ASSESSING THE FRESHWATER CONSERVATION POTENTIAL OF TERRESTRIAL PROTECTED AREAS

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Project Team:
Drew Casey
Pete Gamberg
Colin Hume
Sarah Neville
Amy Samples
David Sena

EXECUTIVE SUMMARY

Physical alteration, habitat loss, water withdrawal, pollution, land use change, overexploitation, and the introduction of nonnative species together negatively influence freshwater ecosystems. Due to these stresses, freshwaters are ranked among the most at risk systems worldwide (Malmqvist and Rundle, 2002). Protected areas (PAs), defined as an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity as well as natural and associated cultural resources and managed through legal or other effective means (IUCN, 1994), are an emerging tool for the protection of biodiversity and natural resources. Despite the well-documented threatened status of freshwater ecosystems, terrestrial targets have received far more attention and resources in the designation of PAs (Abell et al., 2007). However, because many terrestrial PAs include freshwater components, use fluvial systems as borders, or affect freshwaters downstream, it is important to understand the role that terrestrial PAs play in freshwater conservation (Abell et al., 2007; Herbert et al., *in press*). The goal of our study was to investigate the conservation potential of terrestrial PAs. As such, using Federal- and State-owned PAs within the Northern Lake Michigan, Lake Huron, and Straits of Mackinac Ecological Drainage Unit of the State of Michigan (TNC, 2001), we evaluated two broad attributes of PAs: (1) the effect of containing land in an undeveloped condition on downstream freshwater key environmental attributes (KEAs: biotic composition, connectivity, hydrologic regime, physical habitat and energy regime, and water quality), and (2) the ability of managers to identify and mitigate negative anthropogenic influences on KEAs.

Our first objective was to determine the effect of total area under protection by terrestrial PAs on KEAs. To do so, data was collected on eight response variables representative of the five KEAs which included: $NO_2 + NO_3$ concentration, total phosphorus concentration, free flowing stream miles, average rate of flow response, low flow expectation, habitat quality score, fish index of biotic integrity, and percent of fish considered intolerant to anthropogenic stress. Next, using Geographic Information Systems (GIS), catchments derived from individual response variable datum locations were delineated and the total percent of land in protection within each catchment was calculated. Finally, the relationship between response variable values and percent land protected was determined using linear regressions. We found significant ($p<0.05$) decreases in $NO_2 + NO_3$ concentration and average rate of flow response with increasing area of catchment in protection, suggesting that by keeping land in a natural state, PAs can contribute to lowering nitrogen concentrations and reducing stream flashiness downstream. We also found significant increases in the percent of fish considered intolerant to anthropogenic stress with increasing area of catchment in protection, suggesting PAs may contribute to

enhancing the total number of environmentally sensitive fish. No significant relationship was found between PAs and total phosphorus concentration, free flowing stream miles, low flow expectation, habitat quality score, or fish index of biotic integrity.

Our second objective was to determine how PA management attends to freshwater conservation. To do so, we randomly selected eleven Federal- and State-owned PAs located within the Northern Lake Michigan, Lake Huron, and Straits of Mackinac Ecological Drainage Unit of the State of Michigan and conducted PA management questionnaires and interviews, based on IUCN's "Evaluating Effectiveness: A Framework for Assessing Management of Protected Areas" guidelines (Hockings et al., 2006) and the principles of integrated water resource management (IWRM; Global Water Partnership, 2009). This process identified what PA managers perceived to be greatest internal (within PA) and external (outside of PA) threats to freshwater KEAs within PAs and what specific activities PA managers conducted to protect or restore KEAs. The alignment between threats and activities was then determined as a measure of management's attendance to freshwater conservation. This analysis revealed that management processes are, with a few exceptions, complementary to identified threats to freshwater systems. However, while our findings suggest positive alignment between management activities and identified threats, the informality of collaborative processes and absence of robust freshwater monitoring programs indicate that management is not fully engaged in IRWM, which limits the capacity for adaptive management.

Our third objective was to determine the relative influences of management and catchment stressors on KEAs. Using previously delineated response variable catchments, we organized response variable values by the study PAs contained within their catchments, and calculated PA-specific response variable scores (Response Variable Score). Next, using the same response variable catchments, we calculated a measure of catchment condition (Catchment Condition Score). Finally, using results from PA management questionnaires, we quantified the degree of activity potentially affecting KEA response variables (Management Activity Score). Catchment Condition Scores and Management Activity Scores were then compared to Response Variable Scores to identify instances where PA management activities were successful in mitigating the effects of catchment stressors on KEAs (Scenario 1) and instances where catchment stressors had an overriding effect on management activities (Scenario 2). The two Scenarios were observed in nearly identical proportions across KEAs and PAs, suggesting that both management activities and catchment stressors vary in their ability to affect freshwater KEA values. However, Scenario 1 was observed more than Scenario 2 for water quality, while the opposite was observed for biotic composition and hydrologic regime, suggesting management activities may be more successful in mitigating the effects of catchment stressors specific to nutrient concentrations.

Our results suggest that terrestrial PAs likely contribute to some components of freshwater KEAs by protecting land from development and through certain management activities. However, further research is warranted to more extensively track the effect of the interaction of anthropogenic stressors and management activities on freshwater systems. If terrestrial protection were sufficient to secure freshwater integrity, we would expect the majority of indicators to be favorably related to total percent protected. Since only three of eight response variables showed the expected relationship, our findings do not support the assumption that watershed protections are synonymous with maintenance of freshwater KEAs.

Our approach provides a framework for evaluating and tracking key freshwater outcomes while addressing the interacting factors of human-induced stress and management attempts to mitigate these stresses. Furthermore, our approach holds utility for any managing entity attempting to produce favorable outcomes for freshwater systems. Future applications of this approach can be tailored to include a different set of management activities, catchment stressors, and response variables, depending on the context of the PA and what data are available for use.

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ACRONYMS LIST

Acronym	Definition
BMP	Best Management Practice
BOD	Biological Oxygen Demand
CARL	Conservation and Recreational Lands
CCS	Catchment Condition Score
DEM	Digital Elevation Model
EDU	Ecological Drainage Unit
EPA	Environmental Protection Agency
FY	Fiscal Year
GIS	Geographic Information System
GLEAS	Great Lakes and Environmental Assessment Section
HDI	Human Disturbance Index
IBI	Index of Biotic Integrity
IFMAP	Integrated Forest Monitoring, Assessment, and Prescription
IHA	Indicators of Hydrologic Alteration
IUCN	International Union for the Conservation of Nature
IWR	Institute of Water Research
IWRM	Integrated Water Resource Management
KEA	Key Environmental Attribute
MAS	Management Activity Score
MCGI	Michigan Center for Geographic Information
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MDNRE	Michigan Department of Natural Resources and Environment
NEDU	Northern Ecological Drainage Unit
NGO	Non-Governmental Organization
NHD	National Hydrography Database
NPDES	National Pollutant Discharge Elimination System
ORV	Off Road Vehicle
PA	Protected Area
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
RAPPAM	Rapid Assessment and Prioritization of Protected Area Management
RMZ	Riparian Management Zone
STORET	STOrage and RETrieval
TNC	The Nature Conservancy

TP	Total Phosphorus
TRI	Toxic Release Inventory
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
USFS	United States Forest Service
USGS	United States Geological Survey
WCPA	World Commission on Protected Areas
WWAT	Water Withdrawal Assessment Tool
WWTP	Waste Water Treatment Plant

1 INTRODUCTION

Anthropogenic impacts on freshwater ecosystems are numerous, widespread, and increasingly exacerbated as humans continue to encroach upon natural systems (Malmqvist and Rundle, 2002). Together, physical alteration, habitat loss, water withdrawal, pollution, land use change, overexploitation, and the introduction of nonnative species contribute to freshwater ecosystems, and the species they support, ranking among the most at risk systems worldwide (Revenga et al., 2005). In fact, the future extinction rate of freshwater animals has been predicted to be almost five times greater than that of terrestrial animals and three times that of coastal marine mammals (Ricciardi et al., 1999). In particular, freshwater fishes are thought to be the world's most threatened vertebrates after amphibians and unless they are protected, 20% of the world's species may become extinct in the next 25-50 years (Moyle and Leidy, 1992). For riverine systems, susceptibility to human impacts is magnified by their linear and unidirectional nature; almost any activity within a catchment has the potential to exert effects for large distances downstream (Malmqvist and Rundle, 2002).

Calls for increased efforts to reverse declining trends have been made (Dudgeon et al., 2006), but mechanisms to do so remain unclear. Protected areas (PAs), defined as an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity as well as natural and associated cultural resources and managed through legal or other effective means (IUCN, 1994), are an emerging tool for the protection of biodiversity and natural resources in terrestrial and marine conservation. There exist over 120,000 nationally and internationally recognized terrestrial PAs worldwide (UNEP-WCMC, 2008), but few were specifically designed for freshwater conservation (Saunders et al., 2002). According to Abell et al. (2007), freshwater-specific PAs can in principle protect against or mitigate place-specific threats such as habitat alteration, which is responsible for impacting 90% of freshwater species listed as critically endangered, endangered, or vulnerable on the 2004 International Union for Conservation of Nature's (IUCN) Red List (IUCN, 2004). Additionally, PAs can aid in the reduction of the overexploitation of species, which is responsible for endangering many of the world's largest freshwater fish (Allan et al., 2005).

Despite the well-documented threatened status of freshwater ecosystems, terrestrial targets have received far more attention and resources when designating PAs (Abell et al., 2007). Often, freshwater habitats in terrestrial PAs are protected only incidentally as part of their inclusion within terrestrial reserves (Skelton et al., 1995; Saunders et al., 2002; Mancini et al., 2005). Previous studies have suggested, however, that such inclusion does not guarantee protection as terrestrial protected areas often fail to address important aquatic concerns such as whole-catchment integrity, hydrology, and introductions of nonnative species (Skelton et al., 1995; Moyle and Randall, 1998; Saunders et al., 2002). Because many terrestrial PAs include freshwater components, or affect freshwater downstream, it is important to understand the role that terrestrial PAs play in freshwater conservation (Abell et al., 2007; Herbert et al., *in press*).

Freshwater ecosystems in terrestrial PAs may be threatened by stressors originating upstream from PA boundaries, a reason for potential shortcomings of many exclusively freshwater PAs, such as American Heritage Rivers, Wild and Scenic Rivers, inland fishery reserves, or riparian buffer zones (Mancini et al., 2005; Abell et al., 2007; Roux et al., 2008). Additionally, PAs may use fluvial systems as borders, resulting in only one side of the system receiving protection (Duckworth et al., 1998; Thieme et al., 2007; Roux et al., 2008). Within PAs, threats from invasive species and dams can override the benefits of land protection (Saunders et al., 2002; Abell et al., 2007; Sowa et al., 2007). In some cases freshwater resources in terrestrial PAs may be threatened by PA management itself, as made evident by the introduction of nonnative sport fishes that have been found to reduce populations of native freshwater fauna (Bradford et al., 1993).

In response to deteriorating or suboptimal environmental conditions, many PA management strategies have been employed to protect or restore freshwater values, potentially mitigating the effect of upstream impacts. Protected area-specific strategies may include preventing introductions of invasive species with constructed barriers, establishment of fishery reserves, restoration of riparian areas, or natural flow management. For example, a total of 1,345 freshwater-related restoration projects have been conducted in the upper Midwest alone (Alexander and Allan, 2005). Such projects include the use of sand traps, riprap, and large woody debris to enhance fish habitat, maintaining riparian buffer strips, and dam removal. While numerous studies have assessed the benefits of individual management strategies (e.g. Kelly and Bracken, 1998; Bednarek, 2001), their effectiveness in conserving freshwater values given the impact of various catchment stressors is unclear. More broadly, the contribution of terrestrial PAs to the improvement or maintenance of freshwater environmental attributes, either through the prevention of land use change or through various freshwater management practices, has not been assessed.

The objective of our study was to determine the freshwater conservation potential of terrestrial PAs. Specifically, our study used Federal- and State- owned PAs located in the Northern Lake Michigan, Lake Huron, and Straits of Mackinac Ecological Drainage Unit of the State of Michigan (TNC, 2001). We performed both quantitative and qualitative analyses to investigate the extent landscape context and PA management influence the maintenance or improvement of key environmental attributes (KEAs). Key environmental attributes include biotic composition, connectivity, energy regime, hydrologic regime, physical habitat and energy regime, and water quality (Karr et al., 1986; Higgins, *unpublished*).

Our approach was three-fold. First, using geographic information systems (GIS) and linear regression analysis, we investigated the effect of total area under protection by terrestrial PAs on freshwater KEA values. We hypothesized that increases in protection would result in improvements to all KEA values. Second, using PA management questionnaires and interviews, based on IUCN's "Evaluating Effectiveness: A Framework for Assessing Management of Protected Areas" guidelines (Hockings, 2006) and principles of integrated water resource management (IWRM), we investigated PA management's ability to attend to freshwater conservation goals. We hypothesized that management adequately addresses external and internal threats to KEAs. Thirdly, using GIS and results from management questionnaires, we investigated the relative influence of PA management activities and catchment stressors on KEAs. In this analysis, we sought to identify instances where PA management activities were successful in mitigating the effects of catchment stressors on KEAs and instances where catchment stressors had an overriding effect on management activities. We hypothesized that the effect of catchment stressors will override the effect management activities in most instances. Such information on the freshwater conservation potential of terrestrial PAs is critical for policy-makers, land managers, and stewards of PAs.

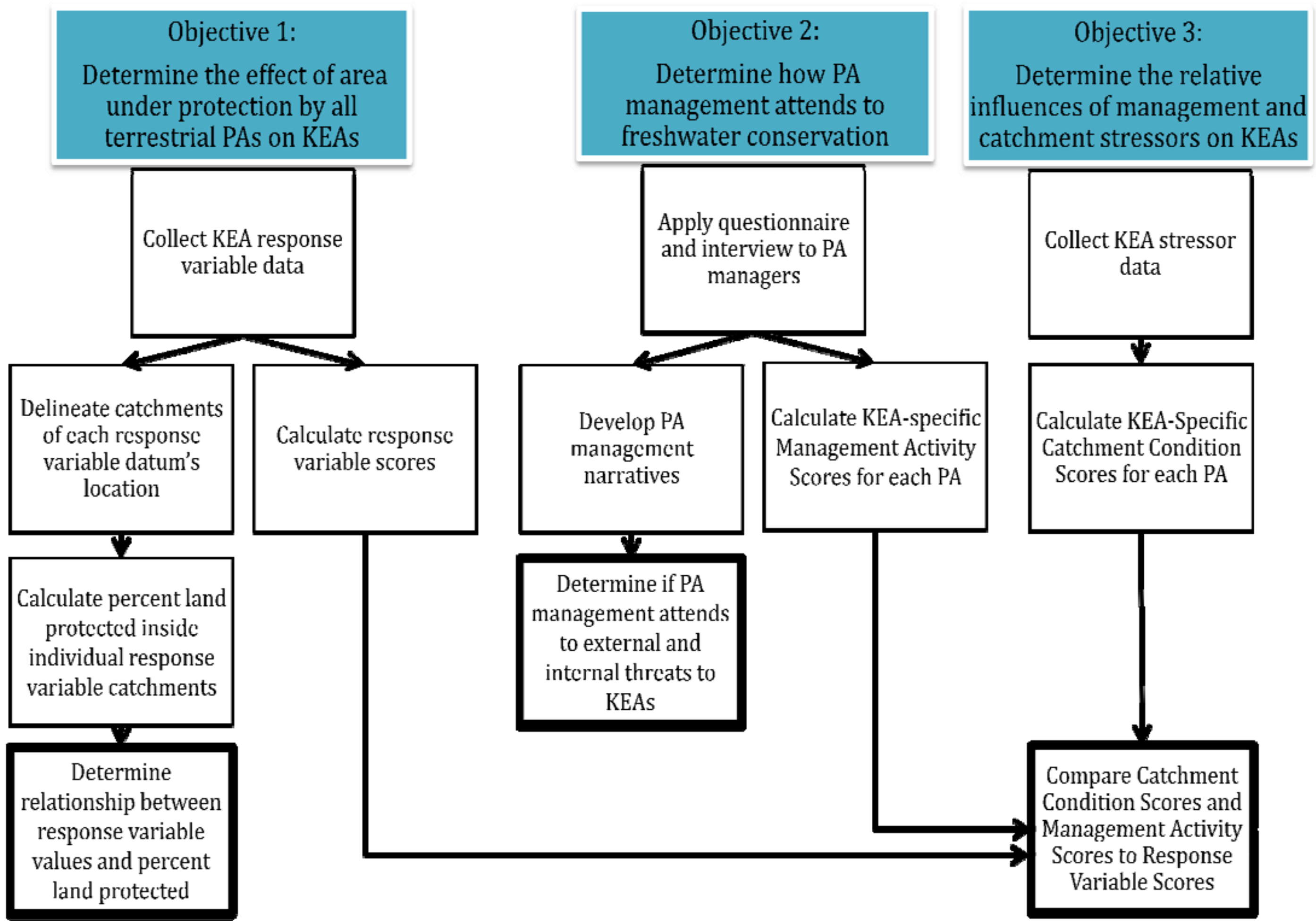

Figure 1. Objectives Flowchart.

2 BACKGROUND

The scientific approach used in answering our research question was influenced by several existing sources, which require some familiarity to understand our methodology and interpretation of results. First, we describe the KEAs utilized in our work as a way to organize and assess ecosystem integrity. In this section, we also describe the IUCN's "Evaluating Effectiveness: A Framework for Assessing Management of Protected Areas." This framework was important as it represents the lens through which we developed and organized our assessment of management effectiveness. In addition to our use of the IUCN framework, the principals of IWRM are described as they are a reference point in the discussion of management philosophies with the potential to effectively manage freshwater systems.

2.1 KEY ENVIRONMENTAL ATTRIBUTES

Karr (1986) developed the concept of KEAs to group factors that are critical to the maintenance of freshwater populations. These included: (1) energy source, (2) water quality, (3) flow regime, (4) biotic interactions, and (5) habitat quality. There is an extensive body of literature supporting the importance of these attributes as key drivers of freshwater ecosystem integrity (Higgins, unpublished). Karr et al. (1986) argues that altering the physical, chemical, or biological processes associated with any KEA has an impact on the integrity of stream biota and, as a result, perturbations of KEA associated processes must be identified in order to improve the biotic integrity of a steam ecosystem. To maintain ecosystem integrity all freshwater KEAs must be sustained within acceptable ranges.

Others have modified Karr's (1986) concept of KEAs to include broader set of environmental attributes. For example, Higgins (*unpublished*) uses a slightly modified group that includes: (1) hydrologic regime, (2) physical habitat, (3) water quality, (4) hydrologic regime, (5) connectivity, and (6) energy regime. This modification included adding "connectivity" as a KEA and changing "biotic interactions" to the more measurable component of "biotic composition." Higgins (*unpublished*) uses the concept of KEAs to hypothesize that the extent to which KEAs are secured by a PA is dependent on the overlap and proximity to freshwater ecosystems, their size and the proportion of a watershed they represent, and their drainage network position. For the purposes of this study, we have further modified the six KEAs to consist of (1) hydrologic regime, (2) physical habitat and energy regime, (3) water quality, (4) hydrologic regime, and (5) connectivity. Due to the data limitation and the relatedness of physical habitat with the components of energy regime (e.g. riparian vegetation provision of woody inputs and other allochthonous materials), the KEAs were combined.

2.1.1 WATER QUALITY

Changes in water quality variables known to signify human influence can be used to measure the relative effects of watershed influences and PA management. Impacts to water quality within human-influenced systems may include: (1) expanded temperature extremes, (2) increased turbidity, (3) altered diurnal cycles of dissolved oxygen, (4) increased nutrients (especially nitrogen and phosphorus), (5) increased solids, and (6) increased toxins, organic, and inorganic contaminants (Karr et al., 1986; Malmqvist and Rundle, 2002). Declines in water quality can result from industrial, residential, and agricultural sources that generate a wide variety of contaminants (Allan and Castillo, 2007).

Point sources of pollution include mine drainage, industrial effluent, waste disposal, and sewer systems. Despite improvements in waste water treatment plant technology, sewer overflows and losses from septic systems in urban areas contribute a significant amount of organic pollution to freshwater ecosystems, resulting in reductions in oxygen and increases in suspended solids. Organic contaminants, such as polychlorinated biphenyl (PCBs) and polycyclic aromatic hydrocarbons (PAHs), historically originated from industrial point sources but now originate from landfill seepage and waste incineration (Malmqvist and Rundle, 2002). These contaminants have effects on organisms through biomagnification. Toxic metals, such as Cu, Hg, Zn, Al, Pb, Cd, have been shown to originate primarily from mining operations, industrial gaseous emissions, or from landfill and sewage works, and can have significant physiological effects on freshwater organisms (Malmqvist and Rundle, 2002). Permitted sites from the United States Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) and facilities represented in the Toxic Release Inventory (TRI) can be used as indicators for point source pollutant sources. These sites indicate discharging facilities of various types including animal feeding operations, sewer and storm water overflows, and water pretreatment (Mattson and Angermeier, 2007).

Contaminants transported in urban and agricultural runoff are primary sources of nonpoint pollution to waterways. Such runoff transports sediments, nutrients, agricultural pesticides and herbicides, and various harmful substances (Allan and Castillo, 2007). Agriculture increases nutrient levels due to fertilizer and animal waste runoff and increases soil erosion, which particularly affects the transport of phosphorus (Allan and Castillo, 2007). Specifically, agricultural sources were responsible for 52% of total nitrogen and 47% of total phosphorus discharged into waterways in the United States (Gianessi et al., 1986). Urban areas can also be significant nutrient sources due to municipal wastes and fertilizers (Osborne and

Wiley, 1988). In addition to increases in contaminants, urbanization has been shown to have an effect on the temperature of streams as water entering streams can be significantly warmed during its passage over paved surfaces (Allan and Castillo, 2007).

2.1.2 HYDROLOGIC REGIME

Hydrologic regime, the magnitude and temporal distribution of flows in a stream system, is influenced by geology, topography, climate, and vegetation. Poff et al. (1997) described the major components of the flow regime as magnitude, frequency, duration, timing (or predictability), and rate of change (or flashiness) of water moving through a system. Because the physical, chemical, and biological components of a fluvial system are all impacted by hydrologic regime, it is an important indicator of ecological integrity. Thus hydrologic alterations, or modifications of the natural flow regime, have cascading effects on the ecological integrity of rivers (Poff et al., 1997).

The calculation of metrics indicative of flow regime is possible by tracking flow over a given period of time, as is done by the U.S. Geological Survey's utilization of continuous stream gauges. For example, the 10th percentile flow exceedance is the flow that is exceeded only 10% of the year, and thus represents a typical high flow. The 90th percentile flow exceedance is a flow that is exceeded 90% of the year, representative of a typical low flow. Minimum and maximum discharges can also be measured to understand flood and drought conditions. For example, a widely used low-flow metric is the 7Q10, defined as the seven day, consecutive low flow with a ten-year return frequency; the lowest stream flow for seven consecutive days that would be expected to occur once in ten years (USGS, 2009). Other metrics that provide insight into the flow regime of a given stream include: frequency and duration of high and low pulses, rise rate, fall rate, number of flow reversals, and magnitude of monthly low flows (TNC, 2009).

Watercourse exploitation, such as damming or the abstraction of water for agricultural, domestic or industrial purposes, directly alters the hydrologic regime of fluvial systems (Malmqvist and Rundle, 2002). Worldwide, the extent of alteration of river flow due to dams is staggering (Allan and Castillo, 2007). Dams often homogenize the flow of a stream system, causing deviation from naturally occurring seasonal high and low flows, and thus limits sediment transport (Thrush et al., 2000). Similarly, water abstractions and diversions have the potential to affect the natural flow variability and channel dynamics due to the reduced volume of water moving though the channel. Finally, land use change, particularly an increase in impervious surfaces, has been shown to dramatically alter hydrologic regime (Allan, 2004). Impervious surfaces prevent precipitation from percolating into soil and, as a result, water is conveyed from land to stream much more quickly. Increases in impervious surfaces have thereby been found to be associated with increases in flood magnitude and frequency, as well as lower baseflows as ground water plays less of a role in recharging the system (Allan, 2004).

2.1.3 CONNECTIVITY

Connectivity is defined as the longitudinal and lateral linkages necessary to maintain ecosystem process dynamics and provide movement among habitats and migration paths for biodiversity. According to Ward (1989), fluvial systems operate in four dimensions, longitudinal, lateral, vertical, and temporal. The longitudinal dimension corresponds to upstream-downstream connections, the lateral dimension corresponds to channel-riparian/floodplain connections, the vertical dimension corresponds to groundwater-channel-atmosphere connections, and the temporal dimension corresponds to changes in connectivity throughout time. Each of these connections affects ecological characteristics such as hydrologic regime, water quality, physical habitat, and energy regime in unique ways. For example, longitudinal variability yields zones of erosion, transfer, and deposition that define significant changes in processes and morphology and delimit distinctive riverine landscapes and habitats (Church, 2002). Lateral connectivity to the floodplain and backwaters is key to provision of seasonal habitats (e.g. spawning, feeding, winter refugia), lateral sediment and nutrient transport, and flood dissipation (Opperman et al, 2010).

Connectivity may be compromised by a number of human activities including shoreline development and channelization, which decreases lateral connectivity, or construction of dams, which obscure longitudinal linkages. Lateral connectivity may be evaluated by riparian and floodplain conditions, level of shoreline development, or field examination of lateral features such as oxbow ponds. Free-flowing stream miles may serve as a metric of longitudinal connectivity.

2.1.4 PHYSICAL HABITAT AND ENERGY REGIME

Physical habitat refers to the substrate and instream cover, channel morphology, riparian and bank structure of a stream reach. These components have been found to be directly pertinent to supporting aquatic communities as they indicate the availability of refugia, migration potential, and substrate type and stability (MDEQ, 2002). Impacts to physical habitat within human-influenced systems may include: (1) decreased stability of substrate and banks due to erosion and sedimentation, (2) more uniform erosion and sedimentation, (3) reduced habitat heterogeneity, (4) decreased channel sinuosity, (5) reduced habitat area due to shortened channel, and (6) decreased instream cover and riparian vegetation (Karr et al.1986). Indices of physical habitat have been developed for quantifying a habitat's ability to support biological communities (MDEQ, 2002). The most important biological habitat parameters are those characterizing bottom substrate and instream cover, embbededness, and water velocity (MDEQ, 2002). Other parameters, such as channel morphology, bank structure, and riparian structure, may be less direct and are often evaluated over a larger stream area (primarily upstream where upstream conditions have a greater impact on the study sites).

Physical habitat quality is directly affected by habitat alteration, which can be categorized into three broad categories: (1) altered hydrology, (2) channelization, and (3) land use practices (Allan and Castillo, 2007). As previously described, hydrologic regime can be altered by instream barriers such as dams, by water abstractions, or through the effects of land use change such as increases in impervious surfaces. Changes in natural hydrologic regime may lead to changes in a stream's ability to move and deposit sediment, thereby effecting channel shape and substrate conditions. For example, dams that release high discharges may cause scouring of fine materials and armoring of the streambed, a process in which the surface substrate becomes tightly compacted (Allan and Castillo, 2007). Land uses that affect habitat quality in streams may include increases in impervious surfaces, riparian clearing, or canopy opening. While increases in impervious surfaces affect physical habitat through their influence on hydrologic regime (flashier flows, higher peak flows, and lower base flows), riparian clearing or canopy openings have a more direct effect. Agriculture or other anthropogenic activities often extend to and affect the riparian area of a stream network, clearing forest canopy and altering bank stability. The loss of riparian vegetation is often accompanied by bank erosion and silt deposition (Hickey and Doran, 2004), decreases in the input of litter and wood, and lower retention of organic benthic matter owing to loss of direct input and retention structures (Allan, 2004).

Channelization also reduces habitat and substrate complexity (Malmqvist and Rundle, 2002). Historical and current land use practices in Michigan have left a network of drainage tiles and ditch networks designed to move water off of fields, or out of urban areas, and directly into freshwater systems often resulting in the need for deeper, straighter channels to convey storm flows (Allan and Castillo, 2007). Stream channels in agricultural and urban areas are often made wider, deeper, and straighter in order to convey greater stream flows (Allan and Castillo, 2007). On the other hand, large rivers are commonly modified for navigation, flood control, and utilization of floodplain land. This modification often occurs through deepening a main channel of a river and removing woody debris, resulting in a simplification and homogenization of habitat often attributed with loss of lateral connectivity in certain reaches of the system (Allan, 2004). Loss of large wood from freshwater systems is also associated with riparian zone clearing tied to agricultural practices or urbanization (Allan and Castillo, 2007).

2.1.5 BIOTIC COMPOSITION

The status and trends of freshwater biota are essential for quantifying human impacts and the effectiveness of management on freshwater ecosystems (Karr et al., 1986). According to Karr et al. (1986), impacts on freshwater biota can be manifested in several ways, including: (1) increased frequency of diseased fish, (2) altered primary and secondary production, (3) altered trophic structure, (4) altered decomposition rates and timing, (5) disruption of seasonal rhythms, (6) shifts in species composition and relative abundances, and (7) shifts in invertebrate functional groups.

In order to quantify the condition of biological assemblages, indices have been developed to integrate multiple indicators of biological condition at many levels of biological organization. Such indices have been developed for fish (Karr, 1981), macroinvertebrates (Kerans and Karr, 1994), and periphyton (Hill et al., 2000). Indices of biotic integrity are multi-metric, meaning they sum numerous individual metrics. Common metrics include percent of total species considered intolerant to environmental conditions, species richness and composition, and trophic composition. As such, biotic indices can serve as effective measures of stream health in response to human alterations to the physical, chemical, and biological components of an ecosystem.

Biological systems are integrators of all stresses to an environment and, as a result, all human activities that have an impact on hydrologic regime, connectivity, physical habitat and energy regime, and water quality have an impact on biotic integrity. For example, water quality impairments from point and nonpoint sources have a direct effect on biological communities through increased mortality rates, growth depression, reduced reproduction rates, endocrine system disruption, and physical avoidance of polluted areas (Allan, 2004). Similarly, increases in nutrients introduced to aquatic ecosystems have been found to be responsible for changes in food web structure resulting in altered nutrient ratios (Turner et al., 1998). Of all threats to biotic composition habitat alteration is considered to be the most significant (Allan and Castillo, 2007). Large portions of watersheds and streams are lost to migratory fishes because of anthropogenic barriers to movement such as dams which effectively decreasing access to high-quality habitat (Sheer and Steel, 2006). Even small-scale obstructions such as culverts can hinder fish movement as their outlets may be perched above the stream bottom or their barrels may create artificially high flow velocities (Love and Taylor, 2003). Habitat alteration, which includes clearing forest canopy and altering bank stability, may affect the riparian area of a stream. This disturbance to the riparian area is typically attributed with stream warming in summer months, increased primary production, and fewer energy inputs in the form of leaf and wood litter to the freshwater system. The absence of such inputs can have profound effects on biological diversity at the local level (Johnson et al., 1997).

Biological systems are also vulnerable to impacts from overexploitation and nonnative species. Nonnative species, those recognized to cause some degree of undesirable ecological, social, or cultural impact, are known as nuisance species and have become abundant since the colonization of the New World by Europeans. The impact of nonnative species has been variable; some nonnative species have little impact while others' contribution to species imperilment is second only to habitat loss (Allan and Castillo, 2007). Declines in native species following fish introductions occur via a number of mechanisms, including species interactions, habitat alterations, introduction of diseases or parasites, trophic alterations, and hybridization (Allan and Castillo, 2007).

Climate change will have important consequences for aquatic ecosystems due to changes in temperatures, flow regimes, riparian vegetation, disturbance intensity and frequency, water chemistry, and species interactions (Meyer et al., 1999). Future climatic impacts are likely, but much uncertainty remains partly because future climate conditions at regional and local scales are uncertain. Additionally, the complexity that results from climate change acting through multiple pathways, and the potential to interact with other threats to aquatic ecosystems, could result in compounded stress to the freshwater system.

2.2 INERNATIONAL UNION OF CONSERVATION OF NATURE

The IUCN's "Evaluating Effectiveness: A Framework for Assessing Management Effectiveness of Protected Areas," was developed as a set of guidelines through which the effectiveness of management activities could be evaluated. Management effectiveness, defined as the extent to which a PA confers the protection of values and achieves stated goals, centers around PA design, appropriateness of management processes, and achievement of PA objectives. In order for PAs to reach their full conservation potential, they must manage for the unique ecological values and services contained within the PA. Additionally, for management strategies to be effective, they must be tailored to the characteristics of the site in question, given that each PA is characterized by a unique set of biological and social characteristics, pressures, and uses (Hockings, 2006).

The determination of the effectiveness of management options utilized to preserve the integrity of a PA calls for an assessment based on an established framework for determining management effectiveness. The IUCN's framework stems from a mandate on the part of the World Commission on Protected Areas (WCPA) to develop a broad assessment for which a number of approaches for reviewing management processes could be included. The guide establishes six categories that must be evaluated to undertake a comprehensive evaluation of management activities: (1) Context, (2) Planning, (3) Inputs, (4) Process, (5) Outputs, and (6) Outcomes (Hockings, 2006). We will briefly describe how each IUCN category was used during our management analysis of federal and state PAs.

