waters impacted by nonpoint pollution? Epidemiology 18(1):21-2.

Stalmaster, MV and Kaiser JL. 1998. Effects of recreational activity on wintering bald eagles. Wildlife Monograph No. 137:46.

Stankey, G, Cole D, Lucas R, Petersen M, Frissell S. 1985. The limits of acceptable change (LAC) system for wilderness planning. Ogden (UT): USDA Forest Service Intermountain Forest and Range Experiment Station. General Technical Report No. USDA INT-176. p. 1-37.

Sukopp, H. 1971. Effects of man, especially recreational activities, on littoral macrophytes. Hydrobiologia 12:331-40.

Sutherland, R, Bussen J, Plondke D, Evans B, Ziegler A. 2001. Hydrophysical degradation associated with hiking-trail use: A case study of hawai'iloa ridge trail, o'ahu, hawaii. Land Degradation & Development 12(71):86.

Suttle, K, Power M, Levine J, McNeely C. 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecol Appl 14(4):969-74.

Tabacchi, E, Lambs L, Guilloy H, Planty-Tabacchi A, Muller E, Decamps H. 2000. Impacts of riparian vegetation on hydrological processes. Hydrological Processes 14:2959-76.

Therrell, L., D. Cole, V. Claassen, C. Ryan and M. A. Davies. 2006. Wilderness and Backcountry Site Restoration Guide. Tech. Report 0623-2815-MTDC. Missoula, MT: U.S. Dept. of Agriculture Forest Service, Missoula Technology and Development Center. 394 p.

Thompson, R. 2004. The zoonotic significance and molecular epidemiology of giardia and giardiasis. Vet Parasitol 126(1-2):15-35.

Tjarnlund, U, Ericson G, Lindesjoo E, Petterson I, Akerman G, Balk L. 1996. Further studies of the effects of exhaust from two-stroke outboard motors on fish. Marine Environmental Research 42(1-4):267-71.

U.S. Dept. of Agriculture Forest Service. 2005. White Mountain National Forest Land and Resource Management Plan; Appendix E: Wilderness Management Plan. Laconia, NH: U.S. Dept. of Agriculture Forest Service.

United States Environmental Protection Agency (USEPA). 2003. Elements of a state water monitoring and assessment program [Internet]. Report No. EPA 841-B-03-003. [cited 2010 March 3]. Available from: http://www.epa.gov/owow/monitoring/elements/

United States Environmental Protection Agency (USEPA). 2007. Methyl tertiary butyl ether (MTBE) [Internet]. [cited 2010 Jan 18]. Available from: http://www.epa.gov/mtbe/

United States Environmental Protection Agency (USEPA). 2007. Recreational water quality criteria: Criteria development plan and schedule [Internet]. Report No. 823-R-08-003. [cited 2010 Jan 30]. Available from: http://www.epa.gov/waterscience/criteria/recreation/plan/developmentPlan.pdf

United States Environmental Protection Agency (USEPA). 2009. Recreational Water Quality Criteria [Internet]. [cited 2010 Jan 30]. Available from: http://www.epa.gov/waterscience/criteria/recreation .

VanMouwerik, M and Hagemann M. 1999. Water quality concerns related to personal watercraft usage [Internet]. [cited 2010 Feb 10]. Available from: http://www.deq.state.mt.us/CleanSnowmobile/publications/pdf/Hagemann.pdf

Vaske, J. J., M. P. Donnelly, K. Wittmann and S. Laidlaw. 1995. Interpersonal versus Social-Values Conflict. Leisure Sciences 17: 205-222.

Vaske, J.J. and L.B. Shelby. 2008. Crowding as a Descriptor Indicator and an Evaluation Standrad: Results from 30 Years of research. Leisure Sciences 30: 111-126.

Wade, T, Calderon R, Sams E, Beach M, Brenner K, Williams A, Dufour A. 2006. Rapidly measured indicators of recreational water quality are predictive of swimming-associated gastrointestinal illness. Environmental Health Perspectives 114(1):24-8.

Wang, Cheng-Ping and C. P. Dawson. 2001. A Comparison of Recreation Conflict Factors for Different Water-Based Recreation Activities. In: G. Kyle (editor), Proceedings of the 2000 Northeastern Recreation Research Symposium, April 2-4, 2000 at Bolton Landing, NY. USDA Forest Service Gen. Tech. Rep. NE-276. Newton Square, PA. Pp 121-130.

Wang, Cheng-Ping and C. P. Dawson. 2005. Recreation Conflict along New York's Great Lakes Coast. Coastal Management 33: 297-314.

Watson, Alan E.; Cole, David N.; Turner, David L.; Reynolds, Penny S. 2000. Wilderness recreation use estimation: A handbook of methods and systems. Res. Pap. RMRS-GTR-56. Ogden, UT: USDA, Forest Service, Rocky Mountain Research Station.

Watson, A., B. Glaspell, N. Christensen, P. Lachapelle, V. Sahanatien and F. Gertsch. 2007. Giving Voice to Wildlands Visitors: Selecting Indicators to Protect and Sustain Experiences in the Eastern Arctic of Nunavut. Environmental Management 40: 880-888.

Wetzel, R. 2001. Limnology: Lake and river ecosystems. 3rd ed. California: Academic Press. 1006pp.

Whittier, T and Kincaid T. 1999. Introduced fish in northeastern USA lakes: Regional extent, dominance, and effect on native species richness. Trans Am Fish Soc 128(5):769-83.

Whittier, T, Paulsen S, Larsen D, Peterson S, Herlihy A, Kaufmann P. 2002. Indicators of ecological stress and their extent in the population of northeastern lakes: A regional-scale assessment. BioScience 52(3):235-47.

Wilkerson, E. and A. Whitman. 2010. Recreation Trails in Maine and New Hampshire: A Comparison of Motorized, Non-Motorized and Non-Mechanized Trails. In Watts, C. E., and C. L. Fisher (eds). Proceedings of the 2009 Northeastern Recreation Research Symposium. Gen. Tech. Rep. NRS-P-66. Newtown Square, PA: USDA Forest Service, Northern research Station. pp. 214-222

Wright, M, Solo-Gabriele H, Elmir S, Fleming L. 2009. Microbial load from animal feces at a recreational beach. Mar Pollut Bull 58(11):1649-56.

Yamasaki, M. 2000. Forestry effects on vertebrate species habitats in the riparian zone. In: Wagner, RG, Hagan, JM, editors. Forestry and the riparian zone conference proceedings; 2000 October 26; Orono (ME). p. 31-35.

York, D. 1994. Recreational-boating disturbances of natural communities and wildlife: An annotated bibliography. Fort Collins (CO): Information Transfer Center National Biological Survey No. A724323. 35 pp.

Yousef, Y, McLellon W, Zebuth H. 1980. Changes in phosphorous concentrations due to mixing by motor boats in shallow lakes. Water Research 14:841-52.

Yuan, Susan; Maiorano, Brian; Yuan, Michael; Kocis, Susan M.; Hoshide, Gary T. 1995. Techniques and equipment for gathering visitor use data on recreation sites. 2300-Recreation, 9523-2838-MTDC. Missoula, MT: USDA, Forest Service, Technology and Development Program.

Zabinski, C and Gannon J. 1997. Effects of recreational impacts on soil microbial communities. Environ Manage 21(2):233-8.