2.2.1 CONTEXT

The aspect of context assessment identifies the current status and threats affecting a given PA. The contextual analysis identifies the values and significance of the area, potential threats, social, economic, and political factors influencing management, and the stakeholders involved. By proving relevant background information, focus can be placed on the most important aspects within a given management strategy. The contextual assessment not only provides an understanding of the values and significance of a PA on a global, national, or local level but also the security of those values in relation to external threats and influences. The foundations for a context assessment include an examination of the values and significance of a PA, potential threats, external influences, and an understanding of the involved stakeholders and local communities (Hockings, 2006).

2.2.2 PLANNING

The undertaking of a planning assessment involves the examination of the adequacy of the PA in addressing conservation goals, the analysis of the design of the management plan, and the evaluation of gaps in the management process that result in inadequate PA conservation. This portion of the management analysis process considers the design features of the PA, the physical, legal, and institutional factors that determine and influence the implementation of management activities. Key criteria thus include PA legislation and policy, design, and management planning (Hockings, 2006).

2.2.3 INPUTS

The assessment of inputs is necessary to determine what resources are needed for management, if sufficient resources are being devoted to managing a PA site, and if the resources are being effectively allocated among the various management activities being undertaken. Multiple assessments of PA effectiveness have pointed to the conclusion that the level of resources available for management has a significant impact on the PA effectiveness. As this analysis is somewhat subjective, and every manager is likely to cite the need for additional resources, assessments must be developed to create an unbiased picture (Hockings, 2006).

2.2.4 PROCESS

A process examination is necessary in order to gain an understanding of how managers conduct the actual management of PAs. The assessment of management processes focuses on the definition of acceptable standards and best practices, decisions about which practices should be placed in terms of the contextual limitations of a given PA, an investigation as to whether the standards are being implemented and met, and recommendations as to whether the systems and standards are appropriate (Hockings, 2006).

2.2.5 OUTPUTS

An output assessment involves the analysis of the implementation of the management plan with specific focus on the results and outputs of management. The foundations for this assessment include the number or level of products and services delivered and the extent to which the stated actions, tasks, and strategies were implemented. Information concerning the outputs of a given management plan can generally be found through review of annual reports and monitoring review activities that are carried out by management officials (Hockings, 2006).

2.2.6 OUTCOMES

The final portion of the PA management assessment involves an analysis of the extent to which the stated objectives and desired outcomes of a selected PA are being achieved. This aspect measures the real effect of management actions with consideration to whether management activities are protecting the core values for which the PA was established. The focus is on the identification of desired outcomes, options for outcome evaluation and monitoring, whether socio-economic and cultural conditions remained constant or improved, and whether specific management objectives were achieved and threats abated (Hockings, 2006).

Since its inception in 2000, the IUCN framework has been widely accepted within the conservation community, firmly establishing its legitimacy in the field. For example, the World Wildlife Fund (WWF) has utilized the framework to develop the Rapid Assessment and Prioritization of Protected Area Management (RAPPAM), currently the most widely utilized approach to conduct rapid assessments of management effectiveness. The Catalan Institution for Natural History, United Nations Foundation, through its UNESCO/IUCN partnership, Metsahallitus Natural Heritage Services, World Bank, and New South Wales National Parks and Wildlife Service has also utilized the framework in the development of their own assessment strategies (Hockings, 2006). Unfortunately, most of these aforementioned frameworks have not served as models for assessments of freshwater protected areas internationally. Our focus on the freshwater components of PAs in Michigan is a promising study that has the potential to facilitate similar research endeavors to inform design and management decisions for PAs worldwide.

2.3 INTEGRATED WATER RESOURCE MANAGEMENT

Within a given catchment, various factors, including hydrological, geochemical, biological, political, cultural, and socio-economic, have the ability to impair water resources (Nakamura, 2003). Due to the interconnected nature of freshwater systems within a catchment, and thus the interconnectedness of stakeholders invested in the use of freshwater resources, conservation mangers and policymakers had to develop management procedures that sought to avert conflict, preempt unrest, and protect the vitality of water resources. In order to address these unique concerns, the approach of IWRM has been elevated as a potential means of managing the interconnectedness of freshwater systems (Global Water Partnership, 2009). An IWRM approach to freshwater conservation places focus on sustainable development that reflects a balance among:

- Economic efficiency: to ensure efficient allocation of water resources to strategically meet the needs of various economic sectors and users.
- Social equity: to ensure equitable access to water resources and associated benefits across gender, socio-economic status, and both within and across countries. Social equity concerns revolve around issues of entitlement, access, and control.
- Environmental sustainability: to ensure the protection of water resources and related aquatic ecosystems.

Multi-sector coordination is utilized in IWRM, across multiple functional scales, to establish effective management institutions and good governance systems that ensure equitable and sustainable decision-making processes (Carriger, 2009). In essence, this evolution towards the integration of IWRM represents a shift away from single purpose water management towards multi-purpose strategies (Nakamura, 2003).

The conceptualization of IWRM arose in response to the perceived failures of traditional management strategies to address the effects of divergent and often conflicting interests of water users. Integrated water resource management also provides the means to effectively coordinate other resource needs such as those of forest management, renewable energy production, and land use planning (Nakamura, 2003). According to Global Water Partnership, IWRM is not a revolutionary approach to resource management but an articulation of best practices and insights concerning good water resource management (Global Water Partnerships, 2009). As such, examples of catchment-level management are prevalent worldwide. For decades such countries as Spain, Senegal, Australia, the U.S., Canada, Mexico, Morocco, Algeria, Germany, and France have utilized such approaches. There are a number of case studies where IWRM has resulted in better outcomes, in terms of social and economic pressures, than traditional management alone (Carriger, 2009).

The process of IWRM begins with the identification of broad policy goals in order to articulate a common vision for the ideal catchment state. Next, problems relating to water management are identified and strategies developed to address the associated impairments to freshwater resources. To monitor progress towards meeting articulated goals and objectives, evaluation criteria must be developed. Following implementation of an established strategy, outcome-based evaluation criteria should be utilized to inform both areas of success and failure as well as to identify management strategies that need to be revised. The sum of these steps represents a cycle of adaptive management, or a "learning-by-doing" management cycle (Global Water Partnership, 2009). For the purposes of this study, IWRM will present one of several lenses through which management practices will be evaluated to determine the extent to which they are able to confer conservation.

3 METHODOLOGY

To assess the contributions of terrestrial PAs to freshwater KEAs we developed an approach to compare differing levels of protection, management activities, and human disturbances on KEAs in the Northern EDU. First, we conducted an analysis to determine the effect of areas under protection by all terrestrial PAs on KEAs. Second, we selected eleven PAs for an investigation of those PA management's ability to attend to freshwater conservation goals. Third, using the same eleven PAs, we investigated the relative influences of PA management and catchment stressors on KEAs.

3.1 STUDY AREA SELECTION

Study area selection was determined from a spatial analysis of the Michigan landscape. The intent was to find a region of Michigan containing a diversity of large PAs under different management with little natural variation in KEAs. For instance, comparisons of fish IBI between the northern part of the Lower Peninsula of Michigan and the southern part of the Lower Peninsula are tenuous given the differing geologies which create cool water streams in the north and warm water streams in the south. This leads to different assemblages of species, so comparisons of fish IBI scores between the regions can be problematic and misleading.

Using The Nature Conservancy's (TNC) concept of EDUs, we selected the Lake Michigan, Lake Huron, and Straits of Mackinac Environmental Drainage Unit (referred to here as the Northern EDU) of Michigan's Lower Peninsula as the region within which to select study PAs. These units are based on Hydrologic Unit Code classifications developed by the United States Geological Survey (USGS) and were adapted to GIS spatial data. Ecological drainage units are groups of watersheds that share ecological and biological characteristics and are defined using variables related to climate, landform, and both current and historic zoogeography.

The Northern EDU is characterized by a mean annual temperature ranging from 43.4 to 46.1 degrees Fahrenheit and a mean annual precipitation of 29.5 to 33.1 inches (TNC, 2001). This study area is 41,141 square kilometers. Its major landforms consist of outwash plains and ice contact features, coarse textured end and ground moraines, drumlin fields in the west, and lacustrine sands in the east and near the Great Lakes shoreline (TNC, 2001). Surface water features consist of kettle lakes in outwash plains, few large lakes, intermittent streams in the lake plain, and many groundwater-fed streams in outwash surrounded by coarse moraines and ice contact (TNC, 2001). The drainage pattern of the Northern EDU roughly bisects the land area, and thus rivers in the west drain to Lake Michigan and those in the east to Lake Huron.

3.2 EFFECT OF AREA UNDER PROTECTION BY ALL TERRESTRIAL PROTECTED AREAS ON KEY ENVIRONMENTAL ATTRIBUTES

Protected areas often contribute benefits beyond their boundaries. In order to account for the range of upstream land use conditions, analysis of total percent protected for each data point was performed to detect a relationship between response variables and total percent of catchment protected upstream PAs. First, we gathered response variable data for each KEA across the Northern EDU. Next, data point-specific catchments were drawn to determine percent of area protected. Finally, we used a linear regression model to explore the relationship between percent of catchment protected and response variable values.

3.2.1 FRESHWATER RESPONSE VARIABLES

To assess the influence of percent of catchment protected, variables representing each KEA (response variables) were determined and collected at sites across our study area (see Table 3.1). Selection of specific response variable data points were further determined by location within each study PA's watershed. Watersheds were delineated from a 90-meter DEM using ArcHydro tools with ArcGIS 9.3ArcHydro 9.3 (see Figure 2, Pane A).

Table 3.1 Response variables used for each key ecosystem attribute and sources of data used in this study (Michigan Department of Natural Resources = MDNR, Michigan Geographic Data Library = MGDL, United States Geological Survey = USGS, Michigan Department of Environmental Quality = MDEQ)

KEA	Response Variable	Data Source
Biotic Composition	Index of biotic integrity for coldwater fish	MDNR
	Percent of total fish considered intolerant to anthropogenic stress	MDNR
Connectivity	Free flowing stream miles	MGDL
Physical Habitat/Energy Regime	Habitat quality score	MDEQ
Hydrologic Regime	Rise Rate/ Fall Rate; Average rate of flow response	USGS
	Water Withdrawal Assessment Tool Low Flows v. Mean August Low Flows	MDEQ, MDNR, USGS
Water Quality	Nitrite + nitrate (NO_2+NO_3)	MDEQ
	Total phosphorus	MDEQ

Two variables were used in our study as a measure of biotic composition, an index of biotic integrity (fish IBI) for fish assemblages in coldwater streams and the percent of all species collected considered to be intolerant to anthropogenic impacts (percent species intolerant). The fish IBI, developed by Lyons et al. (1996), is calculated using five metrics: (1) number of intolerant species, (2) percent of all individuals that are tolerant species, (3) percent of all individuals that are top carnivore species, (4) percent of all individuals that are native or exotic stenothermal coldwater or coolwater species, and (5) percent of salmonid individuals that are brook trout (*Salvelinus fontinalis*; see Appendix 1 for scoring criteria). The MDNR provided data for both variables for stream reaches throughout our study sites.

We used nitrite plus nitrate (NO_2+NO_3) and total phosphorus (TP) as a measure of water quality in our study. Data were obtained from the EPA's STORET Database (EPA, 2009), and were originally collected by the MDEQ. These samples were collected over the spring and summer months (May, June, July, and August) from 2000-2008.

As a measure of physical habitat and energy regime, a MDEQ habitat score was used in our study. This score is based on surveys that examine three major components of a stream reach: (1) substrate and instream cover, (2) channel morphology, and (3) riparian and bank structure (see Appendix 2 for scoring criteria). Habitats were surveyed and scored by the MDEQ using Great Lakes and Environmental

Assessment Section (GLEAS) Procedure 51 Survey Protocols for Wadeable Rivers (MDEQ, 1997).

As a measure of connectivity, the number of dams per stream length was calculated as an estimation of free flowing stream miles. Data were obtained from the USGS National Hydrography Dataset (NHD) for rivers and streams, and from the MDNR for dams and barriers ranging in height from 1 - 90 feet. Though road crossings were considered as an additional limitation to connectivity, we could not establish with confidence the degree individual road crossing affect connectivity and did not include this variable.

Hydrologic regime and alterations thereof were assessed through two approaches. First, TNC's Indicators of Hydrologic Alteration (IHA) tool (TNC, 2009) was applied to USGS data sets for gauge sites within PA catchments with over 20 years of daily data (USGS, 2010). This yielded the number of reversals and rise and fall rates as indicators of hydrologic alteration. The rise rate and fall rate were averaged to estimate an average rate of flow response. Second, as an estimation of expected low flow versus measured low flows, the mean August low flow calculated through the IHA tool was compared to the expected low flow estimated by the Beta Version of the Water Withdrawal Assessment Tool (WWAT) developed by MDEQ, MDNR, USGS, and the Institute of Water Research (IWR, 2006; Konrad, personal communication, March 4, 2010).

3.2.2 DELINEATION OF RESPONSE VARIABLE POINT CATCHMENTS

For each data point used as a response variable, catchments were delineated from a 90-meter DEM using ArcHydro tools with ArcGIS 9.3. The percent of its catchment occupied by the all terrestrial PAs was then calculated using the Conservation and Recreational Lands (CARL) database, a GIS layer containing PAs within the Great Lakes region (TNC, 2007). This database contains such recreational lands as golf courses, country clubs, and gravel pits, though we excluded this last category as they are not considered PAs under IUCN's definition (IUCN, 2004). See Figure 2, Pane B for an example response data point and its catchment boundary; see Appendix 3 for maps of all study PAs and response data points.

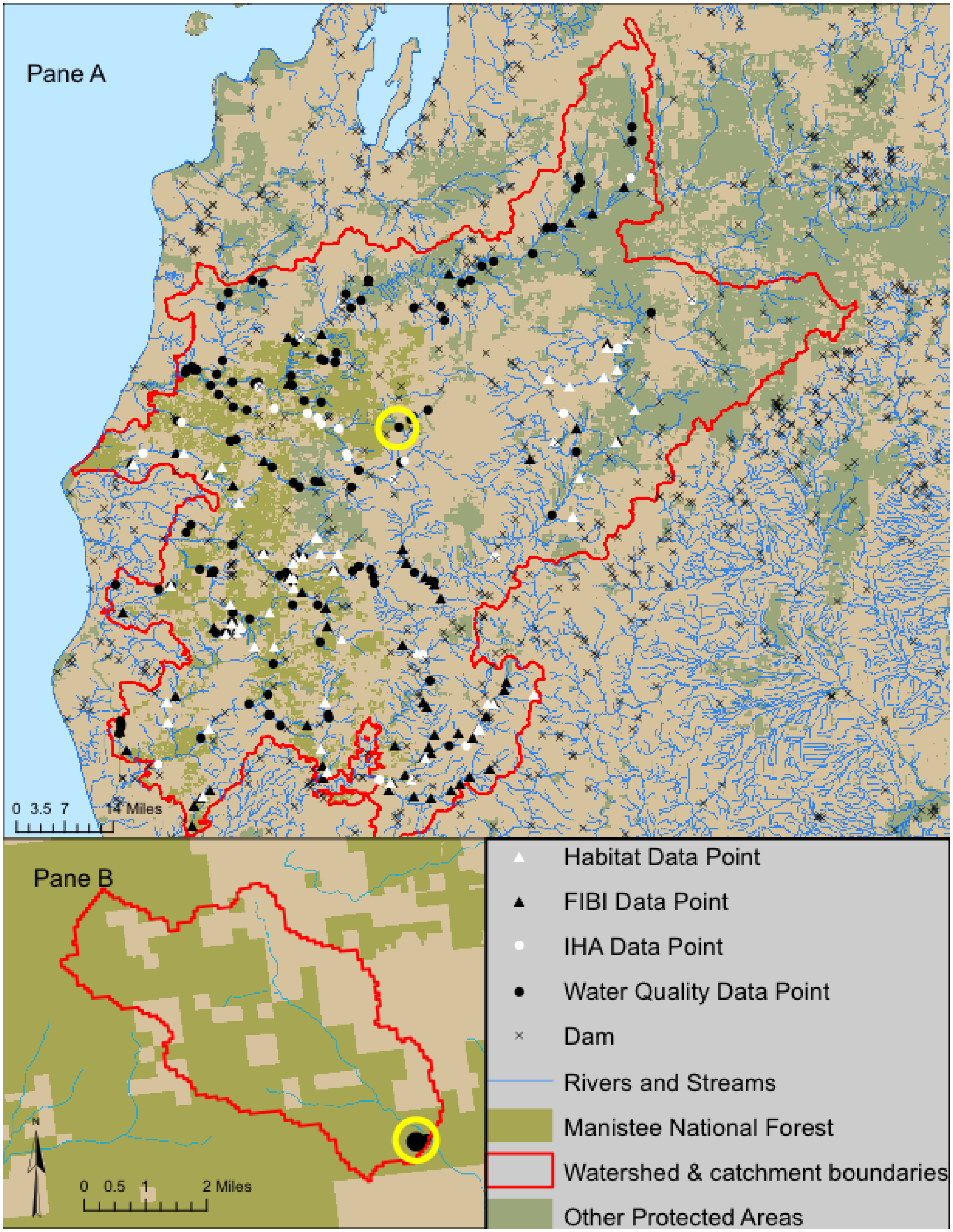

Figure 2. The delineation of study protected area watershed for Manistee National Forest (Pane A), with response data points. Pane B illustrates a sample response variable data point catchment (highlighted in yellow in both panes).

3.2.3 STATISTICAL ANALYSIS

A linear regression was used to test the influence of percent catchment protected upstream on KEA response variable values. The overall distribution of each response variable (i.e. fish IBI, nutrient concentration, habitat quality score, etc.) was checked for normality, and when data were skewed, a log transformation was performed to normalize the data to facilitate statistical analysis.

Response variables belonging to each of the five KEAs: water quality, hydrologic regime, connectivity, physical habitat and energy regime, and biotic composition were regressed against percent of catchment protected by all terrestrial PAs. Resulting p-values and t-statistics were used to identify the significance and type of effect percent catchment protected had on the response variables.

3.3 EVALUATING PROTECTED AREA MANAGEMENT

To determine the extent management activities influence freshwater conservation goals, we also evaluated management effectiveness. This assessment utilized the IUCN's "Evaluating Effectiveness: A Framework for Assessing Management Effectiveness of Protected Areas" to guide the development of a questionnaire surveying PA managers on specific actions that could directly or indirectly impact freshwater systems. Questions developed for the management questionnaire were classified by which KEA they pertained to. The questionnaire was then used, along with information collected through follow-up phone interviews, to create management narratives, which qualitatively assess PA management .

3.3.1 PROTECT AREA SELECTION

Within the Northern EDU, PAs were selected from TNC's CARL database. From all of the Federal- and State- owned PAs within the Northern EDU, we randomly selected eleven, offering a variety of management types and contexts. These PAs included Atlanta State Forest Area, Cadillac State Forest Area, Gaylord State Forest Area, Grayling State Forest Area, Huron National Forest, Manistee National Forest, Manistee River State Game Area, Traverse City State Forest Area, Pigeon River Country State Forest Area, Fisherman's Island State Park and Wilderness State Park (see Figure 3). The two national forests in our study are overseen by the United States Department of Agriculture's Forest Service and managed jointly under a single planning body. The state PAs are overseen by the MDNR, which has recently (2010) merged with the MDEQ to form the Michigan Department of Natural Resources and Environment (MDNRE).

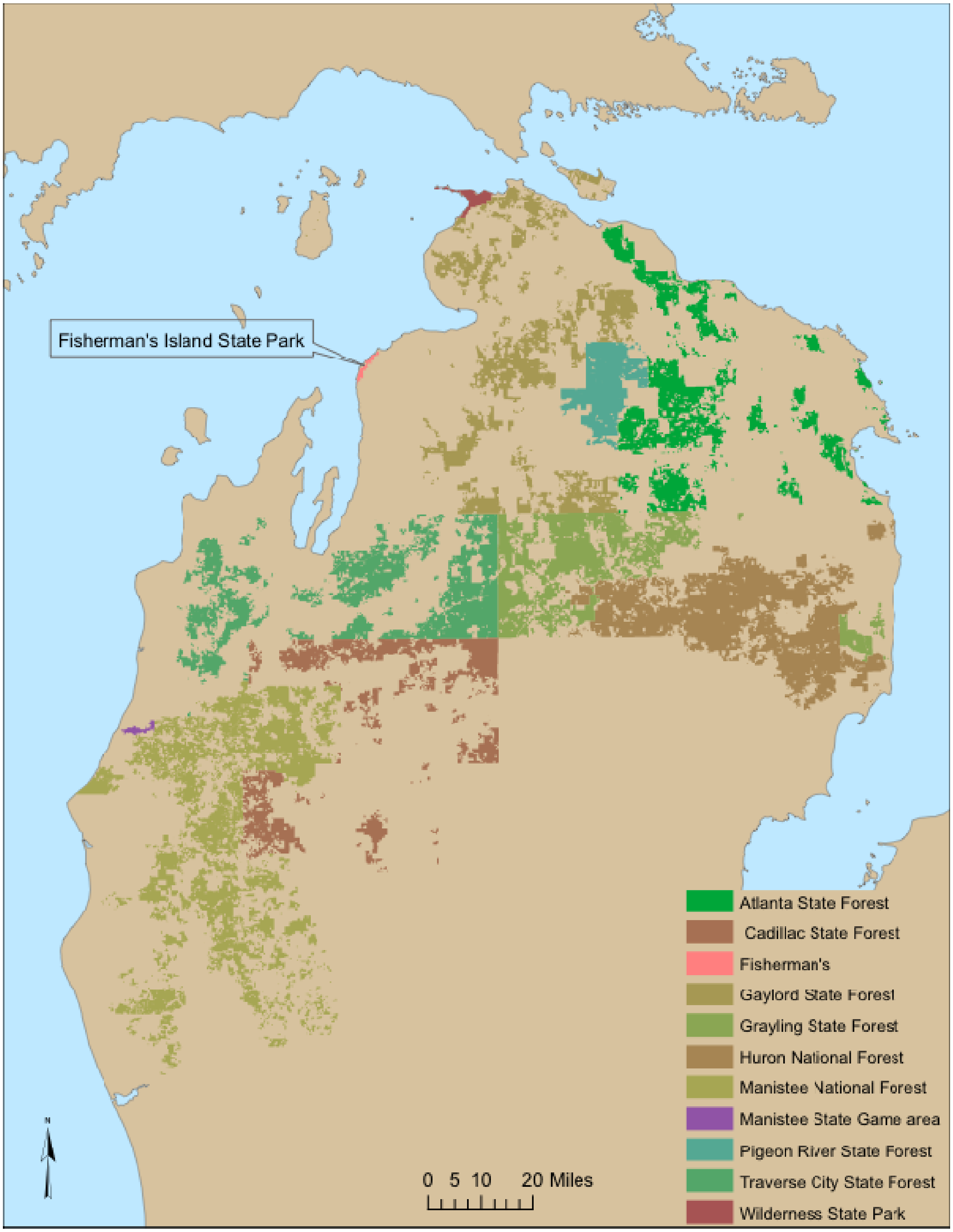

Figure 3. Northern Ecological Drainage Unit protected areas evaluated in this study.

3.3.2 QUESTIONNAIRE DEVELOPMENT

The questionnaire was divided into three master questions, each supported by a matrix of response options. The first two master questions utilize the IUCN's context category and ask PA managers to rank internal (within PA) and external (outside of PA) threats by "no alteration, low alteration, moderate alteration, high alteration, unsure, or not applicable". The third master question prompted PA managers to identify specific management activities used to protect or restore freshwater KEAs. Protected area managers were asked to respond to this question by classifying the extent to which the management activities are implemented by "often, occasionally, rarely, never, unsure, and not applicable". See Appendix 4 and 4 for complete questionnaire and results. The selection of potential threats and respective management activities was developed through a literature review of the five KEAs. The following overview describes the threats and activities that likely affect the condition of that KEA:

I. Connectivity: Questions were asked concerning the extent to which the effects of channelization, dam presence, impassable culverts, levees, the intersection of road networks and streams, shoreline development, surface and groundwater withdrawals, and weirs impacted freshwater conservation activities. Additionally, the management activities of culvert removal and upgrade, installation of fish passages and ladders, education programs, removal of dams, removal of weirs, removal of levees, restoration of channel shape, size and sinuosity, and riparian buffer restoration were identified as potential management strategies potentially utilized to restore channel connectivity (Smith et al., 2008; Gomez et al., 2007; Freeman et al., 2007; Pringle, 2001; Poff et al.,1997).

II. Biologic Composition: Questions were asked concerning the extent to which invasive species, species exploitation, stocking of species, and boating activities were identified as potential threats to freshwater biological composition within a PA. Identified management activities to address such threats include fishing regulation and enforcement, installation of fish ladders/passages, installation of levee bypasses, education programs, invasive species management, post disturbance re-vegetation, prohibition of species extractions, recovery of native species, stocking of native species, and use of physical barriers to prevent exotic colonization (Gomez et. al., 2007).

III. Water Quality: Questions were asked concerning the extent to which acid mine drainage, industrial discharge of organic or inorganic chemicals, municipal sewage discharges, nutrient loading, nonpoint source runoff from impervious surfaces, land use practices, thermal pollution, on-site sewage discharges from tourist infrastructure, gravel mining, hiking and camping activities, off road vehicle erosion or pollution, and filling of wetlands impaired freshwater systems. Management activities utilized to counter threats to water quality included acid mine drainage remediation, erosion control methods, education programs, promotion of forest best management practices, reduction of impervious surfaces, riparian buffer restoration and creation, road construction and maintenance best management practices, in stream habitat practices, storm water management, stream bank stabilization, upgrade of septic system to performance standards, and wetland restoration (Alexander and Allan, 2006; Malmqvist and Rundle, 2002; Allan and Castillo, 2007).

IV. Hydrologic Regime: Identified threats to hydrologic regime included channelization, dam presence, filling of wetlands, impassable culverts, levees, the intersection of road networks and streams, storm water outfalls, surface and ground water withdrawals, timber extraction, and weirs were identified as potential threats. Management activities utilized to address issues relating to degradation of hydrologic regime included culvert removal, education programs, post-disturbance re-vegetation, removal of dams, weirs, or levees, restoration of channel shape, size or sinuosity, and storm water management activities (Smith et al., 2008; Gomez et al., 2007; Freeman et al., 2007; Pringle, 2001; Poff et al., 1997).

V. Physical Habitat: Identified threats to physical habitat included channelization, dam presence, filling of wetlands, gravel mining, impassable culverts, levees, shoreline development, storm water outfalls, surface and ground water withdrawals, timber extraction, weirs, loss of natural riparian vegetation, hiking and camping, boating activities, off road vehicle erosion or pollution, the intersection of road networks and streams, nonpoint source pollution from impervious surfaces, thermal pollution, and filling of wetlands were all identified as potential threats to the integrity of physical habitat within the PA's freshwater resources. Management activities utilized to address physical habitat included culvert removal or upgrade, erosion control methods, education programs, post-disturbance re-vegetation, promotion of forest best management processes, reduction of impervious surfaces, removal of dams, weirs, or levees, restoration of channel size, shape, or sinuosity, storm water management, stream bank stabilization, and wetland restoration (Smith et al., 2008; Scottish Environmental Protection

Agency, 2003; Raven et al., 2000; State of California Department of Water Resources, 2009).

Energy Regime: Losses of riparian forest corridor cover and associated large woody debris inputs, and altered hydrology are threats. Management activities that could mitigate for altered energy budgets include post-disturbance re-vegetation, promotion of forest best management processes, reduction of impervious surfaces, and stream bank stabilization (Roberts, 2003 ; Sponseller, 2001; Oelbermann & Gordon, 2000; Stout, 1982).

3.3.3 INTERVIEW DEVELOPMENT

In addition to the questionnaire, we interviewed PA managers to gain a better understanding of the role of freshwater conservation in management activities. The interview was developed to understand high-level management goals and objectives as well as the manner in which management activities relating to freshwater conservation are undertaken. As such, interview questions were the primary means of assessing not only the context category of the IUCN framework but also the categories of planning, process, inputs, outputs, and outcomes. Information from the IUCN's "Evaluating Effectiveness: A Framework for Assessing Management Effectiveness of Protected Areas" and "Strategic Approaches to Freshwater Management: Background Paper – The Ecosystem Approach" were used to inform the development of interview questions (IUCN, 1998; Hockings et al., 2006). Finally, the WWF's "Rapid Assessment and Prioritization of Protected Areas Management Methodology" and "Southeast Freshwater Management Survey" guided question development and helped us identify areas of importance in relation to freshwater conservation goals (Thieme and Rudulph, 2009; Ervin, 2003). See Appendix 6 for the list of interview questions.

3.3.4 QUESTIONNAIRE AND INTERVIEW PROCESS

The questionnaire was distributed to all eleven PA managers in both electronic and hard copy formats. Once the results of the questionnaire were returned and reviewed, we scheduled phone interviews with one or more members of each PAs management staff, including national and state forest planners, state park managers, fisheries biologists, and wildlife biologists. This interview enabled us to pinpoint areas for follow-up questions in addition to the pre-determined set of high-level management questions. For instance, if the questionnaire indicated that invasive species were a large threat, related questions could be posed in the interview.

3.3.5 CASE STUDY DEVELOPMENT

Information gathered from both the questionnaire and interviews were utilized to qualitatively assess the extent managers address freshwater needs. A narrative was created for each PA that compares external and internal threats to management activities to determine if managers are adequately (i.e. selecting "Often" or "Occasionally") addressing the external and internal threats they themselves indicated to be of highest concern (i.e. those marked High or Medium Alteration). For example, if a manger identified the threat of culverts as "high levels of alteration," complementary management would include culvert removal or upgrade on either an "Often" or "Occasional" basis. Finally, responses from the interview were used to determine how freshwater conservation goals are integrated within existing management activities, as well as potential limitations in this area for PA managers.

3.3.6 PUBLICATIONS USED FOR CASE STUDY DEVELOPMENT

We used the following publications to inform our management narratives, with specific focus on the degree to which freshwater conservation goals are included in agency-wide management plans and the extent to which the actions of PA managers are aligned with site and agency level management plans.

3.3.6.1 SUSAINABLE SOIL AND WATER QUALITY PRACTICES ON FOREST LAND

Prior to the recent merger of the MDNR and MDEQ (2010), the "Sustainable Soil and Water Quality Practices on Forest Land" manual governed much of Michigan's management activities relating to freshwater bodies (MDNR & MDEQ, 2009). We used this document as a reference to inform strategies employed by PA management (MDNR & MDEQ, 2009). This manual describes a set of voluntary Forestry Best Management Practices (BMPs) that protect soil and water resources while allowing use of forest resources. This document provides policies and procedures in the following categories for the protection and conservation of freshwater ecosystems, biodiversity, and aquatic species:

- Forestry Best Management Practices (BMPs; timber harvesting & equipment operations) allowed within Riparian Management Zones (RMZs)
- Activities permitted along designated Natural River Areas (State-protected river reaches)
- Forest road construction policies for the protection of water quality
- Stream crossings

- Permitted activities in wetland areas
- Sedimentation control

All rivers and streams found in our selected PAs were designated by the State as coldwater trout streams. The "Sustainable Soil and Water Quality Practices on Forest Land" publication has specific policies directed towards management practices for coldwater systems in the northern lower peninsula and upper peninsula of Michigan.

3.3.6.2 STATE AND FEDERAL PROTECTED AREA MANAGEMENT PLANS

Where possible, management narratives included a review of PA management plans to assess the manner in which freshwater conservation activities had been articulated. Additionally, management plans were utilized to supplement self-reported information and to determine the alignment between stated responses, from both the questionnaire and interview, and management goals, as specified by the management plan. Discussion with PA managers indicated that the MDNR is currently working on the "Northern Lower Peninsula Regional State Forest Plan" which will guide all future management activities for State Forest Areas including those directed towards freshwater systems; however, it is still in draft format and thus unavailable for review. In addition, State Parks are also involved in a coordinated effort to update management plans.

3.4 INVESTIGATION OF THE RELATIVE INFLUENCES OF PROTECTED AREA MANAGEMENT AND CATCHMENT STRESSORS ON KEY ENVIRONMETNAL ATTRIBUTES

Next, we examined the relative influences of management activity and catchment stressors on KEA response variables. Using catchments delineated from response variable data point locations, we calculated the percent protected by a study PA, a measure of catchment condition, and measure of management activity for that study PA.

3.4.1 CALCULATION OF PERCENT PROTECTED BY A STUDY PA WITHIN RESPONSE VARIABLE DATA POINT CATCHMENTS

Within each response variable catchment (see Section 3.2.2) the percent of its catchment occupied by a study PA was calculated. See Figure 2, Pane B for an example response data point and its catchment boundary; see Appendix 3 for maps of all study PAs and response data points.

Protected areas varied in the number of response data points they contained. Some of the smaller PAs were represented by relatively few or no data points for individual response variables. In fact, Wilderness State Park and Fisherman's Island State Park had too few available response data to allow quantitative analyses.

3.4.2 RESPONSE VARIABLE NORMALIZATION AND SCORING

To achieve a relative comparison of response variables across disparate geographies and land areas, data were normalized and scored. When possible, each PA's response variable values were averaged and recorded. This range was segmented into quartiles using Predictive Analytics SoftWare (PASW) to yield comparative determinations of response values across the PAs. These quartiles were then converted to scores on the scale of one to four (1-4), with a higher response variable score reflecting a comparatively higher indication of ecological integrity. For example, total phosphorous concentrations ranged from 0.066 to 3.200 milligrams per liter before averaging was performed. Then PA-specific total phosphorous values were averaged and split into quartiles (0.0112 to 0.0126, 0.0127 to 0.021, 0.022 to 0.0244, and 0.0245 to 0.028) and scored. The first quartile (0.0112-0.0126) received a score of four (4) as lower phosphorous concentrations signify less human impact (Allan and Castillo, 2007) while the fourth quartile (0.0245-0.028) received a score of one (1) indicating high phosphorous concentrations, reflective of an adverse ecological impact. It should be noted that these comparisons are relative and a score of one (1) does not necessarily mean that the response variable is indicative of a negative response, but rather that it is lower comparatively. Assumptions supporting the scoring protocol are included in Table 3.2 below.

Table 3.2 Quartile assignment and assumptions used in the determination of quartile values to assign for each Key Ecosystem Attribute response variable

KEA	Response Variable	Quartile = Score	Assumptions
Water Quality	Nitrate + Nitrate (mg/L)	Q1 = 4, Q2 = 3, Q3 = 2, Q4 = 1	Higher mg/L of Nitrogen are harmful to the system.
Water Quality	Total Phosphorous (mg/L)	Q1 = 4, Q2 = 3, Q3 = 2, Q4 = 1	Higher mg/L of Phosphorous are harmful to the system.
Biotic Composition	Fish Index of Biotic Integrity	Q1 = 1, Q2 = 2, Q3 = 3, Q4 = 4	Higher IBI scores are indicative of high ecological integrity.
Biotic Composition	Percent Intolerant Species	Q1 = 1, Q2 = 2, Q3 = 3, Q4 = 4	Higher percentages of intolerant species are indicative of reduced ecological integrity.
Hydrologic Regime	Average Flow Response Rate (Rise and Fall Rates cubic feet/second)	Q1 = 4, Q2 = 3, Q3 = 2, Q4 = 1	Higher values reflect increased response rate, a proxy for flashiness, and may be indicative of reduced ecological integrity. (Note: this metric does not account for natural flashiness.)
Hydrologic Regime	Low Flow Expectation (WWAT Expected – August Low Flow Observed)	Q1 = 4, Q2 = 3, Q3 = 2, Q4 = 1	Higher values indicate a greater difference (positive or negative) between observed and expected low flows. Where observed low flow values do not match estimations produced by the State's WWAT model, there is a mismatch of management assumptions and ecological reality.
Physical Habitat and Energy Regime	Habitat Quality Score	Q1 = 1, Q2 = 2, Q3 = 3, Q4 = 4	Higher habitat ratings are indicative of high ecological integrity.
Connectivity	Stream miles per Dam	Q1 = 1, Q2 = 2, Q3 = 3, Q4 = 4	Longer stretches of free flowing stream miles are positively related to ecological integrity.

3.4.3 FRESHWATER STRESSOR VARIABLES

For each delineated catchment of a response variable data point within a PA's overall watershed, we identified the key landscape conditions and human development characteristics which are sources of stress on freshwater systems using the work of Danz et al. (2007) and Smith et al. (2008) as guiding frameworks. Existing sources of geospatial data containing attributes that could be used as proxies of landscape stressors were identified and compiled (see Table 3.3 for stressor components, unit calculated, and source of data). Stressor proxy variables included: number of dams, number of NPDES permits, number of TRI facilities, road density, average free flowing stream miles, number of wells, and number of large scale water diversions. From these source data layers, we normalized the data to reflect the relation of each stressor variable to the scale of data point catchment area. This allowed comparisons between catchments of different sizes. For instance, dams were quantified as density per stream mile, road density was calculated to total distance per catchment area, and NPDES permits were expressed as number per catchment area.

Table 3.3 Stressor variables used in quantification of catchment stress on key ecosystem attributes of the freshwater systems of study PAs. GIS data layer, unit calculated, and source of data are indicated (MDNR = Michigan Department of Natural Resources; MGDL = Michigan Geographic Data Library)

Stressor component	Data Layer used	Unit Calculated	Source of data layer
% Agriculture in catchment	IFMAP Landcover 2002	% area in agriculture of some form	MGDL
% impervious surface in catchment	IFMAP Landcover 2002	% of area considered to be impervious	MGDL
% Agriculture in riparian zone (100m)	IFMAP Landcover 2002	% agriculture within 100 meter buffer of stream	MGDL
% Impervious surface in riparian zone (100m)	IFMAP Landcover 2002	% impervious surface within 100 meter buffer of stream	MGDL
Population Density	Urban centers layer	population of urban areas/catchment area	MGDL
Toxic Release Inventory Facilities	TRI	# TRI / catchment area	MDNR
Road Crossings	MI Geographic Framework all roads data layer	# crossings/catchment stream mile	MGDL
Road density	MI Geographic Framework all roads data layer	# meters of road/catchment area	MGDL
Dam density	Dams location layer	# dams/catchment stream mile	MDNR
NPDES permit density	NPDES permit location layer	# permits issued/catchment area	MDNR
Well Density	Wells Complete Database	# wells per catchment area	MGDL
Density of Large Scale water Diversions	Non-agricultural Groundwater Use	# large scale diversions/catchment area (industrial, golf course, power plant)	MGDL

To further understand the landscape context of each data point catchment and associated stressors, we examined the land cover for the catchment and riparian corridor (within 100 meters of streams) based on the GIS-based 2002 Integrated Forest Monitoring, Assessment, and Prescription (IFMAP) of Michigan, created by MDNR (MDNR, 2002). Land cover attributes quantified from this GIS layer included: percent area impervious surface, percent area in agriculture, percent area urban, percent area natural cover, percent area pasture, and percent area in row crops.

Quantification of impervious surface was calculated by classifying dense urban cover, roads and airports as 100% impervious, low density urban cover as 60%, parks cover as 20% impervious, and every other land cover category as 0% impervious. Percent area in agriculture cover included non-vegetated farmland, row crops, and orchards/vineyards/nurseries. Percent urban contained low density, high density, airports, and roads categories of land cover. Percent area natural cover included herbaceous open land, upland shrub, all forests, and all water/wetlands. Pasture consisted of non-vegetated farmland, forage crops, and herbaceous open land. This rough method of calculating impervious surface was deemed adequate for our need (i.e. for relative comparison), though more refined calculations could be made.

3.4.4 DETERMINING COMPONENTS OF THE KEA-SPECIFIC CATCHMENT CONDITION SCORE

Catchment Condition Scores (CCSs) were developed on KEA-specific basis to assess the cumulative influence of stressors on response variables across the PAs. The KEA-specific CCS aggregates and quantifies the subset of stressors identified as having a negative influence on a particular KEA. In order to identify interrelated variables, a test for covariance was performed amongst all combinations of potential stressor variables. Any stressors directly correlated were narrowed down to the use of just one from the pair. All of the correlation between stressor variables fell within the differing land cover categories. To eliminate this problem, percent agriculture and percent impervious surface were selected to be representative of the landscape, as they have the greatest potential to influence response variables. We determined that the CCS stressor variables should include: The final pool of stressor variables that could be selected from to compose the CCS were determined to be: well density (# of wells/catchment area), large scale diversion density (# diversions/catchment stream mile), TRI site density (#sites/catchment area), density of NPDES permits (# NPDES permits issued/catchment area), road crossings (number of road crossings/stream mile), road density (meters/catchment area), population density (population of urban areas/catchment area), percent agriculture (area in agriculture/catchment area), percent of riparian corridor in agriculture (area of riparian corridor in agriculture/catchment area), percent impervious surface (area of catchment likely impervious/catchment area), percent of riparian corridor impervious (area of riparian corridor likely impervious/catchment area). The components of landscape stressor data included for KEA-specific CCSs are presented in Table 3.4.

Table 3.4 The designation of stressor variables comprising the KEA-specific Catchment Condition Scores used in the creation of the Freshwater Activity Matrix

Stressor Variables	Water Quality	Biotic Composition	Physical Habitat	Connectivity	Hydrologic Regime
Toxic Release Inventory Sites per m2		x			
NPDES Facilities per m2 of Catchment		x			
Large Scale Withdrawals per m2 of Catchment		x	x	x	x
Roads Meters per Catchment	x	x	x	x	x
Wells per m2 of Catchment		x			x
# of Road Crossings in Catchment	x	x	x		x
Population of Urban Center(s) Present in Catchment Area	x	x	x		x
Catchment % Ag.	x	x	x		x
Catchment % Impervious	x	x	x		x
Riparian Corridor (100m buffer) % Ag.	x	x	x		x
Riparian Corridor (100m buffer) % Impervious	x	x	x		x
Dam Density	x	x	x	x	x

3.4.4.1 STRESSOR VARIABLE NORMALIZATION AND SCORING TO QUANTIFY CATCHMENT CONDITION

Catchment Condition Scores (CCSs) were created from stressor data to allow relative comparisons of individual stressors to response data point catchments. Not all response data point catchments associated with a study PA were used in this analysis. Those catchments existing fully upstream from a study PA (though within the PAs watershed) were excluded because they weren't relevant to our PA-based assessment model.

Original stressor values for each point-specific catchment were segmented into quartiles representing the full range of values across the Northern EDU and scored with a one (1) indicating high stress and a four (4) indicating low stress on response variables. These values were then averaged to yield a normalized stressor score for each stress category, across each PA, relative to each KEA category. To calculate CCSs, the normalized stressor scores were then averaged for each PA. Tables 3.5 and 3.6 illustrate the process of quantifying CCSs for water quality KEA across the study PAs.

Table 3.5 Average of all individual stressors affecting water quality data point catchments. Values are used to determine quartile based scores as in Table 3.6, then Water Quality-Catchment Condition Scores (last column of Table 3.6)

Protected Area (Sample size of water quality response variable data points)	Roads Meters per area (m2) of catchment	# of Road Crossings per area (m2) of catchment	Population of Urban Center(s) per catchment area m2	Dam density (#/ stream meter) in catchment	Catchment % area in agriculture	Catchment % area impervious surface	Percentage Agriculture in riparian corridor (100 m buffer)	Percentage riparian corridor (100 m buffer) Impervious
Atlanta SFA (33)	0.07	0.03	0.00	0.10	19.83%	6.40%	2.46%	11.40%
Cadillac SFA (36)	0.13	0.07	0.04	0.14	12.99%	2.73%	4.75%	3.10%
Gaylord SFA (76)	0.13	0.02	0.01	0.08	8.49%	3.28%	8.88%	2.76%
Grayling SFA (14)	0.13	0.09	0.02	0.17	3.88%	2.48%	4.73%	1.09%
Huron NF (12)	0.09	0.17	0.03	0.27	4.00%	1.62%	13.17%	1.36%
Manistee NF (123)	0.22	0.09	0.06	0.06	18.92%	3.65%	11.35%	4.15%
Manistee SFA (60)	0.11	0.75	0.15	0.09	2.33%	5.75%	4.12%	1.00%
Pigeon River Country SFA (21)	0.10	0.02	0.03	0.08	3.08%	2.09%	6.69%	0.89%
Traverse City SFA (28)	0.11	0.03	0.02	0.02	30.68%	1.83%	2.59%	1.73%

Table 3.6 Quartile scores resulting from normalization of water quality stressor average values across the Northern EDU, with resultant Water Quality Catchment Condition Score (4= high, 3= medium high, 2= medium low, 1= low)

Protected Area (n)	Roads Meters per area (m2) of catch.	# of Road Crossings per area (m2) of catch.	Population of Urban Center(s) per catch. area m2	Dam density (#/ stream meter) in catch.	Catch. % area in Ag.	Catch. % area impervious surface	Percent Ag. in riparian corridor (100 m buffer)	Percent riparian corridor (100 m buffer) impervious	Water Quality CCS
Atlanta SFA (33)	4	3	4	2	1	1	4	1	1.5
Cadillac SFA (36)	1	2	1	5	2	2	3	1	1.125
Gaylord SFA (76)	2	4	4	3	3	2	1	2	1.625
Grayling SFA (14)	1	2	3	4	4	3	2	3	1.875
Huron NF (12)	4	1	2	1	3	4	1	2	1.25
Manistee NF (123)	1	1	1	4	1	1	1	1	0.375
Manistee SFA (60)	2	1	1	2	4	1	4	4	1.375
Pigeon Riv. Co. SFA (21)	3	4	2	3	2	3	2	4	1.875
Traverse City SFA (28)	3	3	3	4	1	4	3	3	2

3.4.5 CREATING A KEY ENVIRONMENTAL ATTRIBUTE-SPECIFIC MANAGEMENT SCORE FOR EACH PROTECTED AREA

To use the information gathered through PA questionnaires in a quantitative comparison with catchment stressors and response variables, the results from the question, "What management activities to protect or restore freshwater environmental attributes in the PA's catchment are used within the PA?" were coded to a numeric scale. For the purposes of this study, it was assumed that a greater extent of activity implementation was positive for freshwater systems. As such, the response of "often" received three (3) points, the response of "occasionally" received two (2) points, and the response of "rarely" received one (1) point. The categories of "never," "unsure," and "not applicable" received zero (0) points under the assumption that these activities were then not carried out within the PA.

A KEA-specific Management Activity Score (MAS) for each PA was calculated by aggregating the numeric values associated with PA manager responses (see Table 3.7 for a description of how management activities were categorized by KEA). Management Activity Score totals were then normalized on a zero to one (0-1) scale by subtracting the minimum total score across all PAs in relation to each KEA and then dividing by the range. The normalized scores were then binned into four categories. The lowest scores, in the range of 0-0.25, were assigned a "1," scores in the range of 0.26-0.50 were assigned a "2," scores in the range of 0.51-0.75 were assigned a "3," and scores in the .076-1 range were assigned a "4." This classification scheme was based on the assumption that low normalized scores equate to the implementation of relatively few management activities. See Appendix 7 for the numeric results for each PA across all of the MASs.

Table 3.7 The key environmental attributes (KEA) likely effected by management activities occurring on study protected area lands. Those activities associated with a KEA comprise the KEA-specific Management Activity Score (MAS) created from manager survey results. WQ= water quality, HR= hydrologic regime, PH= physical habitat, C = connectivity, ER = energy regime, B = biotic composition

Management Activity	**Key Environmental Attribute**
Acid mine drainage remediation	WQ
Culvert removal/upgrade	HR, C, PH
Erosion control methods	WQ, PH
Fishing regulation enforcement (bait or take regulations)	B
Installation of fish ladders/passages	B, C
Installation of levee bypasses	B
Education programs (e.g. signage, pamphlets, informational meetings, etc.)	B, C, HR, PH, WQ
Invasive species management (e.g. eradication or best management practices to prevent introduction)	B
Post-disturbance re-vegetation (e.g. timber extraction, construction, etc.)	B, PH, ER, HR
Prohibition of species extractions (non-fish)	B
Promotion of forest management best management practices	WQ, PH
Reduction of impervious surfaces (e.g. use of permeable pavements, green roofs)	HR, WQ, PH
Removal of dams, weirs*, or levees	C, PH, HR
Restoration of channel shape, size, or sinuosity	PH, C, HR
Riparian buffer restoration and creation	WQ, C
Road construction and maintenance best management practices	WQ
Instream habitat practices (e.g. sediment removal)	WQ, PH
Recovery of native species	B
Stocking of native species	B
Storm water management (detention and retention systems)	HR, WQ, PH
Stream bank stabilization efforts (e.g. fascines, riprap, woody debris management)	PH, WQ
Upgrade of septic systems to performance standards	WQ
Use of physical barriers to prevent exotic colonization (e.g. weirs* or low-head dams)	B
Wetland restoration	WQ, PH

3.4.6 FRESHWATER ACTIVITY MATRIX DEVELOPMENT

The relative influences of management activities and catchment stressors on response variable values were investigated using the Freshwater Activity Matrix (FAM). With this framework, we compared the normalized and quartiled KEA-specific MASs and CCSs to normalized and scored response variable values, organized by PA. The FAM presents our results with color-coded tables, each color representing a different quartile (see Table 3.8 for a key). For each PA-specific response variable score, the average percent of catchment protected by the particular PA for response variable data points was also included in the FAM to aid in the interpretation of the effect of MASs.

Table 3.8 Key to the Freshwater Activity Matrix

Key	
1	Low
2	Medium-low
3	Medium-high
4	High

All scored values, however, are relative to data collected, not to a broader set. In other words, what is marked as "low" is only indicative of a low quantity or quality relative to our unique data (see Appendix 7, 8, and 9 for raw data used to calculate FAM scores)

3.4.6.1 COMPARISONS OF INTEREST: SCENARIO 1 AND 2

The FAM was used to observe the effectiveness or ineffectiveness of management based on two potential scenarios (see Table 3.9). The first scenario (Scenario 1) exists when the KEA-specific MAS was high or medium-high (suggesting KEA is actively managed for), the KEA-specific CCS was low or medium-low (characteristic of a human-impacted environment), and KEA-specific response variables were scored high or medium-high (characteristic of an environment demonstrating ecological integrity). Such a scenario may suggest management activities play a role in mitigating impacts of upstream catchment stressors. Alternatively, we were interested in a second scenario (Scenario 2) when the KEA-specific MAS was high or medium-high, the KEA-specific CCS score was low or medium-low, and response variables were scored low or medium-low (characteristic of a degraded environment). Such a scenario may suggest that PA management plays little or no role in promoting the integrity of environmental attributes compared to the effects of upstream stressors.

Table 3.9 Two scenarios used to compare effectiveness of management activities (management activity score) on freshwater KEAs (response variable score), relative to the impact of catchment stressors (catchment condition score).

	Scenario 1	**Scenario 2**
	Management has a positive effect	Management is overridden by catchment stressors
Management Activity Score	High, medium-high	High, medium-high
Catchment Condition Score	Low, medium-low	Low, medium-low
Response variable score(s)	High, medium-high	Low, medium-low

4 RESULTS

4.1 Regression Analysis Results

The results from the linear regression analysis suggest a marginal relationship between response variables and the percent of land protected within a catchment. Results indicate a significant relationship, at 95 percent confidence, between the percent of protected land within a catchment and the response variables of total nitrogen, percent intolerant species, and average rate of flow response. See Table 4.1 below for information on the level of significance (p-values) and the direction of the significant relationships. Our regression analysis also indicates that there is no significant relationship between the percent of protected land within a catchment and the response variables of total phosphorus, fish IBI, habitat score, dam density, and WWAT - August low flow difference.

Table 4.1. The type and strength of relationship between each KEA response variable and percent land protected within a KEA response variable catchment

Response Variable	**F (total % protected)**	**Relationship with percent of catchment protected**	**P-value**
Nitrogen	Total protection is inversely proportional to Total N	Inverse	.0034
Phosphorus	No effect	No relationship	.793
Fish IBI	No effect	No relationship	.082
% Intolerant	Total protection is proportional to % Intolerant	Proportional	.0013
Habitat Score	No effect	No relationship	.672
Dams/sqm	No effect	No relationship	.908
WWAT - August low flow difference	No effect	No relationship	.480
Average rate of flow response	Total protection is inversely proportional to Average Rate of Response	Inverse	.008

4.2 MANAGEMENT SURVEY AND INTERVIEW RESULTS

To inform an analysis of the extent to which management attends to threats to freshwater conservation priorities, information from the management questionnaire and interview were combined. The following narratives were developed to identify gaps between threats to freshwater systems and implemented management activities to examine the extent to which principles of the IUCN's framework were incorporated into management activities. See Appendix 5 for full questionnaire results.

4.2.1 PROTECTED AREA MANAGER SURVEY SUMMARY: MANISTEE RIVER STATE GAME AREA

4.2.1.1 CONTEXT: MANISTEE RIVER STATE GAME AREA

The Manistee River State Game Area was created to enhance the value of the lower Manistee River floodplain for wetland wildlife species, eliminate the seasonal fluctuation in wetland habitat (a goal which has since been eliminated), and improve hunting, trapping, and non-consumptive uses of wetland wildlife. Within the PA, management encourages a range of different activities as long as they do not interfere with the primary purpose of wildlife management. In the Manistee River State Game Area Strategic Plan, goals and objectives include restoration and management of wild birds and mammals and provision of public uses of wildlife resources. Additionally, the Strategic Plan identifies Peter's Bayou impoundment as a predominant feature of the PA. The Peter's Bayou impoundment is separated into two units by highway M-55 and is connected by two culverts beneath M-55 to allow water exchange. Within Peter's Bayous, a two-way pumping station draws or empties water into the Manistee River to maintain water levels.

Although conservation and restoration of freshwater resources have not been explicitly designated as management goals, and in general have been less prioritized than terrestrial activities, the management has indirectly addressed freshwater conservation. For example, in order to preserve the integrity of wildlife species, management activities that improve freshwater resources, in particular wetland habitat, have been identified as priority concerns. Information gathered through the interview process shows that management has also internalized social, cultural, and ecosystem values including open space, recreation, protection of species, recognition of tribal activities and tourism.

When questionnaire responses concerning external and internal threats were compared against those activities actually implemented, Manistee managers indicated that for the water quality KEA, land use threats presented a moderate external alteration of freshwater resource integrity within the PA. Additionally, off road vehicle (ORV) erosion and pollution and filling of wetlands were indicated as moderate internal threats to freshwater resources. Results from the questionnaire indicate that management of the PA has undertaken activities that could mitigate the external and internal pressures altering water quality. The most commonly implemented activities include erosion control methods, education programs, promotion of forest BMPs, riparian buffer restoration and creation, road construction and maintenance BMPs, instream habitat practices, storm water management, stream bank stabilization and wetland restoration.

Protected area management indicated that dam presence, both internal and external, cause high levels of alteration to connectivity of freshwater systems. Additionally, external shoreline development and weirs were indicated to moderately alter water resources. Road networks intersecting streams and weirs within the PA were also indicated to moderately alter water resources. Activities to address alterations of connectivity included occasional installation of fish ladders or passages, implementation of educational programs, restoration of channel shape, size, or sinuosity, and promotion of riparian buffer restoration or creation. Management has utilized an array of activities to address external and internal pressures. Although dam, weir, and levee removal activities were not undertaken, connectivity concerns were still addressed through other procedures, suggesting a complementary relationship between management activities and factors negatively impairing the quality of freshwater resources.

Protected area management indicated dam presence, filling of wetlands, storm water outfalls, and weirs were external threats exhibiting either a high or moderate level of alteration to hydrologic regime. Internal factors altering hydrologic regime included dam presence, road networks intersecting streams, and weirs. In response to these threats, management implemented education, post-disturbance re-vegetation, restoration of channel shape, size or sinuosity, and storm water management programs. The failure to implement dam, weir, and levee removal programs in light of their high alteration of freshwater resources is one point of concern. However, due to limitations associated with a network of upstream dams (there are 67 dams upstream of the protected area and one within), isolated dam removal activities may not confer much improvement of hydrologic regime. For the remainder of external and internal threats, management appeared to be implementing relevant programs and projects toward protecting hydrologic regime. For example, storm water outfalls were identified due to their moderate alteration of freshwater resources and PA management is addressing this threat though a storm water management program. As was the case for water quality and connectivity, the PA appears to have adequately identified external and internal threats based on the type of programs and projects implemented.

In response to impairments of physical habitat and energy regime, external threats identified as having either a high or moderate level of alteration included dam presence, filling of wetlands, shoreline development, storm water outfalls, weirs, and loss of natural riparian vegetation. Internal threats identified as high or moderate level include dam presence, loss of natural riparian vegetation, ORV erosion and pollution, road networks intersecting streams, weirs, and filling of wetlands. Activities associated with these KEAs that have been implemented often or occasionally include erosion control methods, education programs, post-disturbance re-vegetation, promotion of forest BMPs, restoration of channel shape, size, or sinuosity, stream habitat practices, storm water management, stream bank stabilization, and wetland restoration. In terms of the promotion of a healthy physical habitat and energy regime, management activities appear well aligned with both internal and external threats. This provides evidence to support the assertion that management of the Manistee River State Game Area has identified and begun undertaking activities that promote habitat quality.

Identified external and internal threats to biotic composition included invasive species and stocking of non-native species. Activities implemented to address these threats include fishing regulations enforcement, installation of fish ladders or passages, education programs, invasive species management, post-disturbance re-vegetation, recovery of native species, and stocking of native species. Similar to other KEAs, the activities implemented align to address those factors negatively impacting biotic composition. These findings further suggest management activities in this PA have addressed concerns surrounding biotic composition.

4.2.1.2 PLANNING: MANISTEE RIVER STATE GAME AREA

With reference to planning aspects of the management evaluation framework, the Manistee River State Game Area showcases some shortcomings. Within the PA, the only freshwater indicator utilized to inform management activities was invasive species monitoring. In particular, *Phragmites australis* was identified as a stream-specific indicator. Based on interview results, managers do not identify or track turbidity, free flowing stream miles, percentage of riparian corridor cover, or population assessments. This information indicates a possible disconnect between management activities and the conditions of freshwater resources. Without adequate knowledge of the health of the freshwater system as determined by stream-specific indicators, it is unclear which management activities have been effective.

With regard to planning, this PA showed positive results through their partnerships with both the Little River Band of Indians as well as representatives of Ducks Unlimited. Their involvement has been cited both for the development of the PA's Strategic Plan and efforts to complete yearly waterfowl breeding and nesting assessments.

4.2.1.3 PROCESS: MANISTEE RIVER STATE GAME AREA

An assessment of the IUCN process category indicates that the management plan does not specifically provide targets for the ideal ranges of freshwater indicators. This fact, coupled with the failure of the PA to track stream specific indicators, indicates a gap in management procedures.

4.2.1.4 INPUTS: MANISTEE RIVER STATE GAME AREA

Protected area management indicated shortcomings in both personnel and budget. Additionally, the limited amount of time spent on freshwater management (approximately 5 person days per year) raises concerns. However, given the stated goals and values of the PA, it would follow that the majority of time is dedicated to terrestrial management. The focus on terrestrial management is also apparent in the fact that the majority of funding dedicated toward freshwater issues directly relates to the cost of running the pump in Peter's Bayou.

4.2.1.5 OUTPUTS AND OUTCOMES: MANISTEE RIVER STATE GAME AREA

No outputs are identified within the Manistee River State Game Area Strategic Plan that could be used to determine progress toward stated management objectives and values. In addition, managers lack stream-specific indicators to determine progress toward meeting stated goals. Without the identification and formalization of evaluation criteria, management may not possess the knowledge necessary to adequately identify or address threats to freshwater conservation goals or to adapt management strategies to changes in environmental conditions (Personal communication, February 19, 2010).

4.2.2 PROTECTED AREA MANAGER SURVEY SUMMARY: WILDERNESS STATE PARK

4.2.2.1 CONTEXT: WILDERNESS STATE PARK

Currently, there are no defined freshwater conservation priorities for Wilderness State Park and, as such, no defined goals or objectives. Although this omission represents a large gap in terms of freshwater conservation, the MDNR are going through the process of updating management plans for State parks and in the next cycle freshwater priorities are anticipated to be formally included. Despite the omission of freshwater priorities, management recognized the social values of open space, recreation, protection of species, and specialized research for their ability to contribute to the maintenance of freshwater systems. Crane Island, Waugoshance

Point, and Big Stone Bay have been designated as Wildlife Preservation Areas within Wilderness State Park. Additionally, management, with the help of the Audubon Society and other conservation groups, is working to set up biodiversity stewardship areas. These findings indicate an informal articulation and prioritization of freshwater conservation. In addition to social values, cultural values relating to indigenous resource use have also been identified. Within Wilderness State Park, management has worked with the Little Traverse Bay Bands of Odawa Indians to protect natural, traditional food sources.

In response to all of the KEAs, management at Wilderness State Park noted no external or internal threats of moderate or high alteration. Although water quality was not perceived to be impaired by external or internal sources, management activities in place include erosion control methods, fishing regulations enforcement, education programs, post-disturbance re-vegetation, prohibition of non-fish extractions, consideration of reducing impervious surfaces in all future construction projects, riparian buffer restoration and creation, road construction and maintenance BMPs, stream bank stabilization, and upgrade of septic systems performance standards. These findings suggest that the management activities undertaken are sufficient to address identified threats to freshwater resources.

4.2.2.2 PLANNING: WILDERNESS STATE PARK

The failure to focus on the intersection between terrestrial activities and corresponding impacts on freshwater resources indicate a gap in the management efforts of Wilderness State Park. The justification for such an omission stems from the fact that Wilderness State Park is bordered on the south by state forest and private land used primarily for hunting. As such, management indicated very few external factors that could compromise water resource integrity within the park. Despite this omission at the level of management planning, evidence indicates that this connection is recognized by individuals. During trail work, there is emphasis on minimizing the impact to freshwater resources. Visitors are educated in order to prevent traffic through vulnerable or unique ecosystems.

An additional point of concern is the omission of the inclusion of freshwater-specific indicators into management activities. Within Wilderness State Park, little has been done to assess freshwater quality in the ponds and streams and the only freshwater indicators frequently measured are the quality of well and beach waters and invasive species inventories.

One highlight of the planning process at Wilderness State Park is the focus on cultivating partnerships to implement activities relating to freshwater conservation.

Management at Wilderness State Park works with the federal government through the Wildlife Division of the MDNR to protect the piping plover (*Charadrius melodus*) and remove spotted knapweed (*Centaurea stoebe*). Currently, these partnerships are cultivated primarily through temporary grant programs. To fully address freshwater resource needs, more formal, permanent guidelines typical of watershed planning may be needed. Collaborative partnerships also exist with the Little Traverse Bay Bands of Odawa Indians to undertake water quality testing throughout Sturgeon Bay, with Central Michigan University to undertake small-mouth bass surveys, and with the North Country Trail Group to complete invasive species surveys.

4.2.2.3 INPUTS: WILDERNESS STATE PARK

Within Wilderness State Park, management indicated that only a small percentage of total funding goes toward freshwater specific activities. This is in large part due to the prioritization of tourism and recreation, as funding for the park is based entirely from revenue generated through these activities. The Park covers over 10,000 acres with 250 campsites on the north side. As most visitors stay within a quarter mile radius of the campgrounds, management has placed focus on maintaining the integrity of these areas. Despite funding challenges, management has indicated the lack of personnel as the largest hindrance to freshwater specific management activities.

4.2.2.4 OUTPUTS AND OUTCOMES: WILDERNESS STATE PARK

Within the current management plan, freshwater conservation goals have not been articulated, nor have goals and objectives been identified to measure progress toward improving the quality of freshwater systems. Although it is anticipated that the future management plan will place emphasis on freshwater resources, goals and objectives to determine progress will not be addressed comprehensively in the future plan. Without the formal designation of goals and objectives and related freshwater-specific indicators to determine progress, it is unclear whether freshwater conservation can adequately be performed. As a result of this omission, determining how management activities are effecting the integrity of freshwater systems will be difficult (Personal communication, February 8, 2010).

4.2.3 PROTECTED AREA MANAGER SURVEY SUMMARY: GAYLORD STATE FOREST, ATLANTA STATE FOREST, PIGEON RIVER COUNTRY STATE FOREST AREA, AND GRAYLING STATE FOREST AREA

4.2.3.1 CONTEXT: GAYLORD STATE FOREST, ATLANTA STATE FOREST, PIGEON RIVER COUNTRY STATE FOREST AREA, AND GRAYLING STATE FOREST AREA

Analyses of Gaylord State Forest, Atlanta State Forest, Pigeon River Country State Forest Area, and Grayling State Forest Area were combined to reflect common management personnel and thus a combined interview process. For this set of PAs, management has successfully articulated freshwater conservation priorities and has done so in part through participation in the development of watershed management plans for the Thunder Bay and Cheboygan watersheds. These watershed management plans lay out procedures regarding management of fisheries, instream ponds, dams and barriers, vegetation, and riparian zones. The use of watershed management planning in preserving the integrity of freshwater systems is important in achieving freshwater conservation priorities.

In addition to participation in watershed management planning processes, based on interview questions, management has also taken a positive step in recognizing freshwater systems for their social, cultural, and ecosystem service values. By incorporating these sets of values, management can anticipate the ways that those resources are appreciated. For example, with regard to tribal interests, specific effort is placed on making sure that management understands how these external parties prioritize water resources and how threats impair uses. Additionally, management actively works with stakeholders to provide education on the resources indicating the presence of two way learning. For example, management works with hunters and anglers to describe issues relating to carrying capacity and natural cycles of game populations so that the public understands the reasoning behind management activities increasing the likelihood of compliance. This integration is important in mitigating potential conflict that may arise in instances of divergent perspectives on resources management.

GAYLORD STATE FOREST AND ATLANTA STATE FOREST

Due to the similarities between the questionnaire results from Gaylord State Forest and Atlanta State Forest, as well shared personnel, the discussion of the two was combined with specific identification of any deviations. Within Gaylord State Forest and Atlanta State Forest, external threats that impair water quality to a moderate extent include nonpoint source runoff from impervious surfaces, land use practices, and thermal pollution. Nonpoint source runoff from impervious surfaces was also identified as a threat originating within the PA to have a moderate level of alteration. In response management frequently implemented forest BMPs and occasionally implemented education programs, road construction and maintenance BMPs, and instream habitat practices. In addition, Atlanta State Forest has undertaken stream bank stabilization projects and Gaylord Sate Forest implemented erosion control programs. For water quality, there appear to be no substantial gaps between freshwater threats and associated management activities.

Dams and shoreline development external to the PAs were indicated to cause a large degree of alteration to freshwater systems within the PAs. Impassable culverts and the intersection of road networks and streams were indicated to moderately impair freshwater resources. Within the PAs threats to connectivity include impassable culverts, the intersection of road networks and streams, and dam presence. In response to the alteration created by impassable culverts, management has implemented programs to remove or upgrade culverts in the PAs. In response to the presence of dams, management has indicated the use of dam, weir, and levee removal programs. Despite efforts to remove dams within the PAs, the Gaylord State Forest has six dams within the PA and 52 dams in the PA's watershed and Atlanta State Forest has 19 dams within the PA and 75 dams within the PA's watershed. Thus, it is unlikely that management can act to fully mitigate the impacts of dams on connectivity within the PAs due to the large network of existing dams within the watershed. Regarding connectivity between freshwater resources, management appears to have implemented programs adequately aligned with the identified threats.

With regard to hydrologic regime, management indicated the presence of dams, filling of wetlands, impassable culverts, the intersection of road networks and streams, and storm water outfalls as threats. Within the PAs, dam presence and the intersection of road networks and streams additionally compromise the integrity of water resources. In response to the identified external and internal threats, management has implemented programs to remove dams, weirs, and levees. Management also removes or upgrades culverts to account for their negative effects. Two potential points of omission include wetland loss and storm water outfalls. Despite indication of moderate severity of these external factors influencing hydrologic regime, it is unclear from survey results the extent to which management activities have been implemented to address contamination from storm water outfalls or the loss of wetlands.

Management indicated dam presence and shoreline development highly alter physical habitat and energy regime. External threats presenting a moderate level of alteration include filling of wetlands, impassable culverts, storm water outfalls, and loss of natural riparian vegetation. Within the PA, dam presence, impassable culverts, road networks intersecting streams, and nonpoint source runoff from impervious surfaces also impact the integrity of aquatic habitats. In response to dam presence and impassable culverts, management has implemented dam removal programs and removed or upgraded culverts. Atlanta State Forest has undertaken stream bank stabilization projects and Gaylord Sate Forest has implemented erosion control programs. Additionally, management has implemented programs focusing on education and instream habitat practices that may address the associated effects of shoreline development, loss of natural riparian vegetation, and external loss of wetlands.

Management identified invasive species as the primary external and internal threat to biologic composition. Species exploitation within the PA was also indicated to result in a moderate level of alteration to biological communities. In response to these threats, management has implemented fishing regulation enforcement, installation of fish bypasses or ladders, education programs, and instream habitat practices. Atlanta State Forest has also implemented programs designed to recover native species within the PA. Management has also removed or updated culverts, removed dams, weirs, or levees and implemented road construction and maintenance BMPs. The sum of these programs contributes to the preservation of biological communities within the PA (Personal communication, February 1, 2010).

PIGEON RIVER COUNTRY STATE FOREST AREA

Pigeon River Country State Forest Area management indicated nonpoint source runoff from impervious surfaces and thermal pollution as external threats to water quality with a moderate degree of impact on freshwater resources within the PA. Activities implemented within the PA that would address such threats including instream habitat practices. It is unclear, however, from questionnaire results if this practice is implemented sufficiently to address the observed external threats. Management has also developed education programs and implemented road construction and maintenance BMPs, forest BMPs, and stream bank stabilization projects that further contribute to the integrity of water quality within the PA.

Management indicated dam presence (there are 19 dams in the PA's watershed and 2 additional dams within the PA) and road networks intersecting streams as external threats to connectivity. Internally these threats, as well as impassable culverts, further limit connectivity. In response to these impairments, management occasionally removed or upgraded culverts, removed dams, weirs, and levees, installed fish passages and ladders, and implemented education programs. The sum of these activities is well aligned with identified threats. This evidence supports the assertion that there exist no gaps between threats and strategies to address said threats in relation to connectivity.

Management indicated dams external to the PA highly alter freshwater resources while dams within the PA moderately alter freshwater resources. Additional external threats, of moderate magnitude, include filling of wetlands and road networks intersecting streams. Internally, dam presence and the intersection of road networks and streams also represent a moderate threat to hydrologic integrity. Many threats to hydrologic regime have been addressed through the removal or upgrade of culverts, education programs, and the removal of dams, weirs, or levees. One potential omission is the failure of management to implement erosion control programs to address the negative effects of road and stream intersections.

Management identified dam presence, filling of wetlands, and loss of natural riparian vegetation as external threats that present either a high or moderate level of alteration to physical habitat and energy regime external to the PA. Internally, dam presence, impassable culverts, road networks intersecting streams, and thermal pollution from onsite dams were indicated. In response to concerns surrounding dams and impassable culverts, management has undertaken dam and culvert removal projects. Potentially, instream habitat practices could be utilized to address concerns associated with thermal pollution and stream bank stabilization processes could address some of the negative effects associated with the external loss of wetlands and natural riparian vegetation. External alterations of physical habitat and energy regime are difficult to address through management activities within the PA alone.

Invasive species present a substantial external and internal threat to freshwater resources within the PA. Species exploitation was also indicated as a moderate threat based on activities conducted within the PA. Management appears to be adequately addressing threats to biological integrity from invasive species through the implementation of fishing regulation enforcement, invasive species management, education programs, instream habitat practices, and recovery of native species. Additionally, culvert removal or upgrade, installation of fish bypasses and ladders, removal of dams, weirs, or levees, road construction and maintenance BMPs, promotion of forest BMPs, and stream bank stabilization projects have all been used to improve the quality of biological communities within the PA (Personal communication, February 1, 2010).

External threats to water quality of moderate degree included: industrial discharges of organic and inorganic chemicals, nutrient loading, and land use practices. Internally, ORV erosion and pollution moderately alter freshwater resources within the PA. In response to these threats management has frequently implemented forest BMPs, road construction and maintenance BMPs, and instream habitat projects. Management has also occasionally undertaken erosion control methods, education programs, reduction of impervious surfaces, riparian buffer restoration and creation, storm water management, stream bank stabilization, and wetland restoration projects. These findings suggest that management is implementing complementary programs to address those threats to water quality within the PA.

Regarding the connectivity of freshwater systems, dam presence and road networks intersecting streams present a moderate external threat. These pressures also exist within the PA, as does the presence of impassable culverts. There are six dams disrupting connectivity within the PA and 103 dams in the larger watershed impairing freshwater resources. To counter the effects of such threats, management has undertaken culvert removal upgrade projects, education programs, dams, weirs, or levees removal, and riparian buffer restoration and creation projects. It appears as though management is implementing complementary activities to external and internal threats.

Dam presence, timber extraction, and road networks intersecting streams threaten hydrologic regime within the PA. To address these threats, management has promoted forest BMPs, removed dams, weirs, or levees, and conducted post-disturbance re-vegetation. Management has also implemented additional management activities that promote hydrologic regime integrity such as culvert removal or upgrade, education programs, post-disturbance re-vegetation, reduction of impervious surfaces, and storm water management. Based on the extent to which management activities correlate with external and internal threats there appear to be no gaps in terms of hydrologic regime.

External threats, of moderate alteration, to physical habitat and energy regime include dam presence, timber extraction, and loss of natural riparian vegetation. Internal threats to the integrity of aquatic habitat include ORV erosion and pollution. Management has addressed such threats through the promotion of forest BMPs, removal of dams, stream bank stabilization projects, erosion control methods, education programs, wetland restoration, and post-disturbance re-vegetation projects. Additionally, management has contributed to the integrity of physical habitat and energy regime by removing or updating culverts, reducing impervious surfaces, and implementing storm water management programs.

The only indentified threat to biological integrity was that of invasive species. To address this threat management has implemented complementary activities such as fishing regulation enforcement, instream habitat practices, education programs, invasive species management, recovery of native species, and stocking of native species. Additionally, they have removed culverts, undertaken erosion control methods, implemented post-disturbance re-vegetation projects, prohibited species extractions, reduced the amount of impervious surfaces, removed dams, weirs, or levees, restored riparian buffer, undertaken storm water management projects, stabilized stream banks, and restored wetlands.

4.2.3.2 PLANNING

In relation to planning initiatives, management at these PAs has made substantial effort to introduce elements of collaborative planning into management activities and to prioritize the importance of stakeholder participation in the facilitation of management activities. Specifically, management works with the Huron Pines Resource Conservation and Development, Tip of the Mitt Watershed Council, road commissions, the Upper Black River Restoration Committee, Trout Unlimited, and the U.S. Fish and Wildlife Service. These partnerships are utilized to manage the watershed for both social and biological aspects, remove and manage dams, remove or upgrade culverts, management woody debris, and create tour habitat. These findings reflect positively on the efforts of management officials to effectively address those threats and concerns relating to freshwater resources.

Another positive point in terms of the planning process in place within the Gaylord State Forest, Atlanta State Forest, Pigeon River Country, and Grayling State Forest Areas is the deliberate focus on the intersection between terrestrial management and the associated impacts of freshwater systems. As a part of the management process, managers work with DNR Fisheries Division, DNR Forest Division, and DNR Wildlife Division in order to gain a holistic understanding of the problem at hand. For example, fishery biologists are involved in oil and gas reviews in order to mitigate any potential harm to freshwater systems.

Management of these PAs has also demonstrated the use of those indicators, necessary to identify and track stream conditions, that are representative of effective management strategies. In these PAs, fish assessments, substrate, water temperature, Ph, alkalinity, and chlorophyll are all tracked to inform management progress. Additionally, these indicators are compared to historic data suggesting the presence of an informal means of measuring progress. Although this represents a positive trend in terms of PA management, there is no indication that this means of determining progress towards meeting stated freshwater goals is formally tied to defined objectives or the means through which management must alter management activities to address such findings.

4.2.3.3 PROCESS

In terms of management processes, one critique stems from the long-term cycle in which the management plan is updated. As management plans within the State of Michigan are updated on a ten-year cycle they are not altered frequently enough to reflect short-term changes in the integrity of water resources as determined by the indicator data. The inability to regularly update management plans to reflect changing conditions within the water resources of the PA represents a hindrance on the ability of management officials to adaptively management the resources in a formalized way. Based on interview results, managers are able to exhibit discretion in responding to new issues but in the absence of formalized review there is not check on the professional judgment of management officials.

4.2.3.4 INPUTS

In terms of input limitations, management officials have indicated that personnel, not funding, is the main limitation on the protection of water resources within the PA. This limitation is largely reflected in the need for management to reach out to external parties in order to ensure activities relating to freshwater conservation are implemented.

4.2.3.5 OUTPUTS AND OUTCOMES

Within management activities there is some indication that outcome based assessment is occurring based on the use of freshwater indicator outputs to inform progress towards meeting stated freshwater objectives. For example, as a part of DEQ Procedure 51 habitat assessment process, regulatory officials review watersheds in relation to the quality and quantity of invertebrate species. Based on these findings management is able to determine limitations or failures in freshwater conservation activities and alter management to address identified problems. The Fisheries Division of the DNR also conducts stream surveys and other basic assessments that are also utilized to alter management procedures according. Although these findings represent the beginning of outcome based assessment, this approach has yet to be formalized in a management plan putting its effectiveness into question and prohibiting external input as to management strategies (Personal communication, February 1, 2010).

4.2.4 PROTECTED AREA MANAGER SURVEY SUMMARY: HURON-MANISTEE NATIONAL FORESTS

4.2.4.1 CONTEXT: HURON-MANISTEE NATIONAL FORESTS

The "Huron-Manistee National Forests Land and Resource Management Plan" (USFS, 2006) directs both short and long-term management efforts, including those that address freshwater resources within the boundaries of the national forests. Freshwater-related goals, objectives, and desired conditions in the Land and Resource Management Plan have been developed for the reduction of non-native species, maintenance of wildlife and fisheries habitats, cooperation with government and tribal land managers, and management of riparian areas and vegetation. The Plan also outlines conservation priorities within the National Forests, including a host of prioritizations for freshwater systems. The United States Forest Service (USFS) places high value on the national significance of pristine coldwater rivers, recreational and fishing opportunities, biodiversity, and rare and threatened species within these National Forests. The same management team oversees both PAs, and there are many similarities between freshwater threat categories and management activities between Huron and Manistee National Forests (Personal communication, February 10, 2010). As such, questionnaire and interview results have been combined into one management summary.

In the context of water quality, management staff indicated that external land use threats (such as agriculture and timber harvesting) and erosion associated with ORVs have led to moderate to high alteration of freshwater rivers and streams within the national forests (Personal communication, February 10, 2010). Forest managers have implemented erosion control programs, created and restored riparian buffers, promoted forest BMPs, and followed instream habitat practices. These activities have demonstrate alignment with issues associated with the degradation of water quality characteristics.

The presence of dams on major river stretches of the Manistee and Ostoll Rivers, culverts associated with road crossings, channelization, and shoreline development have been identified as causing moderate to high alteration to connectivity and hydrologic regime attribute within the PAs. To address these threats, the National Forests employ road construction and maintenance BMPs, as well as the removal and/or upgrade of existing culverts (Personal communication, February 10, 2010) in order to mitigate impacts. Although most influences to freshwater connectivity and hydrologic regime attributes have been addressed, management has not found an approach to stressors associated with dam presence in and around the National Forests.

With respect to physical habitat and energy regime, dam presence, impassable culverts, shoreline development, and the loss of natural riparian vegetation are recognized as causing high alteration to freshwater ecosystems within the National Forests. Substantial shoreline development (e.g. residential cottages and cabins) has occurred upstream of the PA (external to PA boundaries). Management activities identified as mitigating impacts to physical habitat and energy regime include culvert removals/upgrades, erosion control, post-disturbance re-vegetation, instream habitat practices, and forest BMPs. Again, the presence of dams is the most significant factor limiting management's effectiveness under these KEA categories.

Invasive species within the Huron-Manistee National Forests represent a moderate alteration to the biological integrity aspect of freshwater resources, and an invasive species management program has been implemented to deal with exotic species issues. Forest managers have also employed a program of restocking salmonid species (Personal communication, February 10, 2010) as a measure to improve recreational opportunities.

4.2.4.2 PLANNING: HURON-MANISTEE NATIONAL FORESTS

The forest management staff relies heavily on successful partnerships with watershed councils, conservation districts, and tribal governments. Recognizing the importance of management goals related to cultural values, consultation with tribal governments is standard practice prior to taking actions affecting resources in which tribal governments may have an interest. This includes review and assessment of plans, projects and programs to assure that tribal governments' rights and interests are considered (USFS, 2006).

Michigan Department Natural Resources is a major partner in freshwater conservation management. Some species management, such as recreational fish management, is deferred to MDNR (Personal communication, February 10, 2010).

"The Huron-Manistee National Forests 2008 Monitoring and Evaluation Report" is lacking in freshwater indicators such as water quality, turbidity, dissolved oxygen (USFS, 2009). However, a new national watershed-scale USFS freshwater management pilot program is under development that may eventually be implemented in the Huron-Manistee National Forests (Personal communication, February 10, 2010). Free flowing stream, road density, road crossings, and riparian corridor health will be included as freshwater measurement indicators in this pilot program. In the interim, monitoring for these indicators should be fully established in the Huron-Manistee National Forests.

4.2.4.3 PROCESS: HURON-MANISTEE NATIONAL FORESTS

"The Huron-Manistee National Forests 2008 Monitoring and Evaluation Report" does not contain targets for ranges of freshwater indicators (water quality, turbidity, etc.). The plan does, however, recommend monitoring of brook trout (*Salvelinus fontinalis*) and mottled sculpin (*Cottus bairdii*) as freshwater indicator species (USFS, 2009).

4.2.4.4 INPUTS: HURON-MANISTEE NATIONAL FORESTS

Much of the funding for management activities dedicated to freshwater conservation for the Huron-Manistee National Forest does not come from their annual operating budget, but rather from additional federal appropriations. Protected area managers estimate that between 7-10% of available funds (including additional appropriations) go toward freshwater conservation initiatives (Personal communication, February 10, 2010). Since mangers cite that personnel resources (USFS employees and volunteers) are limited, partners with the State, NGOs, and tribes are critical to perform watershed-oriented management activities.

4.2.4.5 OUTPUTS & OUTCOMES: HURON-MANISTEE NATIONAL FORESTS

"The Huron-Manistee National Forests 2008 Monitoring and Evaluation Report" summarizes ongoing site-specific monitoring of habitat improvements and fish populations (USFS, 2009). The report is used to qualitatively assess the accomplishment of conservation goals and objectives as a result of ongoing watershed restoration activities. Select fish species are the primary freshwater indicators used to determine the effects of management practices on wildlife and fish populations. At the forest planning level, freshwater management objectives are linked to monitoring of *S. fontinalis* and *C. bairdii* to assess overall ecosystem health. This aspect of the planning process is an example of outcome-informed management. Inclusion of additional freshwater indicators could further develop a more comprehensive outcome-based management model for the Huron-Manistee National Forests.

4.2.5 PROTECTED AREA MANAGER SURVEY SUMMARY: CADILLAC AND TRAVERSE CITY STATE FOREST AREAS

4.2.5.1 CONTEXT: CADILLAC AND TRAVERSE CITY STATE FOREST AREAS

Managers report a primary focus for the Cadillac and Traverse City State Forest Area managers as providing optimum fishery experiences for anglers. Fishing licenses are a major source of revenue for the state, and MDNR has tremendous incentives to protect the health of the fisheries within these PAs. Tourists and local residents also use state forest lands for other recreational uses, such as camping, hiking, etc. The agency also emphasizes biodiversity, cultural, and tribal values. Although the "Northern Lower Peninsula Regional State Forest Plan" is under development, there are watershed management plans for individual rivers, such as the Manistee River and Boardman Rivers.

In the context of water quality, land use practices such as agriculture (external to PA) and timber harvesting (both internal and external to PA) are linked to moderate alteration of freshwater bodies within the PAs. Forest management has implemented erosion control procedures, stream bank stabilization, and the restoration of riparian buffers to potentially address impacts to the watersheds from land use practices and erosion-related damages (Personal communication, February 5, 2010). Cadillac State Forest Area also implements road construction and maintenance BMPs within these forested lands.

Moderate alteration to connectivity attributes can be attributed to channelization, dam presence, impassable culverts, road networks intersecting streams, and shoreline development. Management activities include programs to upgrade or remove culverts (Personal communication, February 5, 2010). In rare cases, dams are identified for risk of failure and targeted for removal. Stream bank stabilization has been employed in certain areas; this approach appears adequate in relation to identified threats to connectivity.

Stressors related to hydrologic regime include channelization, dam presence, road networks intersecting streams, and shoreline development, which all cause moderate alteration to freshwater systems within the PAs. In these cases, culvert removal/upgrade and post-disturbance re-vegetation are the management activities most commonly implemented to deal with these stressors. In rare cases, dams within the PA are identified for risk of failure and targeted for removal.

Moderate alteration to physical habitat and energy regime KEA characteristics are linked to channelization, dam presence, loss of natural riparian vegetation, and shoreline development. With regards to shoreline development, clearing of shoreline areas for cabins or recreational purposes occurs quite frequently in areas external to the PAs (Personal communication, February 5, 2010). Stream bank stabilization has been employed in certain areas; this approach appears adequate to deal with damage caused by shoreline development.

No threats to biologic integrity attributes were recognized for the Cadillac and Traverse City State Forest Areas. However, managers still occasionally perform invasive species management activities and frequently enforce fishing regulations within the PA boundaries.

4.2.5.2 PLANNING: CADILLAC AND TRAVERSE CITY STATE FOREST AREAS

State forest managers, wildlife biologists, and fisheries biologists meet with MDEQ on a weekly basis to review permits and permit applications that may impact wetlands, fish populations, and general health of streams. This cooperation often involves on-site visits, working with landowners, providing feedback to MDEQ on whether to approve or deny a permit. Forest staff also work with U.S. Fish and Wildlife Service in Cadillac's Great Traverse Conservation District on lamprey control programs. The Army Corps of Engineers acts as a partner on Lake Michigan projects. Watershed projects often involve NGOs as participants, and sometimes these groups offer additional funding. Partner groups such as Conservation Resource Alliance also conduct work to improve the habitat of streams and to identify and report issues to MDNR fisheries biologists (Personal communication, February 5, 2010).

Monitoring of freshwater indicators, as part of habitat and fisheries assessments, is conducted by MDNR Fisheries and Wildlife divisions. The "Northern Lower Peninsula Regional State Forest Plan" is under development, and will contain more details on the specific freshwater indicators MDNR monitors for.

4.2.5.3 PROCESS: CADILLAC AND TRAVERSE CITY STATE FOREST AREAS

Michigan Department of Natural Resources Fisheries and Wildlife divisions have established targets for ranges of freshwater indicators included in fisheries and habitat assessments.

4.2.5.4 INPUTS: CADILLAC AND TRAVERSE CITY STATE FOREST AREAS

Michigan Department of Natural Resources has fisheries biologists on staff that dedicates 100% of their time toward management of the state's fisheries. However, management cited lack of personnel as a major limitation to freshwater conservation related goals (Personal communication, February 5, 2010). The state benefits from revenue brought in through licensing and permits, but would have the capacity to perform more comprehensive fish and habitat assessments with additional funding.

4.2.5.5 OUTCOMES AND OUTPUTS: CADILLAC AND TRAVERSE CITY STATE FOREST AREAS

Fisheries and habitat assessments are used to assess the health of rivers and streams within PA boundaries. These assessments are intended to determine the effectiveness of management activities (Personal communication, February 5, 2010). However, these fisheries and habitat assessments are not utilized in conjunction with freshwater conservation goals and objectives for the PAs, thus hindering an effective adaptive management approach. Since the existing forest management plans are outdated, their outcomes and outputs do not reflect current freshwater threats, trends, and environmental conditions.

4.2.6 PROTECTED AREA MANAGER SURVEY SUMMARY: FISHERMAN'S ISLAND STATE PARK MANAGEMENT

4.2.6.1 CONTEXT: FISHERMAN'S ISLAND STATE PARK MANAGEMENT

Daily management activities at Fisherman's Island State Park flow from a range of diverse goals. They are directed towards general stewardship of the park's natural resources, but do not have a particular focus on inland freshwater resources (Personal communication, February 22, 2010). Though the MDNR "Michigan Parks and Recreation 2009 Strategic Plan" includes recreation-oriented freshwater objectives, the plan lacks KEA-oriented management goals (MDNR, 2009). Furthermore, the park's management plan does not outline specific goals and objectives for inland freshwater resources. Daily management activities for the entire park include erosion control, maintenance of shoreline structures, and general upkeep of both terrestrial and freshwater areas around the park. Preservation of park natural resources, including both terrestrial and freshwater ecosystems, is important to maintaining tourism (which is the only source of revenue for the park's operating budget).

In the context of water quality, hiking, camping, and associated recreational uses of the park were the only stressors to water quality identified as causing moderate alteration to freshwater rivers and streams. Management staff reported performing road and construction maintenance BMP's often, and occasionally erosion control activities (Personal communication, February 22, 2010), which are aligned with stressors related to recreational use.

No external or internal stressors were identified as having medium or high alteration to connectivity, hydrologic regime, physical habitat, and energy regime. However, stream bank stabilization, erosion control, and riparian buffer restoration activities are conducted along inland waterway shorelines. Additionally, the state park management employs BMPs for road construction and maintenance (Personal communication, February 22, 2010).

Park management has not identified any influences, such as invasive species, that have an impact on biotic composition. Michigan Department of Natural Resources forest managers have employed a program of restocking salmonid species (Personal communication, February 10, 2010), which are treated as "native" species for recreational management purposes.

4.2.6.2 PLANNING: FISHERMAN'S ISLAND STATE PARK MANAGEMENT

Partnership with other MDNR divisions is an essential component of the freshwater resources management approach of Fisherman's Island State Park. Management relies heavily on other MDNR divisions and MDEQ for support as they are required to work directly with the Army Corps of Engineers and MDEQ for permitting issues on wetland areas (Personal communication, February 22, 2010).

Fisherman's Island State Park management staff do not monitor water quality, riparian cover, or free flowing stream miles. They rely heavily on MDNR Fisheries and MDNR Wildlife staff, as well as MDEQ, for water quality testing and fish and habitat assessments (Personal communication, February 22, 2010). Park management staff does conduct random visitation of rivers and streams, focusing on excessive sedimentation, invasive species, and shoreline vegetation. They report any issues or concerns to the MDNR Parks and Recreation Division. However, monitoring of freshwater indicators within the park is not used to inform the park management plan goals and objectives.

4.2.6.3 PROCESS: FISHERMAN'S ISLAND STATE PARK MANAGEMENT

Park management staff does not set targets for ranges of freshwater indicators, but targets are established and measured by MDNR Fisheries and Wildlife divisions.

4.2.6.4 INPUTS: FISHERMAN'S ISLAND STATE PARK MANAGEMENT

The majority of operating expenses are generated through tourism revenue. Park officials estimate that 10% of available total PA funding has been allocated toward *P. australis* control (on Lake Michigan's shoreline) and erosion control on lake shorelines and stream corridors.

Management has indicated that the park is understaffed. Even with seasonal staff and volunteers, the management activity required to sustain tourism does not leave adequate time for projects related to inland freshwater resources. Approximately 10% of management efforts are dedicated toward freshwater, with most of this allocation focused on lake shoreline projects, rather than inland waterways (Personal Communication, February 22, 2010).

4.2.6.5 OUTCOMES AND OUTPUTS: FISHERMAN'S ISLAND STATE PARK MANAGEMENT

Outcomes and outputs for freshwater conservation do not exist in the park management plan, but outcome-based management is employed by MDNR Fisheries and MDNR Wildlife division teams that conduct monitoring within park boundaries. Management decisions are made on a daily basis, their impacts are not linked directly to freshwater indicators, and this hinders the formalization of a long-term adaptive management strategy focused on freshwater outcomes. Management activities for Fisherman's Island State Park encompass a wide range of targets and goals, but those related to freshwater are primarily focused on the Lake Michigan shoreline, not inland rivers and streams. Management resources are dedicated towards Lake Michigan shoreline areas that experience the most tourist traffic, especially during the summer months.

4.3 FRESHWATER ACTIVITY MATRIX

Our comparative results are reported as a Freshwater Activity Matrix (FAM), which is comprised of color-coded tables organized by KEA. Each matrix (i.e. table) displays response variable scores (of which there are eight separate named scores), Catchment Condition Scores (CCSs), and Management Activity Scores (MASs). See Table 4.2 for a key to the scoring scheme. All comparisons, however, are relative to data collected, not to a broader data set. In other words, what is marked as "low" is not necessarily indicative of a low quantity or quality in the broad sense, but relative to our unique data. Raw data that informed the FAM is included in Appendices 7, 8 and 9.

Table 4.2 Key to the Freshwater Activity Matrix

Key	
1	Low
2	Medium-low
3	Medium-high
4	High

4.3.1 KEY ENVIRONMENTAL ATTRIBUTES ROLE IN FRESHWATER ACTIVITY MATRIX

Key environmental attributes are regarded as crucial components of freshwater ecosystems. Where they are preserved, high ecological integrity can be expected. The following sections evaluate the nexus between management, catchment condition, and response variables on a KEA basis. Results organized by KEA enable a discussion based on ecologically relevant terms.

4.3.1.1 WATER QUALITY

A broad range of nitrogen and total phosphorus (TP) concentrations were observed across the PAs. The highest Nitrogen Scores were received for Atlanta State Forest Area and Pigeon River Country State Forest Area, indicating concentrations of nitrogen in Atlanta State Forest Area were lowest. Conversely, Cadillac State Forest Area and Gaylord State Forest Area received the lowest Nitrogen Scores, indicating relatively high concentrations were observed. Manistee National Forest and Atlanta State Forest Area both received low TP Scores while Huron National Forest, Traverse City State Forest Area, and Grayling State Forest Area received high TP Scores. Atlanta State Forest Area was unique in that it received a high Nitrogen Score but a low TP Score.

Catchment condition scores for water quality trended low across PAs with one of nine PAs receiving a low Water Quality CCS, and eight of nine PAs receiving a medium-low CCS. The lowest Water Quality CCS was received by Manistee National Forest, suggesting this PA incurrs the most nutrient-related stress from upstream sources. Traverse City State Forest Area received the highest Water Qualitly CCS, suggesting this PA incurs the least nutrient-related stress.

Generally, PA managers reported high attention to activites that may influence water quality, specifically nutrient reduction. In fact, five of nine PAs received high Water Quality MASs, including both Manistee National Forest and Traverse City State Forest. One of nine PAs received a medium high Water Quality Score. In comparison, four of nine PAs received low Water Quality MASs, including Atlanta State Forest Area, Pigeon River Country State Forest Area, and Traverse City State

Forest Area (see Table 4.3).

Table 4.3 Freshwater Activity Matrix comparing water quality response variable scores (nitrogen and total phosphorus), Catchment Condition Scores, and Management Activity Scores (4= high, 3= medium high, 2= medium low, 1= low) for study protected areas. Average percent of catchment area protected by individual study PA is indicated for response variable samples (n = sample size) used in scoring.

Protected Area	Nitrogen Score	Avg. % catchment protected by study PA for nitrogen data points (n)	Total Phosphorus (TP) Score	Avg. % catchment protected by study PA for Total P data points (n)	Water Quality Catchment Condition Score	Water Quality Management Activity Score
Atlanta State Forest Area	4	31.58% (25)	1	31.58% (25)	1.5	1
Cadillac State Forest Area	1	15.71% (18)	2	14.96% (19)	1.125	4
Gaylord State Forest Area	1	28.15% (42)	3	26.31% (45)	1.625	1
Grayling State Forest Area	3	5.35% (7)	4	5.35% (7)	1.875	4
Huron National Forest	3	19.47% (5)	4	19.47% (5)	1.25	4
Manistee National Forest	2	30.5% (58)	1	30.50% (58)	0.375	4
Manistee River State Game Area	3	0.33% (1)	3	0.33% (1)	1.375	3
Pigeon River Country State Forest Area	4	23.58% (14)	2	23.58% (14)	1.875	1
Traverse City State Forest Area	2	26.55% (23)	4	27.31% (22)	2	4

4.3.1.2 HYDROLOGIC REGIME

We observed a range of average rate of flow response and low flow expectation values across PAs. High Average Rate of Flow Response Scores were received by Atlanta State Forest Area and Cadillac State Forest Area, indicating a low level of flashiness. Pigeon River Country State Forest and Traverse City State Forest Area received the only high Low Flow Expectation Scores, indicating proper estimation of hydrologic regime. Hydrologic regime was most compromised in Huron National Forest and Manistee State Game Area, which received both a low Average Rate of Flow Response Score and a Low Flow Expectation Score.

Catchment stressor levels were generally low for hydrologic regime across PAs. One of nine PAs received a low Hydrologic Regime CCS, seven of nine PAs received a medium-low CCS, and only one of nine PAs received a medium-high CCS. Manistee National Forest received the lowest CCS, suggesting this PA incurs the most stress to hydrologic regime from upstream sources. The highest Hydrologic Regime CCS was received by Atlanta State Forest Area, suggesting this PA receives the least amount of hydrologic regime stress.

For management of hydrologic regime, three of nine PAs received a medium-low Hydrologic Regime MAS, three of nine PAs received a medium-high MAS, and three of nine PAs received a high MAS. Management activity related to hydrologic regime was scored highest in Cadillac State Forest Area, Grayling State Forest Area, and Traverse City State Forest Area (see Table 4.4).

Table 4.4 Freshwater Activity Matrix comparing hydrologic regime response variable scores (average response rate and low flow expectation), Catchment Condition Scores, and Management Activity Scores (4= high, 3= medium high, 2= medium low, 1= low) for study protected areas. Average percent of catchment area protected by individual study PA is indicated for response variable samples (n = sample size) used in scoring.

Protected Area	Average Response Rate Score	Avg. % catchment protected by study PA for gauge data points (n)	Low Flow Expectation Score	Avg. % catchment protected by study PA for gauge data points (n)	Hydrologic Regime Catchment Condition Score	Hydrologic Regime Management Activity Score
Atlanta State Forest Area	4	27.97% (2)	3	27.97% (2)	2.75	2
Cadillac State Forest Area	4	10.71% (2)	3	10.71% (2)	1.25	4
Gaylord State Forest Area	3	13.07 (8)	2	13.07 (8)	1.5	2
Grayling State Forest Area	2	28.16% (6)	2	28.16% (6)	1.5	4
Huron National Forest	1	14.02% (4)	1	14.02% (4)	1.75	3
Manistee National Forest	3	17.4% (6)	2	17.4% (6)	1	3
Manistee River State Game Area	1	15.41% (1)	1	15.41% (1)	1.25	3
Pigeon River Country State Forest Area	2	12.50% (2)	4	12.50% (2)	2	2
Traverse City State Forest Area	3	29.60% (2)	4	29.60% (2)	2	4

4.3.1.3 CONNECTIVITY

Average stream meters per dam values ranged evenly across PAs. Low Stream Meters per Dam Scores were calculated for Atlanta State Forest Area and Huron National Forest, suggesting these PAs have the highest density of dams within their borders. The highest Stream Meters per Dam Scores were calculated for Gaylord State Forest Area and Grayling State Forest Area, indicating high connectivity.

Connectivity CCSs trended low, indicating streams linking PAs to their catchments are often disconnected. While only one of nine PAs received a low Connectivity CCS, seven of nine received a medium-low Connectivity CCS. The lowest score was received by Manistee National Forest while the highest scored, and only PA to receive a medium-high connectivity CCS, was Atlanta State Forest Area.

Connectivity MASs were generally high, with seven of nine PAs receiving a medium-high Connectivity MAS and two of nine PAs receiving a high MAS. Cadillac State Forest Area and Traverse City State Forest Area received the highest MAS, suggesting these PAs conduct the most management activities relative to enhancing lateral and longitudinal connectivity (see Table 4.5).

Table 4.5 Freshwater Activity Matrix comparing connectivity response variable scores, Catchment Condition Scores, and Management Activity Scores (4= high, 3= medium high, 2= medium low, 1= low) for study protected areas. Average percent of catchment area protected by individual study PA is indicated for response variable samples (n = sample size) used in scoring.

Protected Area	Stream meters per Dam Score	Avg. % catchment protected by study PA for all data point catchments	Connectivity Catchment Condition Score	Connectivity Management Activity Score
Atlanta State Forest Area	1	27.78% (40)	2.75	3
Cadillac State Forest Area	2	16.58% (33)	1.25	4
Gaylord State Forest Area	4	18.54% (43)	1.5	3
Grayling State Forest Area	4	19.31% (27)	1.5	3
Huron National Forest	1	24.58% (25)	1.75	3
Manistee National Forest	3	22.49% (103)	1	3
Manistee River State Game Area	3	0.33% (1)	1.25	3
Pigeon River Country State Forest Area	2	22.76% (14)	2	3
Traverse City State Forest Area	2	30.43% (38)	2	4

4.3.1.4 PHYSICAL HABITAT/ENERGY REGIME

Habitat quality values were similar across PAs and we observed few extremes with four of six PAs receiving a medium-low or medium-high Habitat Quality Score. The only PA to receive a low Habitat Quality Score was Cadillac State Forest Area, and the only PA to receive a high Habitat Quality Score was Traverse City State Forest Area. Unfortunately, habitat quality data were not available for Atlanta State Forest Area, Manistee River State Game Area, and Pigeon River State Forest Area.

Physical Habitat and Energy Regime CCSs trended low as three of nine PAs received a low CSS, three of nine PAs received a medium-low CSS, and three of nine PAs received a medium-high CSS. Physical Habitat and Energy Regime CCSs were similar to Biotic Composition CCSs, both being the lowest of all KEA-specific CCSs. Gaylord State Forest Area and Grayling State Forest Area received the lowest Physical Habitat and Energy Regime CCSs, and Manistee National Forest received the highest CSS, the latter indicating that relatively little stress to the KEAs originates in this PA's catchment.

Of KEA-specific management scores, Physical Habitat and Energy Regime MASs were the highest, suggesting an elevated level of management attention to this KEA. Specifically, one of nine PAs received a medium-high Physical Habitat and Energy Regime MAS, five of nine PAs received a high MAS, and only three of nine PAs received a medium-low MAS. Cadillac State Forest Area, Traverse City State Forest Area, Grayling State Forest Area, Huron National Forest, and Manistee National Forest were among those receiving Physical Habitat and Energy Regime MASs (see Table 4.6).

Table 4.6 Freshwater Activity Matrix comparing habitat response variable scores, Catchment Condition Scores, and Management Activity Scores (4= high, 3= medium high, 2= medium low, 1= low) for study protected areas. Average percent of catchment area protected by individual study PA is indicated for response variable samples (n = sample size) used in scoring.

Protected Area	**Habitat Quality Score**	**Avg. % catchment protected by study PA for habitat score data points**	**Physical Habitat and Energy Regime Catchment Condition Score**	**Physical Habitat and Energy Regime Management Activity Score**
Atlanta State Forest Area	n/a	n/a	0.25	2
Cadillac State Forest Area	1	19.43% (11)	1.75	4
Gaylord State Forest Area	3	30.12% (12)	0.75	2
Grayling State Forest Area	3	22.65% (7)	0.75	4
Huron National Forest	2	34.22% (8)	1.25	4
Manistee National Forest	2	26.13% (33)	2.25	4
Manistee River State Game Area	n/a	n/a (0)	3	3
Pigeon River Country State Forest Area	n/a	n/a (0)	3	2
Traverse City State Forest Area	4	23.81% (12)	1.25	4

4.3.1.5 BIOTIC COMPOSITION

We observed a range of fish IBI and percent intolerant values across PAs. For both metrics, two of seven PAs received a low score and one of seven received a high score. However, for only Gaylord State Forest Area were scores the same in both metrics; furthermore this was also the only PA to receive a high score ("4") in either metric. Huron National Forest and Grayling State Forest Area, which share similar catchments, each received low Fish IBI Scores. Cadillac State Forest Area and Manistee National Forest each received low Percent Intolerant Scores. Unfortunately, neither fish IBI nor percent intolerant species data were available for Pigeon River Country State Forest Area or Manistee State Game Area.

Biotic composition stressors were relatively high in the study area as three of nine PAs received a low Biotic Composition CCS, five of nine received a medium-low CCS, and only one PA received a medium-high CSS. The lowest Biotic Composition CCSs were observed in Cadillac State Forest Area, Grayling State Forest Area, and Traverse City State Forest Area. Because Biotic Composition CCS includes all stressors, stressors, our results suggest these PAs incur the most amount of stress from upstream sources (see Table 3.4).

For management of biotic composition, three of nine PAs received a low Biotic Composition MAS, three of nine PAs received a medium-low score, and three of nine PAs received a high score. Both Atlanta State Forest Area and Gaylord State Forest Area received a low Biotic Composition MAS. Cadillac State Forest Area, Grayling State Forest Area, and Traverse City State Forest Area each received the highest Biotic Composition MASs (see Table 4.7).

Table 4.7 Freshwater Activity Matrix comparing biotic composition response variable scores (fish IBI and percent intolerant species), Catchment Condition Scores, and Management Activity Scores (4= high, 3= medium high, 2= medium low, 1= low) for study protected areas. Average percent of catchment area protected by individual study PA is indicated for response variable samples (n = sample size) used in scoring.

Protected Area	Fish IBI Score	Avg. % catchment protected by study PA for fish IBI data points (n)	Percent Intolerant Score	Avg. % catchment protected by study PA for % Intolerant data points (n)	Biotic Composition Catchment Condition Score	Biotic Composition Management Activity Score
Atlanta State Forest Area	2	20.89% (22)	3	20.89% (22)	1.083	1
Cadillac State Forest Area	2	21.04% (8)	1	21.04% (7)	0.5	4
Gaylord State Forest Area	4	45.17% (10)	4	45.17% (10)	1.25	1
Grayling State Forest Area	1	15.63% (7)	3	15.63% (6)	1	4
Huron National Forest	1	53.93% (12)	2	53.93% (12)	1.333	2
Manistee National Forest	3	25.26% (30)	1	25.26% (30)	1.333	2
Manistee River State Game Area	n/a	n/a (0)	n/a	n/a (0)	1.667	2
Pigeon River Country State Forest Area	n/a	n/a (0)	n/a	n/a (0)	2.917	1
Traverse City State Forest Area	n/a	n/a	n/a	n/a (0)	n/a	n/a

4.3.2 EVALUATIVE SCENARIO RESULTS

Scenario 1 and 2 were similarly observed across all PAs and there were few intra-KEA differences (see Table 4.8). Scenario 1, wherein management may have a positive effect is reported where management activity scores are high/medium-high (MAS=3-4), catchment condition scores are low/medium-low (CCS = 1-2), and response variable scores are low/medium-low (RVS = 1-2). Scenario 2, wherein catchment stressors may override management, is reported where management activity scores are high/medium-high (MAS = 3-4), catchment condition scores are low/medium-low (CCS = 1-2), and response variable scores are low/medium-low (RVS = 1-2).

Scenario 1 was observed 19 times, while Scenario 2 was observed 21 times. For water quality, Scenario 1 was assigned three times, Scenario 2 assigned twice, plus one mixed result. For biotic composition, Scenario 2 was reported once, as was one mixed result. For hydrologic regime there were three Scenario 2s, two Scenario 1s, and one mixed result. For physical habitat and energy regime there were two of each Scenario 1 and 2. For connectivity, there were four each of Scenario 1 and 2.

Table 4.8 Scenario 1 and 2 counts observed in the FAM for each KEA

	Scenario 1: Management has a positive effect	**Scenario 2: Management is overridden by catchment stressors**
Water quality	7	5
Biotic composition	1	3
Hydrologic regime	5	7
Physical habitat and energy regime	2	2
Connectivity	4	4
Total	19	21

Either Scenario 1 or 2 was observed in all PAs except Atlanta State Forest Area (see Table 4.9). Scenario 1 was observed at least three times in Cadillac State Forest Area, Grayling State Forest Area, Manistee State Game Area, and Traverse City State Forest Area. Scenario 2 was observed at least three times in Cadillac State Forest Area, Grayling State Forest Area, Huron National Forest, and Manistee National Forest. Traverse City State Forest Area had the highest ratio of Scenario 1 to Scenario 2 with twice as many Scenario 1s, suggesting this PA's management may be the most successful in maintaining of improving KEA values. Conversely, Huron National Forest had the lowest ratio of Scenario 2 to Scenario 2 with half as many Scenario 2s, suggesting this PA's management may the least successful in mitigating the effect of upstream catchment stressors. Mixed results are reported when two response variable were utilized and they did not agree.

Table 4.9 Evaluative Scenario results comparing relationships between response variable scores, catchment condition scores, and management activity scores. Scenario 1, wherein management may have an effect is reported where management activity scores are high/medium-high (MAS=3-4), catchment condition scores are low/medium-low (CCS = 1-2), and response variable scores are low/medium-low (RVS = 1-2). Scenario 2, wherein catchment stressors may override management, is reported where management activity scores are high/medium-high (MAS = 3-4), catchment condition scores are low/medium-low (CCS = 1-2), and response variable scores are low/medium-low (RVs = 1-2). "Mixed" results are reported when two response variables were utilized and did not agree.

Protected Area	Water Quality Scenario	Biotic Composition Scenario	Hydrologic Regime Scenario	Physical Habitat and Energy Regime Scenario	Connectivity Scenario
Atlanta State Forest Area	n/a	n/a	n/a	n/a	n/a
Cadillac State Forest Area	Scenario 2	Scenario 2	Scenario 1	Scenario 2	Scenario 2
Gaylord State Forest Area	n/a	n/a	n/a	n/a	Scenario 1
Grayling State Forest Area	Scenario 1	Mixed (MAS = 4, CCS = 1.25, RVs = 1, 3)	Scenario 2	Scenario 1	Scenario 1
Huron National Forest	Scenario 1	n/a	Scenario 2	Scenario 2	Scenario 2
Manistee National Forest	Scenario 2	n/a	Mixed (MAS = 3, CCS = 1, RVs= 3, 2)	n/a	Scenario 1
Manistee River State Game Area	Scenario 1	n/a	Scenario 2	n/a	Scenario 1
Pigeon River Country State Forest Area	n/a	n/a	n/a	n/a	Scenario 2
Traverse City State Forest Area	Mixed (MAS = 4, CCS = 2, RVs =2, 4)	n/a	Scenario 1	Scenario 1	Scenario 2

5 DISCUSSION

5.1 TOTAL PERCENT PROTECTED TO RESPONSE VARIABLE COMPARISON

5.1.1 PROTECTED AREA QUANTITY AND FRESHWATER QUALTITY RELATIONSHIPS

Understanding the relationship between indicators of ecological condition and the conservation tool of land protection is essential when analyzing the effectiveness of efforts to maintain or increase the quality of freshwater systems. By examining the relationship between our response variables and the total percent of land protected within a catchment, we gained insight into the extent to which land conservation, independent of management, can confer conservation potential.

Three of the response variables were found to have had significant linear relationships with the percent of land protected within a catchment. For the response variable of nitrogen, results from the linear regression analysis suggest that an increase in the percent of land protected will result in decreased nitrogen loading. Nitrogen inputs to watersheds are removed in streams and on the landscape through storage, denitrification, and interbasin transfers of agricultural products (Alexander et al., 2002).

For the response variable of percent intolerant, results indicate that an increase in the percent of land protected within a catchment will result in an increase in the percent intolerant score. This finding is consistent with other studies on the effects of land protection on biotic composition (Pinto et al., 2006, Heino et al., 2009). Assemblage indices, such as percent species intolerant, are considered to be especially important sentinels of environmental conditions (Karr, 1995). These indicator types are subject to multiple stressors. As such, cumulative stress measures are the best way to track responses in biological assemblages (Danz et al. 2007). As percent of land protected within a catchment was found to influence the percent intolerant score, there is some evidence to suggest that the amount of protected land may have an influence on the quality of freshwater systems. However, the lack of statistical evidence to support the relationship between percent of land protected within a catchment and fish IBI, another cumulative stress measure, suggests this influence is marginal.

Finally, results suggest that the average rate of flow response will decrease as a result of an increase in protected land within a catchment. Typically, streams with decreasing natural cover result in higher magnitudes and shorter return intervals of high flows, and streams also generally display shorter duration flows with high flashiness (Paul and Meyer, 2001). Thus, the preservation of land cover types such as forests and grasses are important when managing watersheds for flood prevention and the maintenance of hydrologic regime within streams (Schoonover et al., 2006).

5.2 MANAGEMENT DISCUSSION

Results from our questionnaire and interview process indicate that management processes are, generally, complementary to identified threats to freshwater systems. The exceptions include isolated instances where the negative effects of stormwater outfalls, wetland loss, and the intersection of road networks and streams were not explicitly addressed through management activities. Although these findings suggest that management is attending to freshwater conservation goals, results from our questionnaire and interview process did not address issues of scale. As such, it is important to note that the presence of an activity may not be enough to address the associated threats. Although our findings suggest positive alignment between management activities and threats, there is indication that management may not be properly attending to freshwater conservation goals when examining management procedures through the study imposed lens of IWRM. For the purposes of this study, IWRM was used as the standard for freshwater management through which current activities could be evaluated. See Appendix 5 for full results from management questionnaires.

5.2.1 LIMITATIONS OF MANAGEMENT STRATEGIES

Ecosystem-based management places focus on the integration of scientific knowledge within the broader socio-political context in order to ensure long-term protection of ecosystem integrity. Encompassed within this concept is the development of socially defined goals and objectives, integrated science, adaptable institutions, and collaborative decision-making. By introducing systems thinking into resource management, an ecosystem-based approach forces consideration of long-term, holistic factors influencing ecosystem integrity that are emblematic of outcome-based, adaptive management (Butler and Koontz, 2005). In light of competing interests and limited resources in relation to freshwater resources, many managers have embraced IWRM, a subset of ecosystem–based management. Integrated water resource management is a strategy that balances various interests by introducing a process that coordinates conservation, management, development, and land and other resources in a way that equitably addresses local economic and social benefits in light of conservation priorities. It is also an approach that many have suggested be utilized to address and organize principles of freshwater conservation in terrestrial PAs (Abell, 2007). For example, the World Park Congress asserts the necessity of IWRM in the establishment of all PAs. Additionally, this sentiment is echoed in Goal 1.2 of the Convention on Biological Diversity, which sets out "to establish and maintain comprehensive, adequate and representative systems of protected areas inland water ecosystem within the framework of integrated catchment/watershed/river basin management."

Through the investigation of external and internal stressors affecting the quality of water resources within the study sample of PAs, loss of natural riparian vegetation, shoreline development, dam presence, the intersection between road networks and streams, impassable culverts, invasive species, and ORV associated erosion and pollution have been identified as the leading factors negatively impacting freshwater systems (See Appendix 10). These findings are supported in the literature where dams, diversions, increases in runoff, nutrient enrichment from land use practices, chemical pollution, sedimentation, channel and floodplain modification, and the introduction of non-native species have been identified as the leading sources of stress to freshwater systems. Furthermore, analysis of trend data relating to the level of alteration from stresses indicates an increase in the magnitude of impairment to freshwater ecosystems. Due to the nature of water resources, namely that the ecological conditions of a given stream reach depend not only on the integrity of the surrounding site but also the conditions upstream, the prevalence of these threats throughout watersheds clearly demonstrates the need for action, both ecological and societal, on a watershed level scale (Braun, 2000). An additional call for watershed level coordination of natural resource management stems from the fact that often such alterations exist outside of reserve boundaries and thus cannot be addressed by PA managers alone (Pringle, 2001). For example, the negative consequences associated with nonpoint source pollution require the involvement of multiple stakeholders and governing bodies across the watershed to be effectively managed (Braun, 2000).

Despite widespread indication of the need for IWRM within the scientific and policy communities, there is evidence to suggest that PAs are insufficiently involved in IWRM planning processes (Abell, 2007). Our own evidence from the questionnaire and interview results supports this notion. Based on analysis of the extent to which collaborative processes are utilized, the articulation of the intersection of terrestrial and freshwater management activities, recognition of values beyond conservation, and the incorporation of indicator data in informing management activities, there appears to be limited incorporation of IWRM approaches to freshwater conservation. This shortcoming highlights a potential limitation of current park management policies.

Local actors are key components of a management strategy based on IWRM principles. Effective lines of communication are required to integrate the values of stakeholders into the development of management plants. Successful implementation of conservation strategies can be achieved only with the involvement of the broader public—namely, local buy-in (IUCN, 1998). The involvement of just such stakeholders was one of the IWRM principals that each PA manager noted as contributing a great deal to the implementation and articulation of management strategies. For example, management at Gaylord State Forest, Atlanta State Forest, Pigeon River Country State Forest Area, and Grayling State Forest Area work with the Huron Pines Resource Conservation and Development, Tip of the Mitt Watershed Council, road commissions, the Upper Black River Restoration Committee, Trout Unlimited, and the U.S. Fish and Wildlife Service. Management officials at Wilderness State Park have cultivated relationships with the Little Traverse Bay Bands of Odawa Indians to undertake water quality testing at different locations throughout Sturgeon Bay, Central Michigan University to undertake small-mouth bass surveys, and the North Country Trail group to complete invasive species surveys. The Huron-Manistee National Forests have also successfully established partnerships with key groups such as watershed councils, conservation districts, and tribal governments. Although many PAs participate in partnerships with a wide range of other organizations, only management at the Huron-Manistee National Forests, Gaylord State Forest, Atlanta State Forest, Pigeon River Country State Forest Area, and Grayling State Forest Area have institutionalized watershed management planning (Personal communications, February 2010). In the absence of formal watershed-wide planning, partnerships alone may not confer the adequate knowledge or ability to influence decision-making at the broader watershed scale.

Throughout the study sample, PA managers frequently cited the use of public education programs in order to inform citizens on ways in which freshwater systems can be better understood or protected. This is a positive step in the IWRM approach to freshwater conservation as the effects of land and water uses on the integrity of freshwater systems are not always evident to the public. For example, a stream may be clear running and recreationally sufficient for various uses but be severely degraded in terms of native biodiversity and ecological function. In order to address these differences in perception concerning freshwater resources, public outreach is an important means of educating local stakeholders and thus ensuring support for conservation efforts (Braun, 2000).

Responses from PA-specific interviews also suggest that management has recognized the intersection of terrestrial activities and the associated effects on freshwater quality and contingent importance of managing for additional values beyond ecosystem integrity. In fact, all but one PA manager noted the recognition of freshwater impacts from terrestrial-based activities. Examples of this awareness include the Wilderness State Park trail work that is conducted with the intent of minimizing the impact to freshwater resources, and the Gaylord State Forest, Atlanta State Forest, Pigeon River Country State Forest Area, and Grayling State Forest Area management working with MDNR Fisheries Division, MDNR Forest Division, and MDNR Wildlife Division to gain a broader understanding of factors influencing potential management strategies. For example, fishery biologists are involved in oil and gas reviews in order to mitigate any potential harm to freshwater systems (Personal communication, February, 2010).

An additional aspect of IWRM is the idea of adaptive management. Adaptive management calls for managers to embrace knowledge gaps, the effects of human activities on ecosystem integrity, and quantifiably evaluate the effectiveness of conservation strategies when implementing projects designed to achieve conservation goals. As a part of this approach to resource management, evaluation and monitoring data are elevated as key components through which the evaluation of activities and resulting alteration of management practices occurs. Adaptive management is an established concept with regards to resources management as evidenced through its use by TNC in their Freshwater Initiatives (Braun, 2000). To engage in effective adaptive management processes sound monitoring data must be available. Management should thus be observing such indicators as rainfall, river flows, infiltration, storage of groundwater within wetlands, annual flooding, acidity, nutrient, pesticides, ammonia, biological oxygen demand (BOD), oxygen, heavy metals, ecosystem functions, and the provision of ecosystem goods and services (International Union for the Conservation of Nature, 1998). Results from this study, however, suggest limited incorporation or connection of monitoring and indicator data to management activities or stated goals and objectives; this represents a likely barrier to progress towards meeting the goals of watershed-wide management strategies.

Based on interview results, three of eleven PA managers interviewed noted the absence of or minimal use of indicator data to inform the state of environmental conditions of freshwater systems within the PAs. The remaining eight PAs utilized indicator data to varying degrees. For example, management at Gaylord State Forest, Atlanta State Forest, Pigeon River Country State Forest Area, and Grayling State Forest Area cited use of such indicator data as fish assessments, substrate type, water temperature, pH, alkalinity, and chlorophyll. Management also recognized of the need to compare data to historic trends to assess how ecosystems have changed over time.   Adaptive management also requires that this information be utilized to evaluate management activities in order to identify areas of potential alteration. Although the identification of indicator data represents a positive trend in terms of achieving goals of IWRM, there was no indication that these indicator data were formally tied to goals and objectives hindering the ability of management to actually be adaptive in addressing prioritized concerns.

In contrast to the limited use of indicators by some PAs, Forest Service lands as well as Cadillac and Traverse City State Forest Areas show positive signs of the use of indicators to inform management strategies (Personal communications, February 2010). According to the IUCN's framework for evaluating the management effectiveness of terrestrial protected areas, the integration of desired outcomes and options for outcome evaluation represent the foundation for effective management (Hockings, 2004). An analysis of the Huron-Manistee Forest Plan indicates that progress towards the creation of an outcome-based framework is underway. This type of analysis is apparent in the foundational structure of the Huron-Manistee Forest Plan which places emphasis on the documentation of what the forest should look like following successful plan implementation, identification of measurable results that highlight progress towards reaching forest-wide desired conditions, promulgation of required actions designed to achieve desired objections and conditions, and use of monitoring efforts to inform progress towards desired forest-wide conditions. Further analysis of the "Huron-Manistee National Forest FY 2008 Monitoring & Evaluation Report" supports the assertion that management is in fact incorporating outcome-based assessment in their management procedures. In the evaluation of the extent to which the minimum viable population of native and desirable nonnative species have been maintained, ongoing site-specific monitoring of habitat improvements and fish populations were used to qualitatively assess the conservation goals achieved through ongoing watershed restoration activities

As PAs in Michigan are frequently multiple use lands, even whole-catchment management strategies can be limited in their effectiveness due to the complexity of exogenous threats imposed on those catchments (Abell, 2007). Furthermore, a whole-catchment management approach implies that every management decision within the PA boundaries is considered for its effect on waterway, and entire catchments are located within the boundaries of designated protected areas (Saunders, 2002). In Michigan for example, PA boundaries are not determined according to catchment size or location, but rather designation of land use (hunting and recreational use in MDNR State Game Areas) or land cover (integrity of forested areas within Huron-Manistee National Forests). It is not likely that these federal and state land boundaries will change to accommodate entire catchment boundaries, but in areas of Michigan where protection of the entire catchment is not feasible, other freshwater conservation approaches are necessary.

5.3 THE FRESHWATER ACTIVITY MATRIX: IDENTIFYING TRENDS

5.3.1 EVALUATIVE SCENARIO DISCUSSION

Scenario 1, the instance where management appears to have a positive effect, and Scenario 2, the instance where management appears to be overridden by catchment stressors, were observed in nearly identical proportions, suggesting that both management activities and catchment stressors vary in their ability to affect freshwater KEA values. However, further analysis of results may reveal where management has provided the greatest benefit to freshwater conservation. For example, Scenario 1 was observed more than Scenario 2 for water quality while the opposite was observed for biotic composition and hydrologic regime. These results suggest that management activities may be more successful in mitigating the effects of catchment stressors specific to nutrient concentrations. Further investigation of the factors contributing to observed trends across KEAs and PAs may reveal what management practices have the potential to provide benefit to freshwater KEAs.

5.3.1.1 WATER QUALITY

We observed Scenario 1 five times and Scenario 2 seven times across PAs for water quality variables. For Grayling State Forest Area and Huron National Forest, we observed Scenario 1 as Water Quality MAS was high, CCS was low, and both nutrient metrics were highly scored. Here, management activities, which included the promotion of forest BMPs, may be linked to positive trends in both response variables. Some forest BMPs, such as leaving buffer strips along streams designed to control sedimentation, can serve to maintain nutrient levels in streams (Chunko, 2008).

Both Scenario 1 and Scenario 2 were observed for Traverse City State Forest Area. Here, a low-range Water Quality CCS was observed, MAS was high, and response variable scores to this relatively highly stressed and highly managed PA are mixed, with a medium-low Nitrogen Score and a high Total Phosphorous score. These results may suggest that management by this PA has a positive effect in mitigating phosphorus levels, but not nitrogen. Traverse City State Forest Area was found to have a high percent of impervious surfaces in its catchment relative to other PAs, indicative of urban areas, which have been shown to be a significant source of nutrients due to municipal wastes and fertilizers (Osborne and Wiley, 1988). Management in this PA includes frequently practicing erosion control methods and bank stabilization. Because increased phosphorus levels are often associated with soil erosion, more so than increased nitrogen levels (Allan and Castillo, 2007), these management activities may explain why the Phosphorus Score was higher than that of Nitrogen.

Scenario 2 was observed for Manistee National Forest and Cadillac State Forest Area. Here, PA management may recognize stress to the system (as evidenced by high MAS), but their actions may be ineffective relative to the effect. In this instance, stressors may be overwhelming management effort. Manistee National Forest received the lowest CCS of all PAs, which was the result of a high degree of stresses from all sources used in the calculation. However, for Cadillac State Forest Area, results may be explained by a relatively high percentage of riparian corridor agriculture. Agricultural land, due to fertilizer and animal waste runoff, is responsible for 52% of total nitrogen and 47% of total phosphorus discharged into waterways in the United States (Gianessi et al., 1986).

For the maintenance of water quality integrity, our results suggest that forest BMPs, stream bank stabilization, and erosion control structures may have the greatest benefit. However, as evident in Cadillac State Forest Area, a high percentage of agriculture, especially when located within a 100 meter corridor of a stream, may override even the most intensive management actions.

5.3.1.2 BIOTIC COMPOSITION

We observed Scenario 1 once and Scenario 2 twice across PAs for biotic composition variables. Scenario 1 and 2 were observed for Traverse City State Forest Area and Cadillac State Forest Area respectively, with both scoring low for Biotic Composition CSS and high for MASs, though Cadillac State Forest Area had a lower IBI and Percent Intolerant Species Scores. Though management attention to biotic composition is high in Cadillac State Forest Area, its biological composition is suffering relative to other PAs. Because cumulative management and catchment stressors between these two PAs are similar, differences in biotic composition response variables may be attributable to differences in a specific catchment stressor or group of stressors. However, because fish are integrators of all physical, chemical, and biological impacts (Karr, 1981), it is difficult to attribute differences to a sole stressor.

Interestingly, Gaylord State Forest Area exhibited the highest scores for response variables despite receiving a low Biotic Composition MAS. In addition, this PA received a medium-low CCS, suggesting biotic composition in Gaylord State Forest Area incurs a relatively high amount of stress. Possibly contributing to high response variable scores is the high average percent protected for response variable catchments (45.17%), which is second highest of all PAs. These results suggest that simply protecting natural land from development can be a successful strategy in preserving freshwater biodiversity.

5.3.1.3 HYDROLOGIC REGIME

We observed Scenario 1 five times and Scenario 2 seven times across PAs for hydrologic regime variables. Paralleling reports from PA managers who cited dams and culverts as major stressors to the system, Hydrologic Regime CCSs were one of the most significantly impacted KEAs in our study area. For both Cadillac State Forest Area and Traverse City State Forest Area, Scenario 1 was observed as MASs were high, CCSs were medium-low, and response variable scores were high. Here, average rate of flow response suggest low flashiness and high specificity between expected and observed values for low flows. We found that management activities occurring occasionally in these PAs included post-disturbance re-vegetation, reduction of impervious surfaces, and removal of dams, weirs, and levees. Because runoff approximately doubles when impervious surface is 10-20% of the catchment (Arnold and Gibbons, 1996), flood peaks increase, and time to peak shortens (Paul and Meyer, 2001), these management activities may play a role in high response variable scores.

Scenario 1 was also observed in Manistee National Forest for Average Rate of Flow Response. Manistee National Forest received the lowest Hydrologic Regime CCS, indicating this PA is subject to the most stress to hydrologic regime from upstream sources, but Average Rate of Flow Response Score was medium-high. The medium-high MAS received by this PA suggest actions, such as the promotion of forest BMPs or the removal and upgrade of culverts in the PA (both conducted often), may play a role in the relatively high hydrologic regime response value. Additionally, while Manistee National Forest is the largest of all PAs of our study, it contains the third lowest number of dams (see Appendix 8).

The high Low Flow Expectation Scores received by both Traverse City State Forest and Pigeon River Country State Forest indicate that the WWAT used by the state to regulate water withdrawals accurately estimated low flow conditions. Since there was a small difference between the expected and calculated flows, the systems are accurately represented in the state's management tool. Our results suggest that in Huron National Forest and Manistee State Game Area, where the Low Flow Expectation Score was low, there is a disconnect between management assumptions and ecological reality, which may lead to further alterations in hydrologic regime as additional withdraws may be permitted resulting from misassumptions about the amount of water moving through the system in the summer months of low flow.

5.3.1.4 PHYSICAL HABITAT AND ENERGY REGIME

We observed Scenario 1 twice and Scenario 2 twice across PAs for the physical habitat and energy regime. Managers reported high levels of activity relating to physical habitat and energy regime. With a high Physical Habitat and Energy Regime MAS and a medium-low Physical Habitat and Energy Regime CCS score, Scenario 2 was observed in Huron National Forest where the Habitat Quality Score was medium-low, possibly indicating that management activities are not mitigating the effect of upstream stress. In this PA, habitat may be affected by a large dam presence in its catchment. There are 15 dams in Huron National Forest's boundaries and 91 dams located in cumulative watershed. Many dams are known to release high discharges downstream, which may cause scouring of fine materials and armoring of the streambed, a process in which the surface substrate becomes tightly compacted (Allan and Castillo, 2007).

Scenario 2 was also present in Cadillac State Forest Area, which received high Physical Habitat and Energy Regime MASs, though a low Habitat Quality Score. In fact, the Cadillac State Forest Area's Habitat Quality Score was the lowest of all PAs. Conversely, Scenario 1 was observed in Traverse City State Forest Area, where the highest Habitat Quality Score was observed. Because the management activities of these two PAs were the same, differences in Habitat Quality Score may be related to differences in specific stressor variable type. There is no significant difference in dam density between the catchments of the two PAs, but we found a higher proportion of impervious surface within Cadillac State Forest Area (see Appendix 8). Impervious surfaces can have a significant impact on the amount and rate of runoff entering streams as pavement and buildings reduce transpiration and infiltration (Allan and Castillo, 2007), perhaps contributing to the lower habitat scores observed in Cadillac State Forest Area.

5.3.1.5 CONNECTIVITY

We observed both scenarios four times across PAs for the connectivity variable. Scenario 2 was observed for Cadillac State Forest Area and Traverse City State Forest Area, which have high scores for Connectivity MASs, middle-range Connectivity CCSs, and middle-low connectivity response variable scores. Similar to other KEAs, stressors may be outpacing management efforts. Specifically, both PAs experience high levels of road crossings, which have been cited as the most ubiquitous anthropogenic features of river networks (Burford et al., 2009).

Atlanta State Forest Area and Huron National Forest have the highest density of dams per stream meter, as reflected in the low response variable score. Though almost a quarter of the relevant catchment areas are protected by these PAs (who both earned medium-high Connectivity MASs), the KEA is still compromised by high dam densities. Management of Huron National Forest is one of few who rarely remove barriers, while most other PA managers report implementation of barrier removal programs on an occasional basis.

5.4 LOOKING FORWARD: A FUTURE FOR FRESHWATER

The methodology utilized in this study was dependent upon the existence, acquisition, and appropriate analysis of data for management, catchment condition, and response variables. In addressing this range of variables, several lessons were learned which may inform future analyses of terrestrial PAs' contribution to freshwater conservation. This section outlines an ideal study design, data management considerations (e.g. working with limited data, scoring norms), and policy alternatives that bear consideration in the analysis of freshwater conservation efforts.

5.4.1 STUDY DESIGN: ASPIRATIONS AND REALITIES

To complete a thorough study of terrestrial PA management effectiveness in freshwater conservation, ecological integrity data should be collected methodically and consistently in direct spatial correlation to PA management activities. Ideally, consistent and long-running data sets would be created for response variables, landscape context, and management practices occurring within the PA and its watershed. The data set would include freshwater-related ecological integrity data directly before PA management jurisdiction and directly after PA management jurisdiction, in the longitudinal sense of moving water. As we searched for such situations, wherein data were available directly upstream and directly downstream of PAs, we realized the limitations of our conceptual design. Many of the PAs selected in this study are comprised of a patchwork of tracts, spotted by private land holdings, thus limiting our ability to attribute upstream-downstream trends to the PA alone. Also, data points may be geographically disparate. In the absence of data tightly linked to PAs, our selection and analysis of data was limited. With the establishment of KEA monitoring points before and after PA management takes effect on the system (i.e. upstream and downstream), we would have the ability to provide a "before and after" picture of PA management effectiveness in freshwater conservation. Due to the rarity of such circumstances in currently existing data, this ideal experiment was not possible. Long-standing, upstream-downstream data sets oriented towards KEAs need to be established to formally test the impact of terrestrial protected areas on freshwaters.

5.4.2 WORKING WITH LIMITED DATA

Stream ecosystem health monitoring and reporting need to be developed in the context of an adaptive process that is clearly linked to identified values and objectives while guiding management actions, responding to stakeholder opinions, and upholding the rigors of science (Bunn et al., 2010). In order to study the direct effects of management and catchment landscape composition, data need to be collected systematically over time following strict methods. Protocols for data analysis need to be devised, enabling a consistent and direct comparison between management and freshwater attributes (Bunn et al., 2010). This would provide the ability to record changes over time, avoiding a space-for-time substitution. Data collection to inform an ideal case for studying management and freshwater ecological indicators presents many challenges. Potential difficulties include gathering data that measures environmental outcomes, allowing for long time horizons between the implementation of collaborative outputs and environmental change, and designing research protocols to untangle the effects of multiple interacting variables shaping environmental change (Koontz and Thomas, 2006).

As seen in this research, data availability and quality present a great challenge. Here, the data used reflects a wide range of inputs from multiple sources. While many agencies provided data, the full range of data identified as being important to our analysis was not always in existence. These data gaps reflect the difficulty of system monitoring across time and space. It is difficult to make claims about the environmental impacts of management collaboration without data that precisely measures changes in environmental conditions (Koontz and Thomas, 2006). Since this type of data is difficult to collect, maintain, and utilize effectively, collaborative management groups tend to focus on outputs (such as plans, projects, management practices, and policies) because outputs are more easily measured than outcomes (Koontz and Thomas, 2006).

Where data collection at the scale of interest is not possible, modeling techniques may be used to fill the void. Sherman et al. (2007) recognize management of land use and the setting of water quality targets across entire watersheds are typically constrained by a lack of observational data. This can be addressed with the use of models to inform management decisions. Sherman et al. (2007) does give warning to the use of spatial models. They warn that GIS-based analysis and modeling can be biased, but that assessment of competing land management scenarios is not severely impacted by model uncertainty provided the interpretation of results is limited to relative changes in the variable of concern (Sherman et al., 2007).

5.4.3 UTILIZATION OF ACCEPTED SCORING APPROACHES

When relying on existing data, it is important to understand how such data has typically been used to inform previous management decisions. Depending on interpretation and valuation of data, differential results may be achieved. Our FAM scoring system for response variables was based on a relative scale, one to four (1 – 4). All comparisons derived from the FAM are based on relative values, and are not informed by the broader context of how the given data might compare to the full range of possible values. Therefore scores are only relative to data collected.

For a more robust representation of how our data fit into the full range of potential response variable conditions and how managers judge these data, it is important to use standardized bins for the scoring process. For example, if a state natural resources agency produces guidelines for categorization of IBI scores into “integrity classes,” as is done by the Ohio EPA, those categorizations could be used as bins for more objective scoring (Ohio EPA, 2010). The Ohio categories were not suitable for our purposes as they are based on warm-water conditions and the Northern EDU should be analyzed using a cold-water IBI metric (Lyon, 1996).

In an initial review of potential hydrologic regime response variables, “flow stability” was considered. Flow Stability Score, a component of the Habitat Quality Scores provided by the MDEQ is based on field observations of flow source and regularity with observations categorized as excellent (16-20), good (11-15), fair (6-10), and poor (0-5) (Michigan Department of Environmental Quality, 1997). For a comparison of relative binning and binning based on observational categories, see Table 5.1 below.

Table 5.1 Comparisons of hydrologic flow stability bins used for scoring in this study to those bins used by the Michigan Department of Environmental Quality.

Quartile Bin	Points	Observational Bin	Points
Q1 = 10.87 - 11.31	1	Poor = 0-5	1
Q2 =11.32 - 11.59	2	Fair = 6-10	2
Q3 = 11.60 - 12.09	3	Good = 11-15	3
Q4 = 12.10 - 15	4	Excellent = 16-20	4

As Table 5.2 shows, the scoring results would be quite different with management-defined observational bins compared to quartile-based bins. Flow stability for all PAs would have been categorized as medium-high under the state's scoring system, whereas, by definition there was more variation in scoring under the quartile approach. At the extremes, Atlanta State Forest Area's flow stability would have been over-scored and Grayling State Forest Area and Huron National Forest flow stability under-scored under the quartile approach.

Table 5.2 Comparison of scoring results (4= high, 3= medium high, 2= medium low, 1= low) for hydrologic flow stability with management-defined bins (procedure 51) versus quartile-based bins used in this study.

Protected Area	Average Flow Stability Rating	Quartile Score	Observational Score Equivalent
Atlanta State Forest Area	15.000	4	3
Cadillac State Forest Area	11.860	3	3
Gaylord State Forest Area	12.090	3	3
Grayling State Forest Area	10.870	1	3
Huron National Forest	11.310	1	3
Manistee National Forest	11.390	2	3
Manistee River State Game Area	n/a	n/a	n/a
Pigeon River Country State Forest Area	n/a	n/a	n/a
Traverse City State Forest Area	11.590	2	3

5.4.4 ALTERNATIVE TOOLS FOR FRESHWATER CONSERVATION

There are non-terrestrial-based approaches to freshwater protection, which may have influenced our analysis of freshwater conservation outcomes. As alternatives to traditional land management, policy options such as zoning of river corridor protections and dam reoperation are increasingly utilized in managing freshwater systems. Though such program evaluation was outside of the scope of our study, future analyses of freshwater conservation should attend to this suite of policy alternatives and their relationship with traditional terrestrial PA management.

Though our management activity survey indicated that freshwaters are considered, there is little formal recognition of freshwater KEAs in management planning. As such, the examination of terrestrial influences (i.e. stressors) and how they interrelate with freshwater attributes is not well incorporated into management activities. Freshwater managers have several options in conferring protection to rivers and streams in Michigan. There are other approaches in addition to IWRM which target future terrestrial PA designation for maximum contribution to freshwater conservation, and engage in the political process to grant Federal and State protection of waterways.

5.4.4.1 PROTECTED AREAS DESIGN: HEADWATERS PROTECTION

Headwaters, locations where a river or stream originates, are characterized by a relatively small area as compared to downstream networks. In many cases, headwaters represent the most pristine portion of the fluvial system since they have fewer upstream inputs and stressors such as invasive species, dams and culverts, and shoreline development. Protection of these environments is as an essential component of freshwater conservation efforts. Downstream regions of catchments are highly influenced by the terrestrial production (e.g. input of debris from riparian vegetation) that occurs in upstream, headwater regions (Saunders, 2002). Accounting for KEA processes in headwater areas goes far in protecting downstream reaches, for if the system is compromised at its origin, subsequent reaches will also be influenced.

5.4.4.2 RIPARIAN BUFFER ZONES

Riparian buffer zones (Abell, 2007), also known as vegetated buffer strips (Saunders, 2002), or riparian management zones (MDNR & MDEQ, 2009), refer to the managed shoreline area adjacent to a river or stream. Focusing freshwater management activities on the land immediately bordering freshwater ecosystems can be effective because it serves as the final buffer to land-use activities and hydrological flows (Saunders, 2002). In Michigan, these zones can mitigate the impacts of terrestrial stressors such as nutrient loading from agricultural runoff and timber harvesting. As previously mentioned, the MDNR has outlined BMPs for RMZs located in State Forest Areas to confer protection to rivers and streams while allowing limited activities, such as timber harvesting, to occur.

5.4.4.3 WILD AND SCENIC RIVERS DESIGNATION

The federal Wild and Scenic Rivers Act was passed in 1968 to introduce a program that now encompasses over 11,000 river miles across the United States. The goal of this legislation is to preserve the natural, cultural, and recreational values of rivers for present and future enjoyment. In Michigan, over 625 river miles are classified as Wild and Scenic Rivers. These waterways travel through both public and private lands, making interagency cooperation (such as between USFS, MDNR, MDEQ) as well as partnerships with watershed councils, private landowners, and non-governmental organizations, essential components of the program.

The classification of a river as "Wild and Scenic" requires a one-quarter mile (400 meters) "buffer" on either side of the river channel to protect the riparian corridor and natural river characteristics. Designation does not affect existing development and does not give the governing agency rights over private property that lie within the buffer boundaries. Existing agricultural practices and residential development may continue following designation (National Wild and Scenic Rivers, 2009). The Wild and Scenic Rivers Act prohibits further development of dams, culverts, or other structures that alter natural river flow. As evidenced across most of our PA study sites, dams have a tremendous impact on freshwater attributes such as physical habitat, connectivity, and hydrologic regime. River characteristics such as riparian vegetation, temperature, sedimentation, and water quality can be drastically altered after dam construction.

5.4.4.4 THE NATURAL RIVERS PROGRAM

Michigan's Natural Rivers Act was passed in 1970, and is now listed under MDNR's Natural Resources and Environmental Protection Act of 1994. The Natural Rivers Program has designated over 2,000 river miles in the state of Michigan as Natural Rivers (MDNR, 1994). Similar to the Wild and Scenic Rivers Act, the Natural Rivers designation serves to preserve and protect the integrity waters in free flowing condition, which supports fish and wildlife habitat, scenic, aesthetic, floodplain, ecologic, historic, and recreational values and uses (MDNR, 1994). Michigan Department of Natural Resources oversees the administration of the Natural Rivers Program and sets requirements for activities related to residential and shoreline development, timber harvesting, public access, and land use practices in areas adjacent to Natural Rivers. Under the supervision and oversight of MDNR officials, local governments are given the autonomy to adopt Natural River zoning standards that allow the locality to become administrators. Due to the limited resources that MDNR can provide to these Natural Rivers areas, such partnerships are paramount to ensuring success. Coordination between these local governments, MDNR, MDEQ, U.S. Forest Service, tribal communities, and other partners is occurring and must continue to advance the Natural Rivers program.

6 CONCLUSION

6.1 WHAT IS THE FRESHWATER CONSERVATION POTENTIAL OF TERRESTRIAL PROTECTED AREAS

Threats to freshwater ecosystems are numerous and widespread. Terrestrial PAs, often initially designated to protect non-freshwater resources, have potential to address freshwater threats as PAs often contain freshwater systems. However, the exact role terrestrial PAs can be expected to play in freshwater conservation has been unclear. To determine the freshwater conservation potential of terrestrial-based PAs, we evaluated two broad attributes of PAs: (1) the effect of containing freshwater systems within or adjacent to land that is in undeveloped condition and (2) the ability of PA managers to identify and mitigate negative anthropogenic influences to the key ecological attributes of freshwater systems that run through, or close to PA borders.

Terrestrial PAs have marginal influence on freshwater KEAs. Independent of management activity, PAs confer direct benefits to freshwaters in that land area under PA designation remains undeveloped. Even PAs initially designated for non-freshwater purposes inherently contribute to freshwater outcomes. However, such a contribution is limited.

Previous analyses regarding the security of freshwater KEAs are likely overstated. Prior freshwater status assessments were informed by overlaying terrestrial PAs with freshwater systems, deeming areas of overlap as secure. We also overlaid PAs with freshwater systems, but took the additional step of tracking KEA-based response variables in order to test actual relationships between catchment protection and ecological indicators of freshwater health.

Alternate approaches to identifying gaps in protection of freshwaters are warranted. If terrestrial protection were sufficient, we would expect the majority of response variables to exhibit expected relationships with total percent of watershed protected. However, our linear regression showed that only three of eight response variables expressed the relationship expected with terrestrial protections. Consequently, our findings do not support the assumption that existing watershed protections are synonymous with preservation and maintenance of freshwater KEAs.

When considering the extent to which PA management is attending to freshwater conservation goals, results from our work highlight both positive trends and potential shortcomings. By comparing questionnaire responses for both threats to freshwater conservation goals and activities in place to address threats, results indicate that management activities are well aligned with those factors identified as negatively impairing freshwater systems. This finding is true across the PAs, for each of the KEAs, with a few isolated instances where management activities were not in place to address identified threats. This finding is important as it suggests that PA management is attending directly or indirectly to freshwater conservation, as PA mangers currently understand it.

Management has shown some progress towards meeting the standards set forth in the IUCN's framework and through principals of IWRM. For example, managers appear to have integrated social and cultural values into management procedures, utilized public education programs to inform resource users, recognized the intersection of terrestrial-based management activities with freshwater systems, and utilized collaborative processes to enhance management resources. Despite these positive findings, however, the limited use of freshwater indicators to assess ecosystem integrity represents a weakness in management activities in achieving adaptive management protocols. Without the implementation of robust monitoring programs there is no way for management to identify the extent to which freshwater resources are being protected. As such, the ability of PA managers to respond to environmental conditions is hindered.

Instances where management appears to have a mitigating effect on negative anthropogenic influences (Scenario 1) and instances where management appears to be overridden by negative anthropogenic influences (Scenario 2) were mixed. The former was observed more often for water quality while the latter was observed more often for hydrologic regime and biotic composition. As no strong trends were found to indicate that terrestrial PA management is able to mitigate the effect of upstream stressors, our results suggest that PA-specific management of freshwater KEAs is somewhat marginal. Without a strong commitment to the interrelated nature of aquatic systems as they move through a variegated landscape, small-scale efforts may be overridden. Of the few trends observed, our results may suggest that PA managers are more successful in mitigating the effects of individual threats to certain responses. For example, there are fewer sources of stress that culminate in nutrient loading than in degraded biotic composition. As Scenario 1 was observed the least for biotic composition, terrestrial PA management may have the most difficulty mitigating the total impact of catchment stressors. This may be a call for IWRM, wherein watersheds are managed proactively at the watershed scale, as opposed to ad-hoc or marginally orchestrated freshwater management approaches.

6.2 THE IMPORTANCE OF OUR APPROACH

Our approach provides a framework for evaluating and tracking key freshwater outcomes while addressing the interacting factors of human-induced stress and management attempts to mitigate these stresses. This holds utility not only for terrestrial PA managers, but also any other managing entity that attempts to produce favorable outcomes for freshwater systems. Our approach can be tailored to include a different set of management activities, catchment stressors, and response variables, depending on the context of the PA and what data are available for use.

The approach used here holds lessons for PA managers, policy makers, and land stewards. Currently, little is known about what contributions terrestrial PAs make to freshwater systems. Our results suggest that terrestrial PAs likely contribute to some components of freshwater KEAs by protecting land from development, and through certain management activities. Further research is warranted to more extensively track the interaction of anthropogenic stressors and management activities in their affect on freshwater systems. This will lead to a clearer understanding of what freshwater conservation outcomes terrestrial PA management can, and cannot be expected achieve.

Many public managers are charged with tracking progress towards achieving management goals (e.g. outputs, outcomes). If managers do not accurately track the results of their activities (i.e. outputs), limited resources may be applied to areas that are inefficient and possibly ineffective. Quantification of the effectiveness of management activities can be extremely problematic. Outputs are often confused with outcomes. Alternatively, outputs may be consciously used instead of outcomes when the latter is deemed too difficult to track. In such instances desired conservation goals may not be achieved. In light of such constraints, we also performed a qualitative evaluation. In the environmental realm, the integration of qualitative and quantitative analyses must be done in the context of the full suite of influences that may be overriding management efforts. If an evaluation of management outcomes does not account for potentially overriding factors, there can be false perceptions of the effectiveness or inadequacy of management activities directed towards freshwater systems.

6.3 THE FUTURE OF FRESHWATER CONSERVATION

Future studies of terrestrial PAs' contributions to freshwater conservation using our methodology would benefit from a long-term, spatially relevant collection of ecological integrity data. Moving forward, data collection efforts must be oriented towards explaining KEAs for rivers and streams within the study catchments. Furthermore, a comprehensive analysis of updated management plans, goals, and objectives would be fruitful. During our outreach to PA managers, we received some indication that freshwater-specific issues will be incorporated within future management policies, such as the MDNR's Regional State Forest Plan. This indicates that managers acknowledge limitations of land management alone in achieving freshwater conservation goals and together with our mixed trends of management efficacy in mitigating stressor impact on KEAs may be a call for renewed prioritization in conservation planning for freshwaters. Such a shift in the freshwater management policies may increase the conservation potential of terrestrial PAs in achieving freshwater conservation goals.

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APPENDIX

Appendix 1 Scoring criteria used in calculation of fish IBI scores used in this study (modified from Lyons et al, 1996). Source of data is Michigan Department of Natural Resources Institute of Fisheries Research.

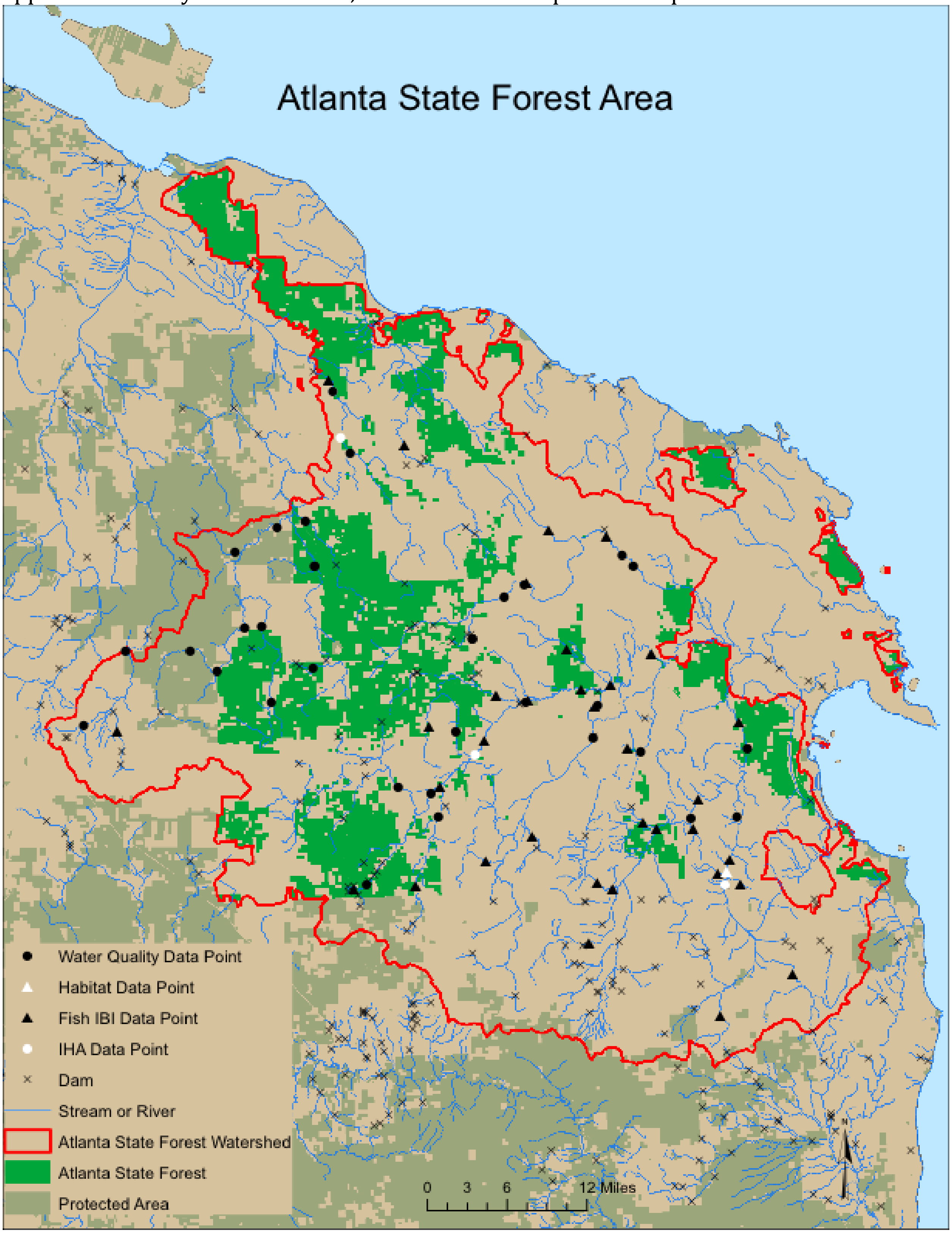
	Scoring Criteria		
Metric	**20 (good)**	**10 (fair)**	**0 (poor)**
1) Number of intolerant species	≥ 2	1	0
2) Percent of all individuals that are tolerant species	0 – 5	6 – 22	23 – 100
3) Percent of all individuals that are top carnivore	46 – 100	15 – 45	0 – 14
4) Percent of all individuals that are stenothermal coolwater and coldwater species (native and exotic)	86 – 100	43 – 85	0 – 42
5) Percent of salmonid individuals that are brook trout	96 – 100	5 – 95	0 – 4

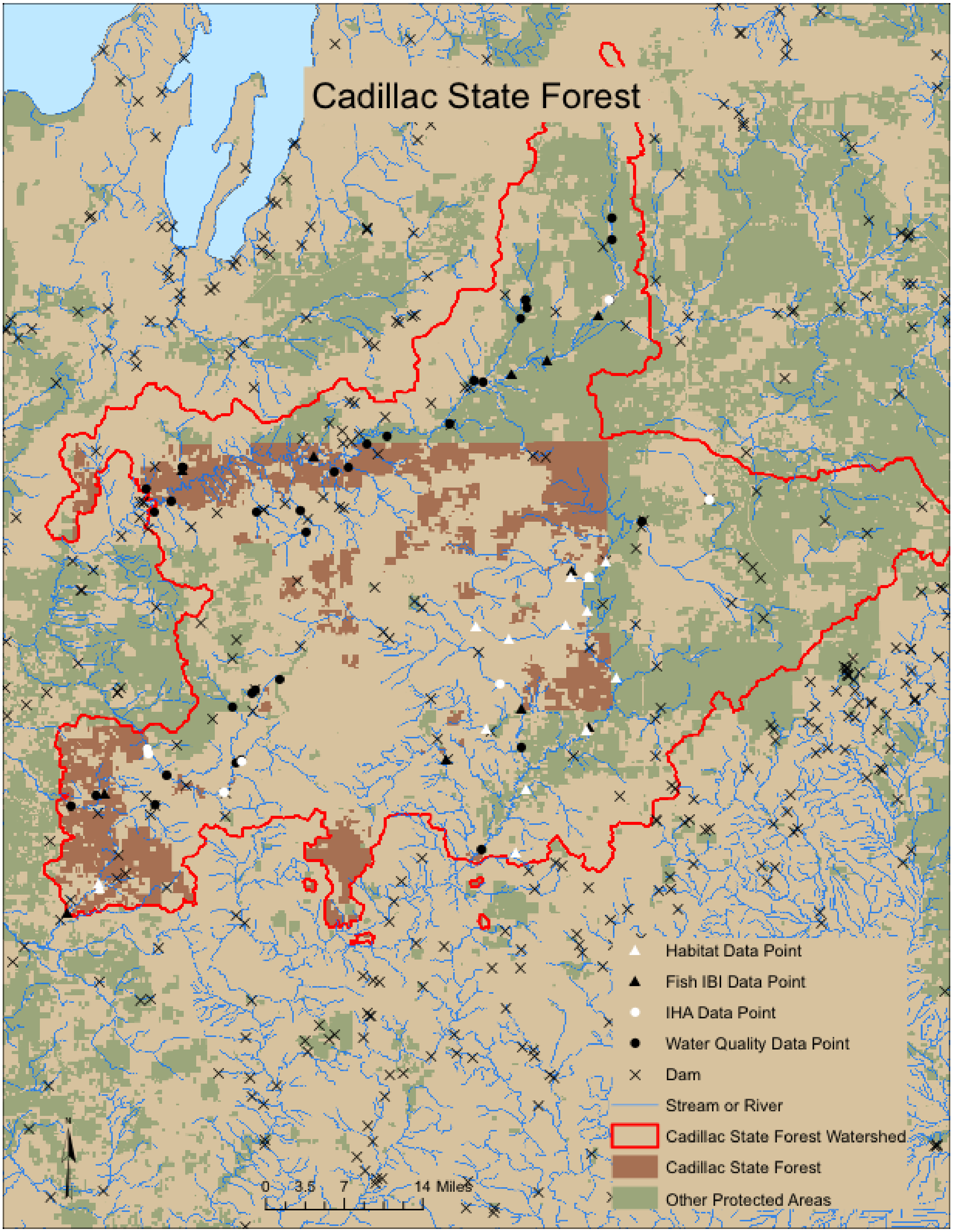
Appendix 2: Scoring Criteria for MDNR procedure 51 habitat quality used as physical habitat and energy regime response variable

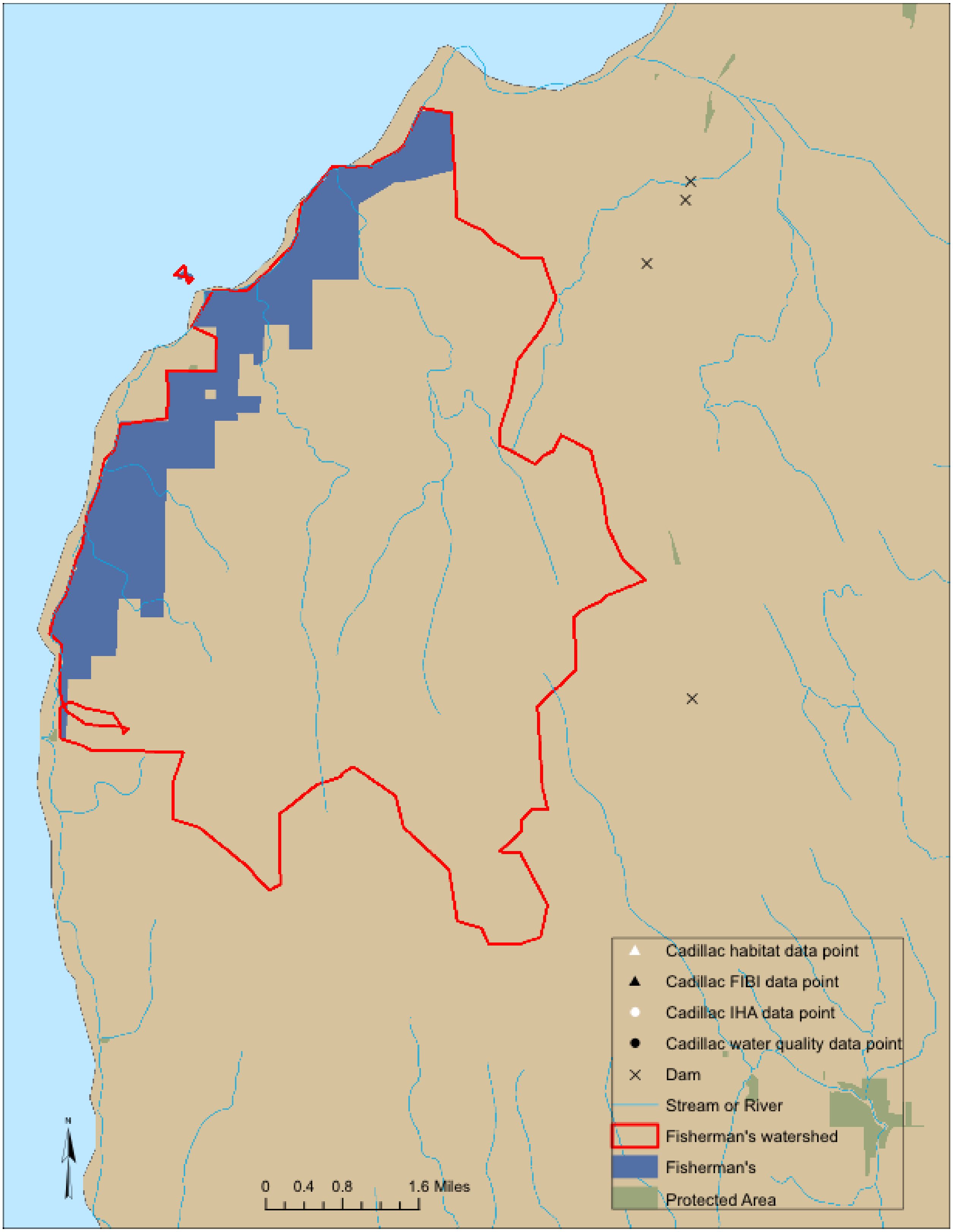
	Excellent	**Good**	**Fair**	**Poor**
Bottom Substrate / Available Cover	Greater than 50% rubble, gravel, submerged logs, undercut banks, or other stable habitat.	30-50% rubble, gravel or other stable habitat. Adequate habitat.	10-30% rubble, gravel or other stable habitat. Habitat availability less than desirable.	Less than 10% rubble, gravel or other stable habitat. Lack of habitat is obvious.
	16 – 20	11 – 15	6 – 10	0 – 5
Embeddedness / Siltation	Gravel, logs, cobble, and boulder particles have between 0 and 25% of their surface covered by fine sediment / silt.	Gravel, logs, cobble, and boulder particles have between 25 and 50% of their surface covered by fine sediment / silt.	Gravel, logs, cobble and boulder particles have between 50 and 70% of their surface covered by fine sediment / silt.	Gravel, logs, cobble, and boulder particles have over 75% of their surface covered by fine sediment / silt.
	16 – 20	11 – 15	6 – 10	0 – 5
Velocity: Depth: Pool <1ft/s >1.5ft Shallow pool <1ft/s <1.5ft Run >1ft/s >1.5ft Riffle >1ft/s <1.5ft	All habitats well represented. None greater than 50% of total area.	Only 3 of the 4 habitat categories present. Or if all 4 are present, one greater than 50% total are	Only 2 of the 4 habitat categories present.	Dominated by one velocity/ depth category (usually pool).
	16 – 20	11 – 15	6 – 10	0 – 5
Flow Stability	Continual flow all year. Natural water supply substantial.	Seasonal high flows. Low flow constant or nearly so. Some point discharge contributes to flow.	Periodic high and low flows. Irregular flow pattern. Discharges contribute substantially to low flow.	Ephemeral stream. Usually no midsummer flow. If it flows year-round, discharges form major contribution to low flow.
	12 – 15	8 – 11	4 – 7	0 – 3
Bottom Deposition / Sedimentation	Less than 5% of the bottom affected by deposition. Hard bottom substrate.	5-30% affected. Some deposition in pools. Soft bottom mainly in pools.	30-50% affected. Deposits, obstructions, constrictions and bends. Some filling of pools with	More than 50% of the bottom affected. Pools almost absent

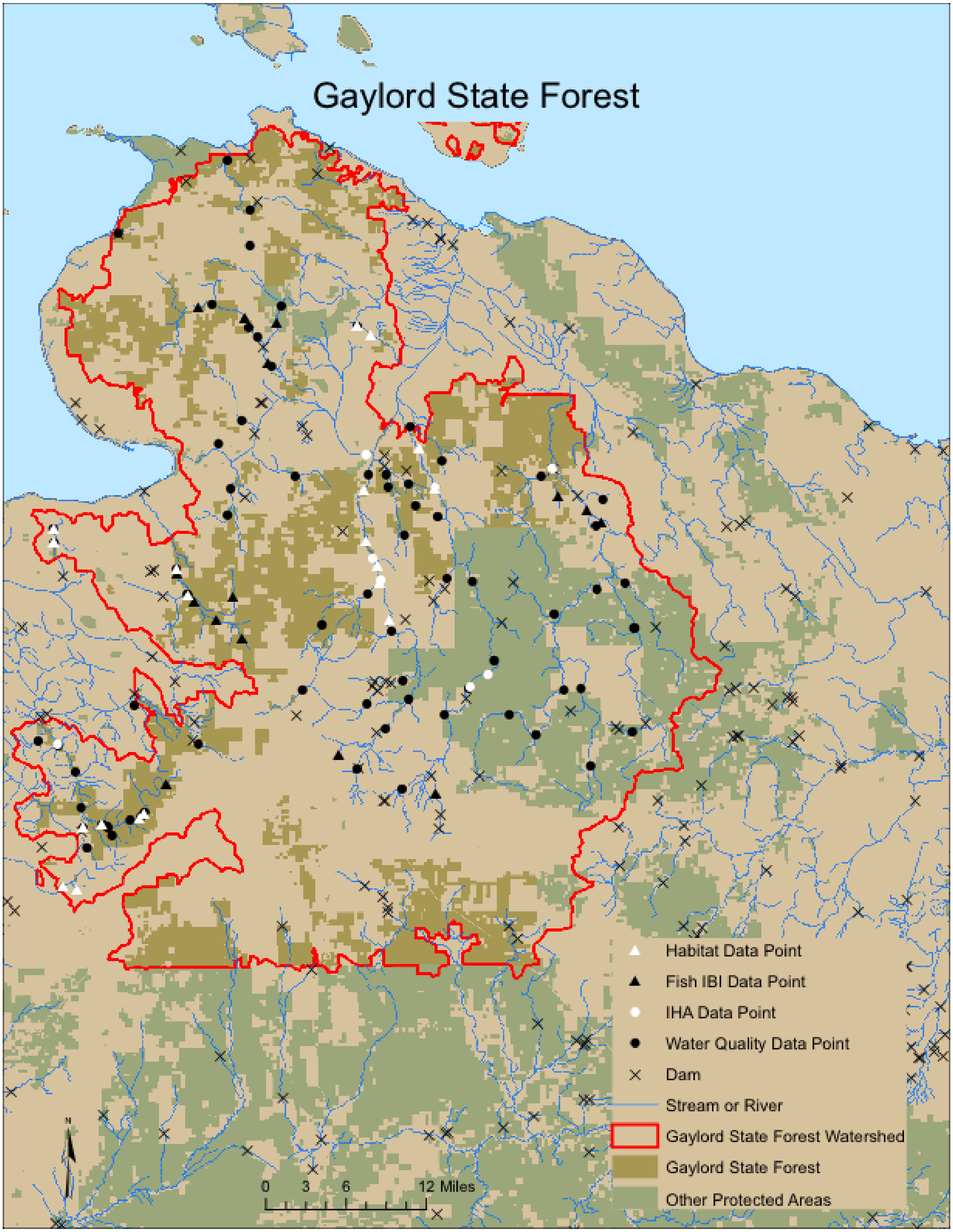
			sediments/sand. Soft bottom more common.	due to deposition. Only large rocks in riffle exposed. Soft bottom, loose deposits very common, often deep.
	12 – 15	8 – 11	4 – 7	0 – 3
Pools-Riffles-Runs-Bends	Variety of habitats. Deep riffles and pools.	Adequate depth in pools and riffles. Bends provide habitat.	Occasional riffle or bend. Bottom contours provide some habitat.	Straight stream. Generally all flat water or shallow riffle.
	12 – 15	8 – 11	4 – 7	0 – 3
Bank Stability	Stable. No evidence of erosion or bank failure. Side slopes generally <30%, little potential for future problem.	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40%. Slight erosion potential in extreme floods.	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60% on some banks. High erosion potential in extreme floods.	Unstable. Many eroded areas. Side slopes >60% common. "Raw" areas frequent along straight sections and bends.
	9 – 10	6 – 8	3 – 5	0 – 2
Bank Vegetative Stability	Over 80% of the stream bank surfaces covered by vegetation or boulders and cobble.	50-79% of the stream bank surfaces covered by vegetation, gravel or larger material.	25-49% of the stream bank surfaces covered by vegetation, gravel or larger material.	Less than 25% of the stream bank surfaces covered by vegetation, gravel or larger material.
	9 – 10	6 – 8	3 – 5	0 – 2
Streamside Cover	Dominant vegetation is shrub.	Dominant vegetation is of tree form.	Dominant vegetation is grass or forbes.	Over 50% of the stream bank has no vegetation. Dominant material is soil, rock, bridge materials, or mine tailings.
	9 – 10	6 – 8	3 – 5	0 – 2

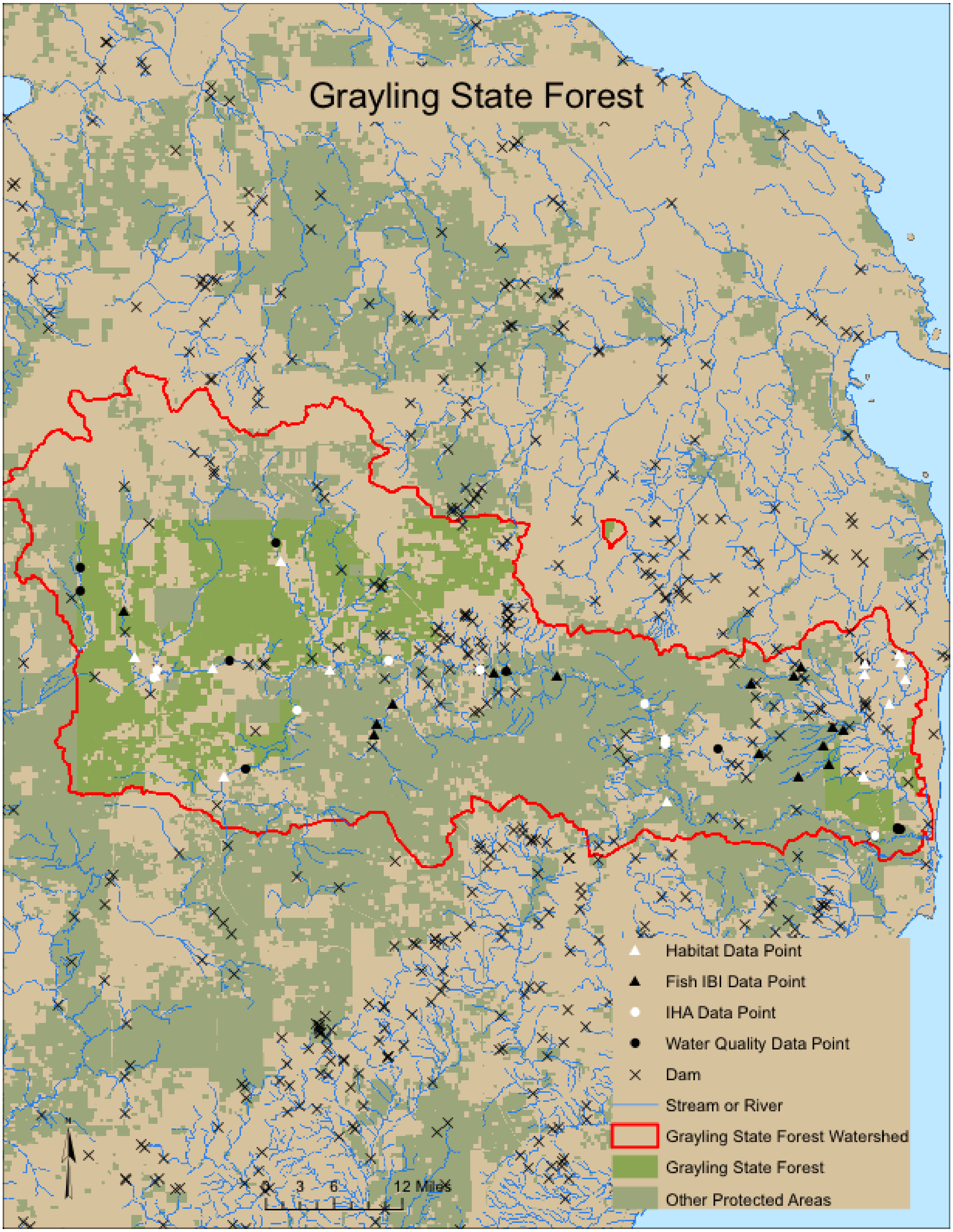
Appendix 3: Study PA boundaries, watershed and response data points

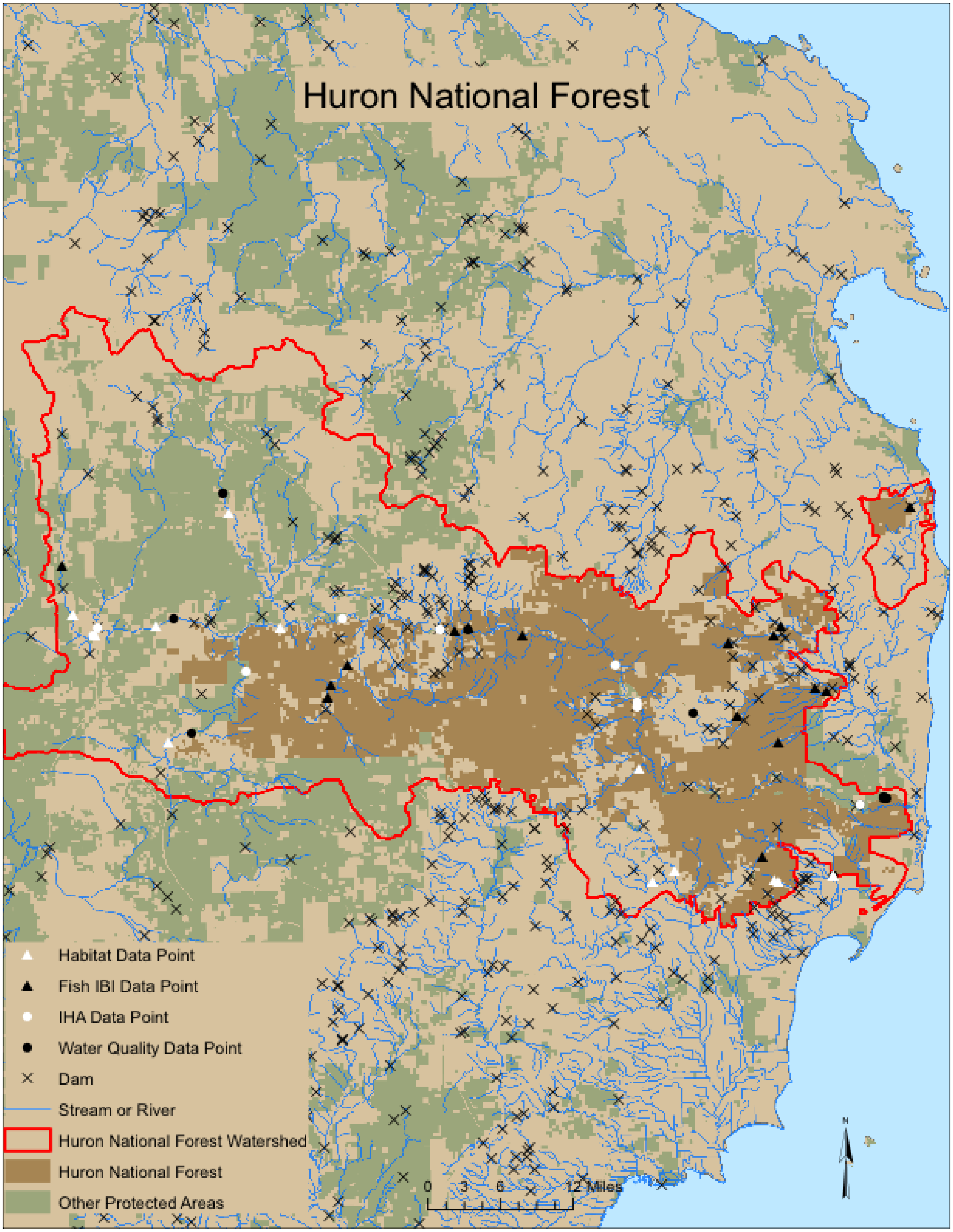



Cadillac State Forest
Habitat Data Point
Fish IBI Data Point
IHA Data Point
Water Quality Data Point
Dam
Stream or River
Cadillac State Forest Watershed
Cadillac State Forest
Other Protected Areas
0 3.5 7 14 Miles

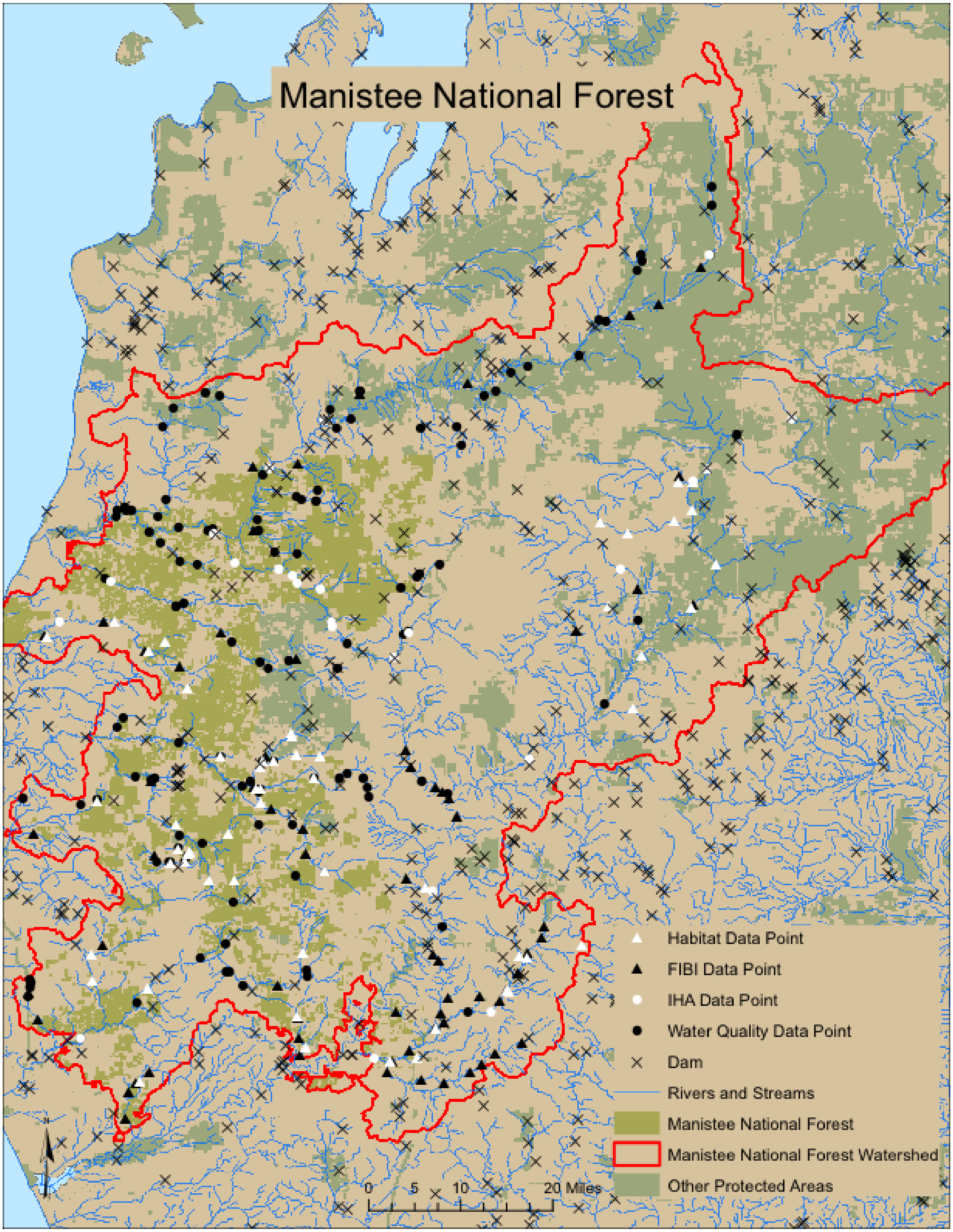

4
Cadillac habitat data point
Cadillac FIBI data point
Cadillac IHA data point
Cadillac water quality data point
Dam
Stream or River
Fisherman's watershed
Fisherman's
Protected Area
0 0.4 0.8 1.6 Miles
N

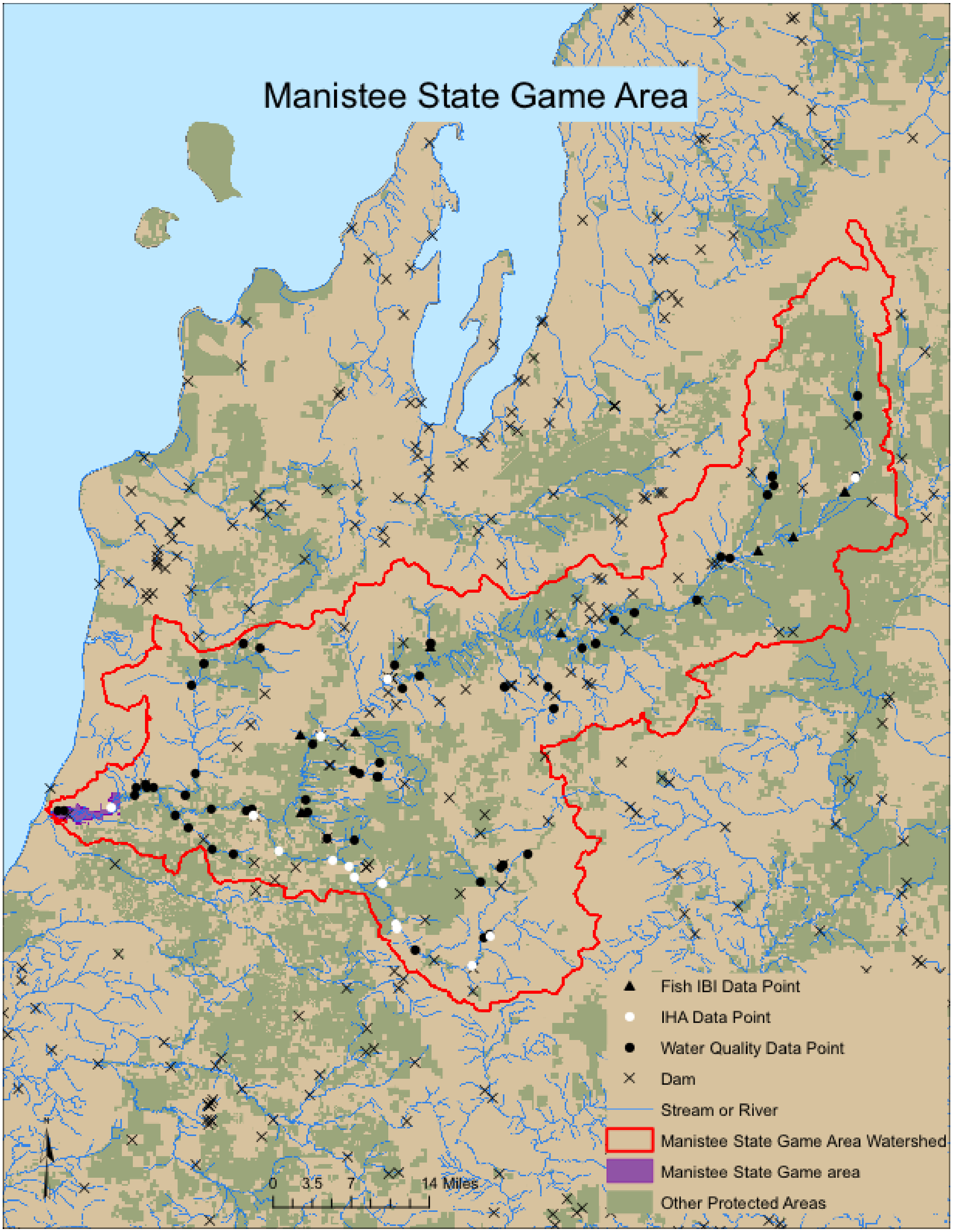

Gaylord State Forest
Habitat Data Point
Fish IBI Data Point
IHA Data Point
Water Quality Data Point
Dam
Stream or River
Gaylord State Forest Watershed
Gaylord State Forest
Other Protected Areas
0 3 6 12 Miles
N

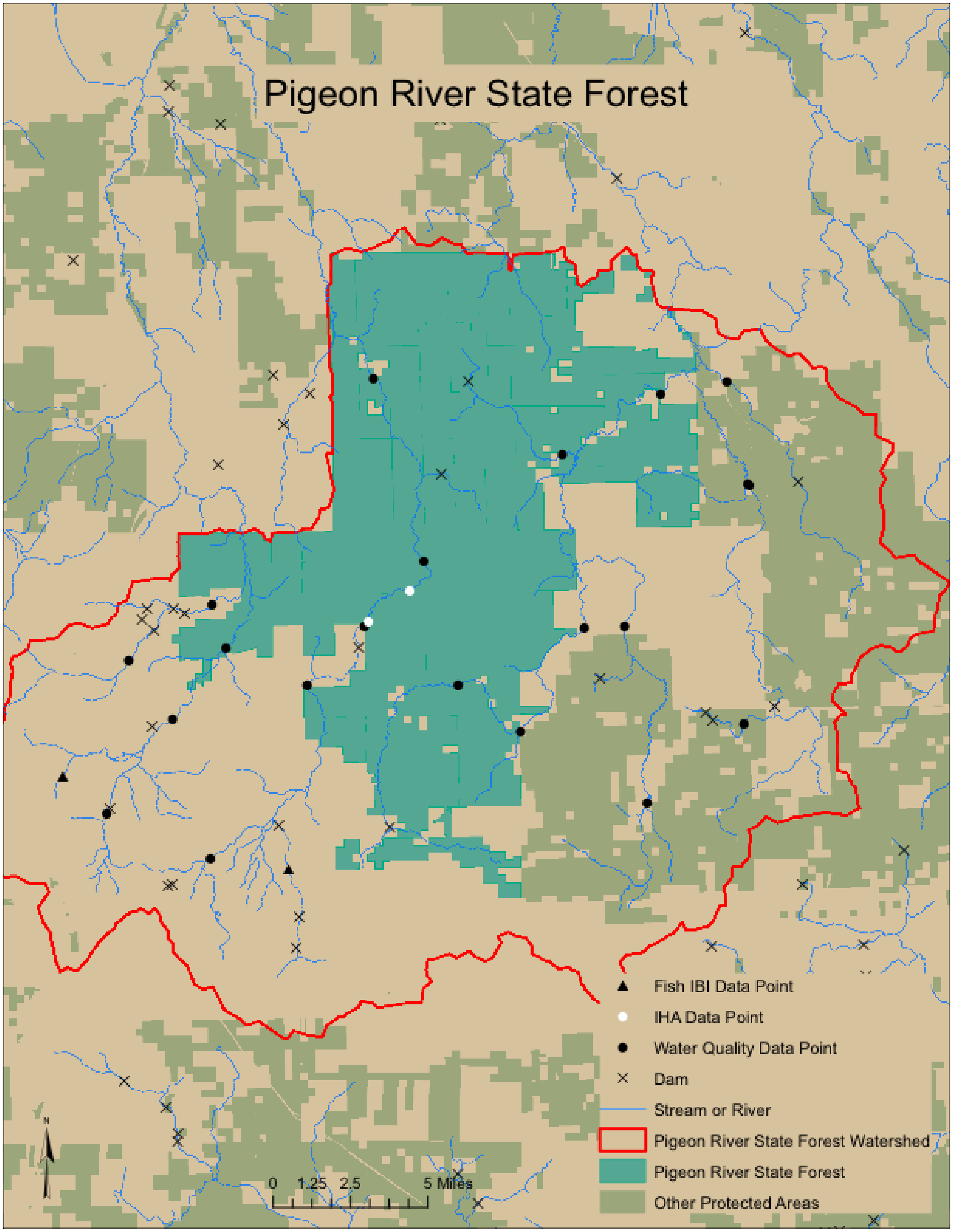

Grayling State Forest
Habitat Data Point
Fish IBI Data Point
IHA Data Point
Water Quality Data Point
Dam
Stream or River
Grayling State Forest Watershed
Grayling State Forest
Other Protected Areas
0 3 6 12 Miles
N

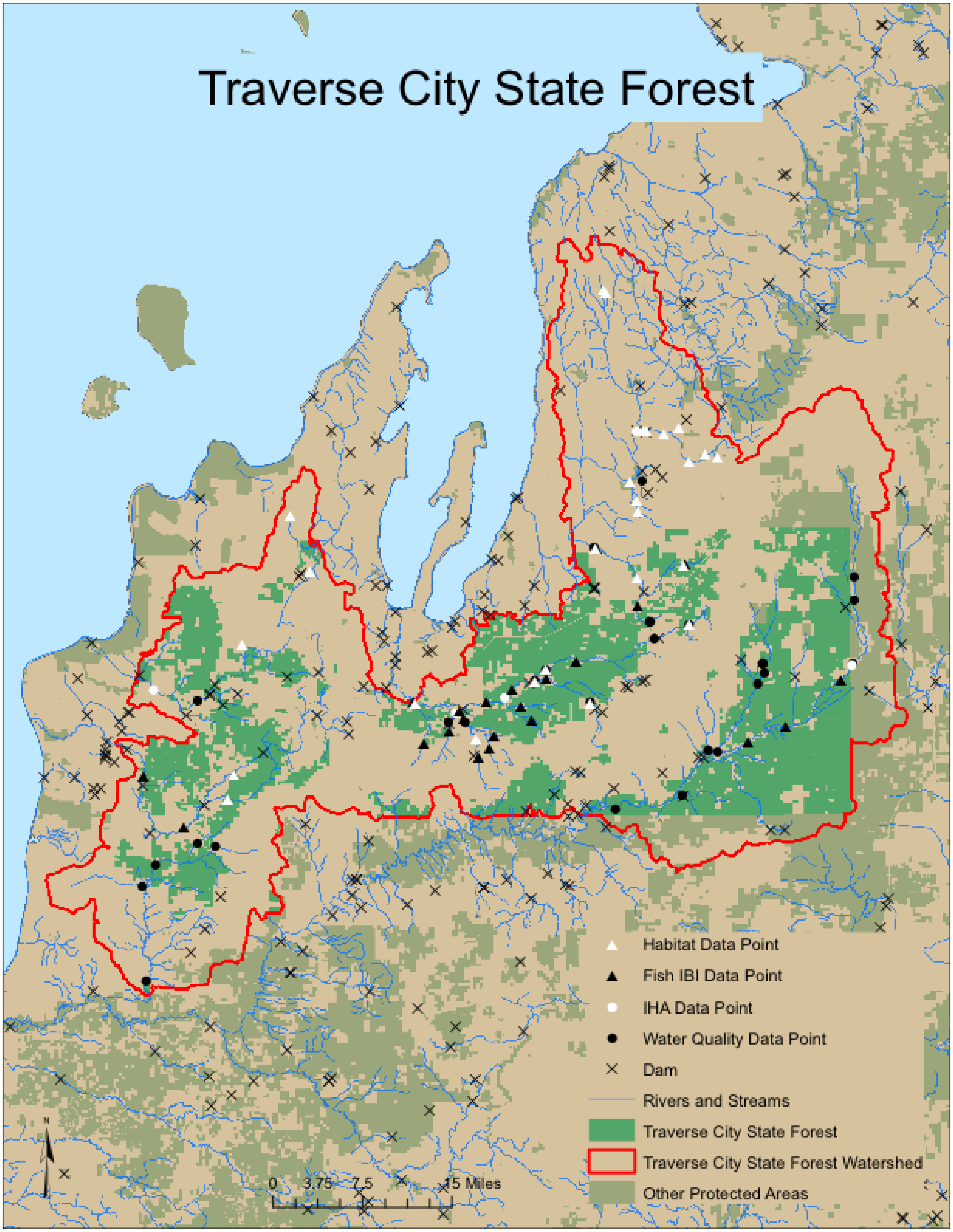


Huron National Forest
Habitat Data Point
Fish IBI Data Point
IHA Data Point
Water Quality Data Point
Dam
Stream or River
Huron National Forest Watershed
Huron National Forest
Other Protected Areas
0 3 6 12 Miles
N

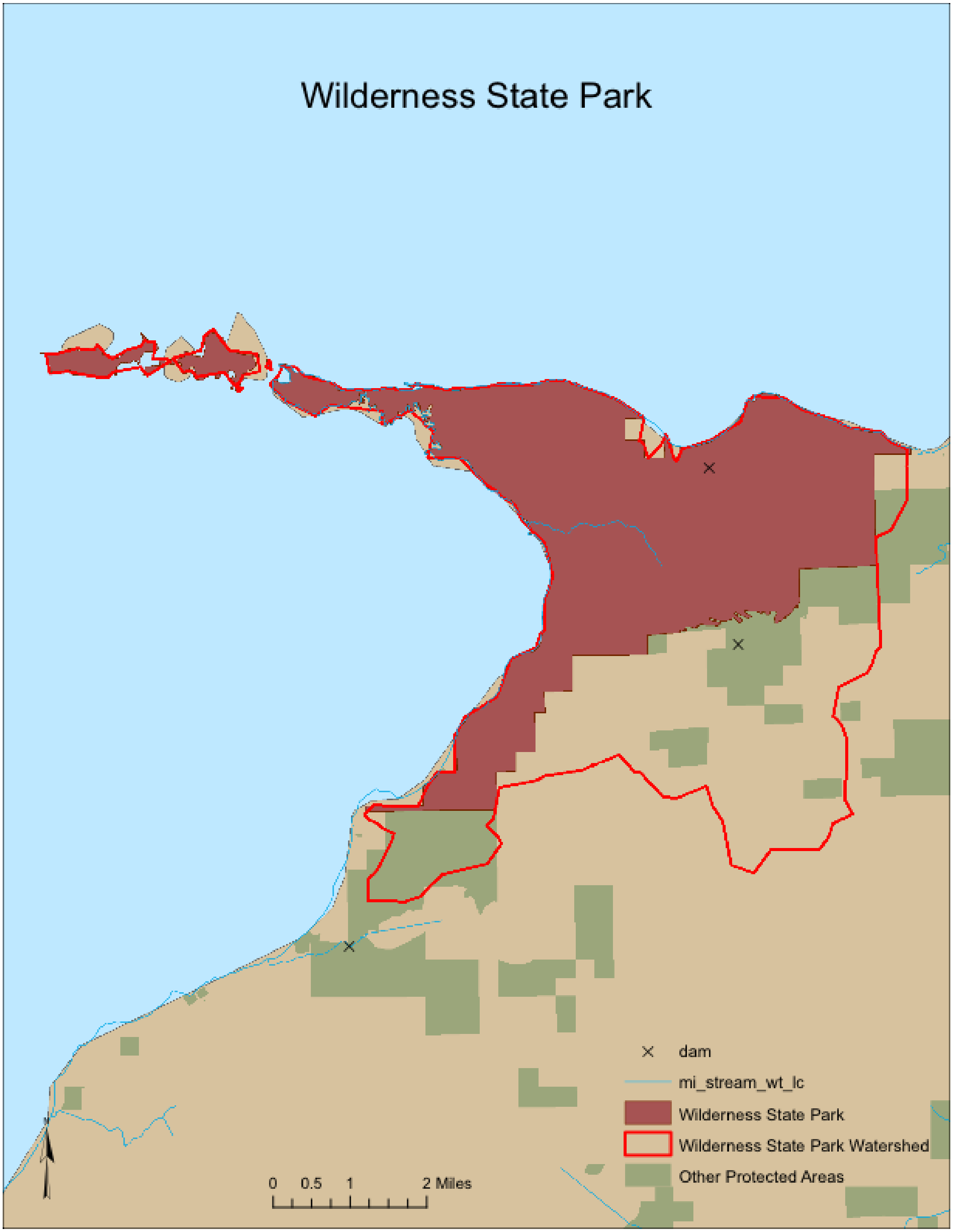

Manistee National Forest
Habitat Data Point
FIBI Data Point
IHA Data Point
Water Quality Data Point
Dam
Rivers and Streams
Manistee National Forest
Manistee National Forest Watershed
Other Protected Areas
0
5
10
20 Miles


Manistee State Game Area
Fish IBI Data Point
IHA Data Point
Water Quality Data Point
Dam
Stream or River
Manistee State Game Area Watershed
Manistee State Game area
Other Protected Areas
0 3.5 7 14 Miles


Pigeon River State Forest
Fish IBI Data Point
IHA Data Point
Water Quality Data Point
Dam
Stream or River
Pigeon River State Forest Watershed
Pigeon River State Forest
Other Protected Areas
0
1.25
2.5
5 Miles
N


Traverse City State Forest
Habitat Data Point
Fish IBI Data Point
IHA Data Point
Water Quality Data Point
Dam
Rivers and Streams
Traverse City State Forest
Traverse City State Forest Watershed
Other Protected Areas
0 3.75 7.5 15 Miles

Wilderness State Park



Appendix 4: Freshwater Conservation Questionnaire distributed to PA managers

NATURAL RESOURCES AND ENVIRONMENT

UNIVERSITY OF MICHIGAN

Drew Casey
(904) 472-1885
drewmc@umich.edu

Sarah Neville
(248) 921-0769
sarnevil@umich.edu

Introduction

In order to assess the impact of terrestrial protected areas on freshwater systems, our team is pursuing information from managers on the activities and issues outside and within the protected area that might impact aquatic conservation goals. Furthermore, we are interested in the management activities that are utilized in the protected area that may impact freshwater ecological attributes. The information collected through this questionnaire will be used, along with water quality information from the protected area's catchment and information on the number of stressors (e.g. number of dams, number of road crossings, number of NPDES permits) within the protected area's catchment, to determine the extent to which the management of terrestrial protected areas contributes to the realization of freshwater conservation in light of external influences. For the purposes of these questions, please consider the physical, chemical, and biological issues as relevant to freshwater systems. A map of the protected area's catchment has been included for your reference.

Defined terms are indicated by an asterisk (*) and the definitions are listed at the end of this document.

PRIVACY STATEMENT: Although your name and title will not be included in the final write-up or presentation of our findings, the name of the protected area may be referenced. If there is any information that you would prefer remain anonymous please indicate your preferences in the final portion of this questionnaire.

Background Information

Name of Protected Area	
Name of Respondent	
Title of Respondent	

Q1: To what degree do issues <u>OUTSIDE</u> of the protected area alter freshwater environmental attributes* <u>WITHIN</u> the protected area?

(Please indicate the level of alteration by selecting (with an "X") the most appropriate column for each issue)

Biological Attributes						
	No alteration	**Low alteration**	**Moderate alteration**	**High alteration**	**Unsure**	**Not applicable**
Invasive species						
Species exploitation (e.g. over fishing)						
Stocking of species						
Other:						

Chemical Attributes						
	No alteration	**Low alteration**	**Moderate alteration**	**High alteration**	**Unsure**	**Not applicable**
Acid mine drainage						
Industrial discharges of organic or inorganic chemicals and/or metals						
Municipal sewage discharges						
Nutrient loading						
Nonpoint source runoff from impervious surfaces						
Other:						

Physical Attributes						
	No alteration	**Low alteration**	**Moderate alteration**	**High alteration**	**Unsure**	**Not applicable**
Channelization or stream modification						
Dam presence (low-head and large)						
Filling of wetlands/floodplains						
Gravel mining/dredging						
Impassable culverts*						
Levees						
Road networks intersecting streams						
Land use practices (agriculture, logging, etc.)						
Shoreline development						
Stormwater outfalls						
Surface/groundwater withdrawals or diversions						
Thermal pollution from power plants or dams						
Timber extraction activities						
Weirs*						
Loss of natural riparian corridor vegetation						
Other:						

Is there any additional information that you would like to share in reference to Q1?

Q2: To what degree do issues ***WITHIN*** the protected area alter freshwater environmental attributes* ***WITHIN*** the protected area?

(Please indicate the level of alteration by selecting (with an “X”) the most appropriate column for each issue)

Biological Attributes						
	No alteration	**Low alteration**	**Moderate alteration**	**High alteration**	**Unsure**	**Not applicable**
Invasive species						
Species exploitation (e.g. over fishing)						
Stocking of non-native species						
Other:						

Chemical Attributes						
	No alteration	**Low alteration**	**Moderate alteration**	**High alteration**	**Unsure**	**Not applicable**
Nonpoint source pollution						
Nutrient loading						
On-site sewage discharges from tourist infrastructure						
Other:						

Physical Attributes						
	No alteration	**Low alteration**	**Moderate alteration**	**High alteration**	**Unsure**	**Not applicable**
Channelization or stream modification						
Dam presence (low-head and large)						
Gravel mining/dredging						
Hiking & camping						
Impassable culverts*						
Boating activities						
Levees						
Loss of natural riparian corridor vegetation						
Recreational vehicle-associated erosion and pollution						
Road networks intersecting streams						
Nonpoint source runoff from impervious surfaces						
Land use practices (agriculture, logging, etc.)						
Surface/groundwater withdrawals or diversions						
Thermal pollution from onsite dams						
Timber extraction activities						
Weirs*						
Filling of wetlands/floodplains						
Other:						

Is there any additional information that you would like to share in reference to Q2?

Q3: What management activities to protect or restore freshwater environmental attributes* in the protected area's catchment* are used ***WITHIN*** the protected area?

(Please indicate the degree of implementation by selecting (with an "X") the most appropriate column for each strategy)

	Often	Occasionally	Rarely	Never	Unsure	Not applicable
Acid mine drainage remediation						
Culvert* removal/upgrade						
Erosion control methods						
Fishing regulation enforcement (bait or take regulations)						
Installation of fish ladders/passages						
Installation of levee bypasses						
Education programs (e.g. signage, pamphlets, informational meetings, etc.)						
Invasive species management (e.g. eradication or best management practices to prevent introduction)						
Post disturbance re-vegetation (e.g. timber extraction, construction, etc.)						
Prohibition of species extractions (non-fish)						
Promotion of forest management best management practices						
Reduction of impervious surfaces (e.g. use of permeable pavements, green roofs)						

	Often	Occasionally	Rarely	Never	Unsure	Not applicable
Removal of dams, weirs*, or levees						
Restoration of channel shape, size, or sinuosity						
Riparian buffer restoration and creation						
Road construction and maintenance best management practices						
Instream habitat practices (e.g. sediment removal)						
Recovery of native species						
Stocking of native species						
Storm water management (detention and retention systems)						
Stream bank stabilization efforts (e.g. fascines, riprap, woody debris management)						
Upgrade of septic systems to performance standards						
Use of physical barriers to prevent exotic colonization (e.g. weirs* or low-head dams)						
Wetland restoration						
Other:						
Other:						
Other:						

Is there any additional information that you would like to share in reference to Q3?

Is there any information from this questionnaire that you would prefer to remain anonymous?

Definitions

Catchment: A catchment is the area of land where all of the water that is under it, or drains off of it, goes into the same place.

Culverts: Channels that allow water to pass under roads.

Environmental Attributes: Physical, chemical, and biological components as relevant to freshwater systems. For example: hydrologic regime, water quality, energy regime, physical habitat, biotic composition, and connectivity.

Weirs: A fence or enclosure built in a waterway for taking fish. A dam set in a stream or river in order to regulate water level or divert flow.

Appendix 5: Management Questionnaire Results

Questionnaire Responses - To what degree do issues OUTSIDE of the protected area alter freshwater environmental attributes* WITHIN the protected area?

External Threat	KEA	Gaylord	Atlanta	Pigeon River Country	Grayling State Forest Area
Invasive Species	B	High alteration	High alteration	High alteration	High alteration
Species Exploitation	B	Low alteration	Low alteration	Low alteration	Low alteration
Stocking of Species	B	Low alteration	Low alteration	Low alteration	Unsure
Acid Mine Drainage	WQ	Not applicable	Not applicable	Not applicable	Unsure
Industrial Discharge of organic/inorganic chemicals	WQ	Low alteration	Low alteration	Low alteration	Moderate alteration
Municipal Sewage Discharges	WQ	Low alteration	Low alteration	Low alteration	Unsure
Nutrient Loading	WQ	Low alteration	Low alteration	Low alteration	Moderate alteration
Nonpoint source runoff from impervious surface	WQ	Moderate alteration	Moderate alteration	Moderate alteration	Unsure
Channelization	C, HR, PH	No alteration	No alteration	No alteration	Unsure
Dam Presence	C, HR, PH	High alteration	High alteration	High alteration	Moderate alteration
Filing of wetlands	HR, PH	Moderate alteration	Moderate alteration	Moderate alteration	Low alteration
Gravel mining	PH	No alteration	Low alteration	No alteration	Low alteration
Impassable culverts	C, HR, PH	Moderate alteration	Moderate alteration	Low alteration	Low alteration
Levees	C, HR, PH	Not applicable	Not applicable	Not applicable	Low alteration
Road networks intersecting streams	HR, C	Moderate alteration	Moderate alteration	Moderate alteration	Moderate alteration
Land use practices	WQ	Moderate alteration	Moderate alteration	Low alteration	Moderate alteration
Shoreline development	PH, C	High alteration	High alteration	Low alteration	Low alteration
Storm water outfalls	HR, PH	Moderate alteration	Moderate alteration	Low alteration	Unsure
Surface/groundwater withdrawals	HR, PH, C	Low alteration	Low alteration	Low alteration	Unsure
Thermal pollution	WQ	Moderate alteration	Moderate alteration	Moderate alteration	Low alteration
Timber extraction	HR, PH	Low alteration	Low alteration	Low alteration	Moderate alteration
Weirs	C, PH, HR	Unsure	Unsure	Unsure	Unsure
Loss of natural riparian vegetation	PH	Moderate alteration	Moderate alteration	Moderate alteration	Moderate alteration

Questionnaire Responses - To what degree do issues OUTSIDE of the protected area alter freshwater environmental attributes* WITHIN the protected area?

External Threat	KEA	Manistee National Forest	Huron National Forest	Traverse City	Cadillac
Invasive Species	B	Moderate alteration	Moderate alteration	Low alteration	Low alteration
Species Exploitation	B	Low alteration	Low alteration	No alteration	No alteration
Stocking of Species	B	High alteration	High alteration	No alteration	No alteration
Acid Mine Drainage	WQ	No alteration	No alteration	Not applicable	Not applicable
Industrial Discharge of organic/inorganic chemicals	WQ	Low alteration	Low alteration	Low alteration	Low alteration
Municipal Sewage Discharges	WQ	Low alteration	Low alteration	Low alteration	Low alteration
Nutrient Loading	WQ	Moderate alteration	Moderate alteration	Low alteration	Low alteration
Nonpoint source runoff from impervious surface	WQ	Moderate alteration	Moderate alteration	Low alteration	Low alteration
Channelization	C, HR, PH	Moderate alteration	Moderate alteration	Moderate alteration	Moderate alteration
Dam Presence	C, HR, PH	High alteration	High alteration	Moderate alteration	Moderate alteration
Filing of wetlands	HR, PH	Moderate alteration	Moderate alteration	Low alteration	Low alteration
Gravel mining	PH	Low alteration	Low alteration	Low alteration	Low alteration
Impassable culverts	C, HR, PH	High alteration	High alteration	Moderate alteration	Moderate alteration
Levees	C, HR, PH	No alteration	No alteration	Not applicable	Not applicable
Road networks intersecting streams	HR, C	High alteration	High alteration	Moderate alteration	Moderate alteration
Land use practices	WQ	Moderate alteration	Moderate alteration	Moderate alteration	Moderate alteration
Shoreline development	PH, C	High alteration	High alteration	Moderate alteration	Moderate alteration
Storm water outfalls	HR, PH	Moderate alteration	Moderate alteration	Low alteration	Low alteration
Surface/groundwater withdrawals	HR, PH, C	Low alteration	Low alteration	Low alteration	Low alteration
Thermal pollution	WQ	Low alteration	Low alteration	Low alteration	Low alteration
Timber extraction	HR, PH	No alteration	No alteration	Low alteration	Low alteration
Weirs	C, PH, HR	Low alteration	Low alteration	Not applicable	Not applicable
Loss of natural riparian vegetation	PH	High alteration	High alteration	Moderate alteration	Moderate alteration

Questionnaire Responses - To what degree do issues OUTSIDE of the protected area alter freshwater environmental attributes* WITHIN the protected area?

External Threat	KEA	Manistee River State Game Area	Fisherman's Island State Park	Wilderness State park
Invasive Species	B	Moderate alteration	Moderate alteration	Unsure
Species Exploitation	B	Low alteration	Low alteration	No alteration
Stocking of Species	B	Moderate alteration	Not applicable	Unsure
Acid Mine Drainage	WQ	Not applicable	No alteration	Not applicable
Industrial Discharge of organic/inorganic	WQ	Low alteration	No alteration	Not applicable
Municipal Sewage Discharges	WQ	Low alteration	No alteration	Not applicable
Nutrient Loading	WQ	Low alteration	No alteration	Unsure
Nonpoint source runoff from impervious surface	WQ	Low alteration	Not applicable	Unsure
Channelization	C, HR,	Low alteration	Not applicable	Unsure
Dam Presence	C, HR,	High alteration	Not applicable	No alteration
Filing of wetlands	HR, PH	Moderate alteration	No alteration	Unsure
Gravel mining	PH	Low alteration	Low alteration	Unsure
Impassable culverts	C, HR,	Low alteration	Not applicable	Unsure
Levees	C, HR,	Low alteration	Not applicable	Unsure
Road networks intersecting streams	HR, C	Low alteration	Low alteration	No alteration
Land use practices	WQ	Moderate alteration	Low alteration	Low alteration
Shoreline development	PH, C	Moderate alteration	Low alteration	Low alteration
Storm water outfalls	HR, PH	Moderate alteration	Not applicable	Unsure
Surface/groundwater withdrawals	HR, PH, C	Low alteration	No alteration	Unsure
Thermal pollution	WQ	Low alteration	No alteration	Low alteration
Timber extraction	HR, PH	Low alteration	No alteration	Low alteration
Weirs	C, PH,	Moderate alteration	Not applicable	Not applicable
Loss of natural riparian vegetation	PH	Moderate alteration	Low alteration	Unsure
Extra Question 1				The Mackinaw State Forest borders Wilderness State Park to the south. This section of the Mackinaw State Forest is administered out of the Gaylord Operation Service Center at 732 M-32 West, Gaylord, Mi. 49735 [(989)0732-3541]. The dam on O'Neal Lake inside this water shed is administered by Wildlife Division of the Department of Natural Resources and Environment and is administered

Question 2 Questionnaire Responses - To what degree do issues *WITHIN* the protected area alter freshwater environmental attributes* *WITHIN* the protected area?

Internal Threats	KEA	Gaylord	Atlanta	Pigeon River Country	Grayling State Forest Area
Invasive Species	B	High alteration	High alteration	High alteration	Low alteration
Species Exploitation	B	Moderate alteration	Moderate alteration	Moderate alteration	Low alteration
Stocking of non-native species	B	Low alteration	Low alteration	Low alteration	Unsure
Nonpoint source pollution	WQ	Low alteration	Low alteration	Low alteration	Unsure
Nutrient Loading	WQ	Low alteration	Low alteration	Low alteration	Low alteration
On-site sewage discharges from tourist infrastructure	WQ	Low alteration	Low alteration	Low alteration	Low alteration
Channelization	C, HR, PH	Low alteration	Low alteration	Low alteration	Low alteration
Dam Presence	C, HR, PH	Moderate alteration	Moderate alteration	Moderate alteration	Low alteration
Gravel mining	PH, WQ	Unsure	Not applicable	Not applicable	Low alteration
Hiking and Camping	WQ, PH,	Low alteration	Low alteration	Low alteration	Low alteration
Impassable culverts	C, PH	Moderate alteration	Moderate alteration	Moderate alteration	Low alteration
Boating activities	WQ, B, PH	Low alteration	Low alteration	Low alteration	Low alteration
Levees	C, HR, PH	Not applicable	Not applicable	Not applicable	Low alteration
Loss of natural riparian vegetation	PH	Low alteration	Low alteration	Low alteration	Low alteration
ORV erosion and pollution	WQ,PH	Low alteration	Low alteration	No alteration	Moderate alteration
Road networks intersecting streams	HR, C, PH	Moderate alteration	Moderate alteration	Moderate alteration	Low alteration
Nonpoint source runoff from impervious surface	WQ, PH	Moderate alteration	Moderate alteration	Low alteration	Low alteration
Land use practices	WQ	Low alteration	Low alteration	Low alteration	Low alteration
Surface/groundwater withdrawals	HR, PH, C	Low alteration	Low alteration	Low alteration	Low alteration
Thermal pollution	PH	Low alteration	Low alteration	Moderate alteration	Low alteration
Timber extraction	PH	Low alteration	Low alteration	Low alteration	Low alteration
Weirs	C, HR, PH	Not applicable	Not applicable	Not applicable	Low alteration
Filing of wetlands	WQ, PH	Low alteration	Low alteration	Low alteration	Low alteration

Question 2 Questionnaire Responses - To what degree do issues *WITHIN* the protected area alter freshwater environmental attributes* *WITHIN* the protected area?

Internal Threats	KEA	Manistee National Forest	Huron National Forest	Traverse City	Cadillac
Invasive Species	B	Low alteration	Low alteration	Low alteration	Low alteration
Species Exploitation	B	Low alteration	Low alteration	No alteration	No alteration
Stocking of non-native species	B	High alteration	High alteration	No alteration	No alteration
Nonpoint source pollution	WQ	Low alteration	Low alteration	Low alteration	Low alteration
Nutrient Loading	WQ	Low alteration	Low alteration	Low alteration	Low alteration
On-site sewage discharges from tourist infrastructure	WQ	Low alteration	Low alteration	Low alteration	Low alteration
Channelization	C, HR, PH	Low alteration	Low alteration	No alteration	No alteration
Dam Presence	C, HR, PH	High alteration	High alteration	Low alteration	Low alteration
Gravel mining	PH, WQ	Low alteration	Low alteration	No alteration	No alteration
Hiking and Camping	WQ, PH,	Low alteration	Low alteration	Low alteration	Low alteration
Impassable culverts	C, PH	High alteration	High alteration	Moderate alteration	Moderate alteration
Boating activities	WQ, B, PH	Low alteration	Low alteration	Low alteration	Low alteration
Levees	C, HR, PH	No alteration	No alteration	Not applicable	Not applicable
Loss of natural riparian vegetation	PH	Moderate alteration	Moderate alteration	Low alteration	Low alteration
ORV erosion and pollution	WQ,PH	High alteration	High alteration	Low alteration	Low alteration
Road networks intersecting streams	HR, C, PH	Moderate alteration	Moderate alteration	Moderate alteration	Moderate alteration
Nonpoint source runoff from impervious surface	WQ, PH	Low alteration	Low alteration	No alteration	No alteration
Land use practices	WQ	Low alteration	Low alteration	Low alteration	Low alteration
Surface/groundwater withdrawals	HR, PH, C	Low alteration	Low alteration	Low alteration	Low alteration
Thermal pollution	PH	Moderate alteration	Moderate alteration	Low alteration	Low alteration
Timber extraction	PH	Low alteration	Low alteration	Low alteration	Low alteration
Weirs	C, HR, PH	Low alteration	Low alteration	Not applicable	Not applicable
Filing of wetlands	WQ, PH	Low alteration	Low alteration	Low alteration	Low alteration

Question 2 Questionnaire Responses - To what degree do issues *WITHIN* the protected area alter freshwater environmental attributes* *WITHIN* the protected area?

Internal Threats	KEA	Manistee River State Game Area	Fisherman's Island State Park	Wilderness State park
Invasive Species	B	Moderate alteration	Low alteration	Unsure
Species Exploitation	B	Low alteration	No alteration	No alteration
Stocking of non-native species	B	Moderate alteration	Not applicable	Unsure
Nonpoint source pollution	WQ	Low alteration	Not applicable	No alteration
Nutrient Loading	WQ	Low alteration	No alteration	Not applicable
On-site sewage discharges from tourist infrastructure	WQ	Low alteration	Not applicable	Low alteration
Channelization	C, HR, PH	Low alteration	No alteration	Low alteration
Dam Presence	C, HR, PH	High alteration	Not applicable	Low alteration
Gravel mining	PH, WQ	Low alteration	Low alteration	Not applicable
Hiking and Camping	WQ, PH,	Low alteration	Moderate alteration	Low alteration
Impassable culverts	C, PH	Low alteration	No alteration	Unsure
Boating activities	WQ, B, PH	Low alteration	No alteration	Low alteration
Levees	C, HR, PH	Low alteration	Not applicable	Not applicable
Loss of natural riparian vegetation	PH	Moderate alteration	Low alteration	Low alteration
ORV erosion and pollution	WQ,PH	Moderate alteration	Low alteration	Low alteration
Road networks intersecting streams	HR, C, PH	Moderate alteration	Low alteration	Low alteration
Nonpoint source runoff from impervious surface	WQ, PH	Low alteration	Not applicable	Low alteration
Land use practices	WQ	Low alteration	No alteration	Not applicable
Surface/groundwater withdrawals	HR, PH, C	Low alteration	Not applicable	Low alteration
Thermal pollution	PH	Low alteration	Not applicable	Low alteration
Timber extraction	PH	Low alteration	Not applicable	Not applicable
Weirs	C, HR, PH	Moderate alteration	Not applicable	Not applicable
Filing of wetlands	WQ, PH	Moderate alteration	Not applicable	Not applicable

Question 3 Questionnaire Responses- What management activities to protect or restore freshwater environmental attributes* in the protected area's catchment* are used *WITHIN* the protected area?

Activities	KEA	Gaylord	Atlanta	Pigeon River Country	Grayling State Forest Area
Acid Mine drainage remediation	B	Not applicable	Not applicable	Not applicable	Unsure
Culvert removal/upgrade	HR, C, PH, B	Occasionally	Occasionally	Occasionally	Occasionally
Erosion control methods	WQ, PH, B	Occasionally	Rarely	Rarely	Occasionally
Fishing regulations enforcement	B	Occasionally	Occasionally	Often	Often
Installation of fish ladders/passages	B, C	Occasionally	Occasionally	Occasionally	Rarely
Installation of levee bypasses	B	Not applicable	Not applicable	Not applicable	Rarely
Education programs	B, C, HR, PH, WQ	Occasionally	Occasionally	Occasionally	Occasionally
Invasive species management	B	Often	Often	Often	Occasionally
Post disturbance re-vegetation	B, PH, ER, HR	Rarely	Rarely	Rarely	Occasionally
Prohibition of species extractions (non-fish)	B	Unsure	Unsure	Unsure	Occasionally
Promotion of forest BMPs	WQ, PH, B	Often	Often	Often	Often
Reduction of impervious surfaces	HR, WQ, PH, B	Rarely	Rarely	Rarely	Occasionally
Removal of dams, weirs, or levees	C, PH, HR, B	Occasionally	Occasionally	Occasionally	Occasionally
Restoration of channel shape, size, or sinuosity	PH, C, HR, B	Not applicable	Not applicable	Not applicable	Rarely
Riparian buffer restoration and creation	WQ, C, B	Rarely	Rarely	Rarely	Occasionally
Road construction and maintenance BMPs	WQ, B	Occasionally	Occasionally	Occasionally	Often
Instream habitat practices	WQ, PH, B	Occasionally	Occasionally	Occasionally	Often
Recovery of Native species	B	Occasionally	Rarely	Occasionally	Occasionally
Stocking of Native Species	B	Rarely	Rarely	Never	Occasionally
Storm water management	HR, WQ, PH, B	Never	Never	Never	Occasionally
Stream bank stabilization	PH, WQ, B	Rarely	Occasionally	Often	Occasionally
Upgrade of septic systems to performance standards	WQ, B	Unsure	Unsure	Unsure	Unsure
Use of Physical barriers to prevent exotic colonization	B	Never	Rarely	Never	Rarely
Wetland Restoration	WQ, PH, B	Rarely	Rarely	Never	Occasionally

Question 3 Questionnaire Responses- What management activities to protect or restore freshwater environmental attributes* in the protected area's catchment* are used *WITHIN* the protected area?

Activities	KEA	Manistee National Forest	Huron National Forest	Traverse City	Cadillac
Acid Mine drainage remediation	B	Not applicable	Not applicable	Not applicable	Not applicable
Culvert removal/upgrade	HR, C, PH, B	Often	Often	Often	Often
Erosion control methods	WQ, PH, B	Often	Often	Often	Often
Fishing regulations enforcement	B	Not applicable	Not applicable	Occasionally	Occasionally
Installation of fish ladders/passages	B, C	Never	Never	Occasionally	Rarely
Installation of levee bypasses	B	Never	Never	Not applicable	Not applicable
Education programs	B, C, HR, PH, WQ	Often	Often	Occasionally	Occasionally
Invasive species management	B	Often	Often	Occasionally	Occasionally
Post disturbance re-vegetation	B, PH, ER, HR	Often	Often	Occasionally	Occasionally
Prohibition of species extractions (non-fish)	B	Not applicable	Not applicable	Rarely	Rarely
Promotion of forest BMPs	WQ, PH, B	Often	Often	Often	Often
Reduction of impervious surfaces	HR, WQ, PH, B	Never	Never	Occasionally	Occasionally
Removal of dams, weirs, or levees	C, PH, HR, B	Rarely	Rarely	Occasionally	Occasionally
Restoration of channel shape, size, or sinuosity	PH, C, HR, B	Rarely	Rarely	Occasionally	Occasionally
Riparian buffer restoration and creation	WQ, C, B	Occasionally	Occasionally	Rarely	Rarely
Road construction and maintenance BMPs	WQ, B	Often	Often	Often	Often
Instream habitat practices	WQ, PH, B	Often	Often	Occasionally	Often
Recovery of Native species	B	Occasionally	Occasionally	Rarely	Rarely
Stocking of Native Species	B	Not applicable	Not applicable	Rarely	Rarely
Storm water management	HR, WQ, PH, B	Never	Never	Rarely	Rarely
Stream bank stabilization	PH, WQ, B	Occasionally	Occasionally	Often	Often
Upgrade of septic systems to performance standards	WQ, B	Occasionally	Occasionally	Rarely	Rarely
Use of Physical barriers to prevent exotic colonization	B	Rarely	Rarely	Rarely	Not applicable
Wetland Restoration	WQ, PH, B	Occasionally	Occasionally	Rarely	Rarely

Question 3 Questionnaire Responses- What management activities to protect or restore freshwater environmental attributes* in the protected area's catchment* are used *WITHIN* the protected area?

Activities	KEA	Manistee River State Game Area	Fisherman's Island State Park	Wilderness State park
Acid Mine drainage remediation	B	Not applicable	Not applicable	Not applicable
Culvert removal/upgrade	HR, C, PH, B	Rarely	Rarely	Rarely
Erosion control methods	WQ, PH, B	Occasionall y	Occasionally	Occasionally
Fishing regulations enforcement	B	Often	Rarely	Occasionally
Installation of fish ladders/passages	B, C	Occasionall y	Not applicable	Not applicable
Installation of levee bypasses	B	Unsure	Not applicable	Not applicable
Education programs	B, C, HR,	Occasionall y	Occasionally	Occasionally
Invasive species management	B	Occasionall y	Occasionally	Often
Post disturbance re-vegetation	B, PH, ER,	Occasionall y	Occasionally	Often
Prohibition of species extractions (non-fish)	B	Rarely	Occasionally	Often
Promotion of forest BMPs	WQ, PH, B	Often	Occasionally	Not applicable
Reduction of impervious surfaces	HR, WQ,	Rarely	Not applicable	Occasionally
Removal of dams, weirs, or levees	C, PH, HR, B	Never	Not applicable	Never
Restoration of channel shape, size,	PH, C, HR, B	Occasionall y	Not applicable	Rarely
Riparian buffer restoration and	WQ, C, B	Occasionall y	Occasionally	Occasionally
Road construction and maintenance	WQ, B	Occasionall y	Often	Occasionally
Instream habitat practices	WQ, PH, B	Occasionall y	Never	Never
Recovery of Native species	B	Occasionall y	Occasionally	Never
Stocking of Native Species	B	Occasionall y	Often	Never
Storm water management	HR, WQ,	Occasionall y	Not applicable	Not applicable
Stream bank stabilization	PH, WQ, B	Occasionall y	Occasionally	Occasionally
Upgrade of septic systems to	WQ, B	Unsure	Not applicable	Often
Use of Physical barriers to prevent	B	Unsure	Not applicable	Not applicable
Wetland Restoration	WQ, PH, B	Occasionall y	Not applicable	Not applicable

Extra Question 1				Prohibition of species extractions (non-fish): The entire park is open to hunting so the taking of game species by legal hunting methods with a valid hunting license is permitted. Removal of none game species of animals is not permitted. Removal of any plant species is not permitted. Reduction of impervious surfaces (e.g. use of permeable pavements, green roofs): In all future construction projects such materials will be considered and used when deemed feasible. Promotion of forest management best management practices: Commercial forest management is prohibited on state park lands.

Appendix 6: Interview Questions for the qualitative management evaluation of study PAs

Context

1. Have freshwater conservation priorities been identified for the watershed? If so, have they been incorporated within the protected area's management plan?

2. Do upstream dam managers consider environmental flows when developing their management plans (e.g. timing, quantity of water releases)?
    - Yes
    - No
    - Unsure
    - Not applicable

3. Are freshwater resources ***within*** the protected area recognized for their social values (e.g. open space, recreation, protection of iconic species, offering research permits)? Please explain how these values are prioritized.

4. Are freshwater resources ***within*** the protected area recognized for their cultural values (e.g. protection of way of life, protection of important cultural species or landscape features)? Please explain how these values are prioritized.

5. Are freshwater resources ***within*** the protected area recognized for their ecosystem services (e.g. water quality, flood control, fisheries, tourism, etc.)? Please explain how these values are prioritized.

6. How does the protected area incorporate natural disturbance cycles (e.g. flooding, wildfire, ice storms, mass wasting) in the management plan?

Planning

7. Within the management processes, how much emphasis is placed on identifying how freshwater and terrestrial management activities within the protected area relate? (General)
    - None
    - Little
    - Moderate
    - Significant
    - Don't Know

8. Does the protected area management identify and track stream-specific indicators?
    - Yes
    - No
    - Don't Know

Which stream-specific indicators are regularly tracked (e.g. turbidity, free flowing stream miles, percentage of riparian corridor cover, population assessments, invasive species, etc.)? If the monitoring of indicators does not occur, please explain.

9. To what extent does the protected area management utilize cross-agency or non-government organization partnerships to address issues relating to freshwater? Please identify key partners.
    - None
    - Little
    - Moderate
    - Significant
    - Don't Know

10. Does the management plan **specifically** provide targets for the ideal range for freshwater indicators?

Process

11. How often are management plans, monitoring approaches, freshwater indicators, and objectives updated?

12. Do protected area managers utilize monitoring data to inform management goals and objectives?

13. Does the management plan **specifically** provide targets for the ideal range for freshwater indicators?
    - Yes.
    - No

Inputs

14. Do inventories (e.g. locations, size, species lists) of the protected area's aquatic habitat exist (e.g. lakes, wetlands, streams, seeps, bogs, fens)?

15. What percentage of the protected area's total funding is allocated towards freshwater management?

16. What percentage of protected area staff time is dedicated to freshwater management issues?

17. Are specialized personnel and/or equipment available to adequately perform activities related to aquatic system management?
    - Yes
    - No
    - Unsure

18. What land cover mapping resources are used in protected area management?

Outputs

19. How is progress towards meeting the stated freshwater related objectives determined? Is management adaptive? (How do you measure progress?)

20. Are freshwater indicators within the protected area tracked annually and compared to historical data to determine management effectiveness?
    - Yes
    - No
    - Don't Know

21. Are data and "lessons learned" made available to stakeholders, partners, analogous agencies, and the public?
    - Yes.
    - No
    - Unsure

Outcomes

22. Are freshwater indicators linked to objectives within the management plan?
    - Yes
    - No
    - Unsure

23. To what extent do management activities protect or maintain freshwater systems directly or indirectly?
    - Not at all
    - Minimally
    - Moderately
    - Significantly
    - Don't Know

Appendix 7: Scoring used to quantify management activities identified by study PA managers as contributing to freshwater KEAs (water quality, hydrologic regime, connectivity, physical habitat and energy regime, and biotic composition)

Water Quality Scoring Results

	Erosion Control Methods		Education Programs		Promotion of Forest BMPs		Reduction of Impervious Surfaces		Riparian Buffer Restoration and Creation		Road Construction & Maintenance BMPs		Instream Habitat Practices		Storm Water Management		Streambank Stabilization		Upgrade of Septic Systems to Performance Standards		Wetland Restoration		Total	Normalized Score	Category
Gaylord	Occasionally	2	Occasionally	2	Often	3	Rarely	1	Rarely	1	Occasionally	2	Occasionally	2	Never		Rarely	1	Unsure		Rarely	1	15.00	0.2	1
Atlanta	Rarely	1	Occasionally	2	Often	3	Rarely	1	Rarely	1	Occasionally	2	Occasionally	2	Never		Occasionally	2	Unsure		Rarely	1	15.00	0.2	1
Pigeon River Country	Rarely	1	Occasionally	2	Often	3	Rarely	1	Rarely	1	Occasionally	2	Occasionally	2	Never		Often	3	Unsure		Never		15.00	0.2	1
Grayling State Forest Area	Occasionally	2	Occasionally	2	Often	3	Occasionally	2	Occasionally	2	Often	3	Often	3	Occasionally	2	Occasionally	2	Unsure		Occasionally	2	23.00	1	4
Manistee National Forest	Often	3	Often	3	Often	3	Never		Occasionally	2	Often	3	Often	3	Never		Occasionally	2	Occasionally	2	Occasionally	2	23.00	1	4
Huron National Forest	Often	3	Often	3	Often	3	Never		Occasionally	2	Often	3	Often	3	Never		Occasionally	2	Occasionally	2	Occasionally	2	23.00	1	4
Traverse City	Often	3	Occasionally	2	Often	3	Occasionally	2	Rarely	1	Often	3	Occasionally	2	Rarely	1	Often	3	Rarely	1	Rarely	1	22.00	0.9	4
Cadillac	Often	3	Occasionally	2	Often	3	Occasionally	2	Rarely	1	Often	3	Often	3	Rarely	1	Often	3	Rarely	1	Rarely	1	23.00	1	4
Manistee River State Game Area	Occasionally	2	Occasionally	2	Often	3	Rarely	1	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Unsure		Occasionally	2	20.00	0.7	3
Fisherman's Island State Park	Occasionally	2	Occasionally	2	Occasionally	2	Not applicable		Occasionally	2	Often	3	Never		Not applicable		Occasionally	2	Not applicable		Not applicable		13.00	0	1
Wilderness State park	Occasionally	2	Occasionally	2	Not applicable		Occasionally	2	Occasionally	2	Occasionally	2	Never		Not applicable		Occasionally	2	Often	3	Not applicable		15.00	0.2	1

Management Activity Scoring for Hydrologic Regime

	Culvert Removal/ Upgrade		Education Programs		Post Disturbance Re-vegetation		Reduction of Impervious Surfaces		Removal of Dams, Weirs, or Levees		Restoration of Channel Shape, Size, or Sinuosity		Stormwater Management		Total	Normalized Score	Category
Gaylord	Occasionally	2	Occasionally	2	Rarely	1	Rarely	1	Occasionally	2	Not applicable		Never		8	0.333333333	2
Atlanta	Occasionally	2	Occasionally	2	Rarely	1	Rarely	1	Occasionally	2	Not applicable		Never		8	0.333333333	2
Pigeon River Country	Occasionally	2	Occasionally	2	Rarely	1	Rarely	1	Occasionally	2	Not applicable		Never		8	0.333333333	2
Grayling State Forest Area	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Rarely	1	Occasionally	2	13	0.888888889	4
Manistee National Forest	Often	3	Often	3	Often	3	Never		Rarely	1	Rarely	1	Never		11	0.666666667	3
Huron National Forest	Often	3	Often	3	Often	3	Never		Rarely	1	Rarely	1	Never		11	0.666666667	3
Traverse City	Often	3	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Rarely	1	14	1	4
Cadillac	Often	3	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Rarely	1	14	1	4
Manistee River State Game Area	Rarely	1	Occasionally	2	Occasionally	2	Rarely	1	Never		Occasionally	2	Occasionally	2	10	0.555555556	3
Fisherman's Island State Park	Rarely	1	Occasionally	2	Occasionally	2	Not applicable		Not applicable		Not applicable		Not applicable		5	0	1
Wilderness State park	Rarely	1	Occasionally	2	Often	3	Occasionally	2	Never		Rarely	1	Not applicable		9	0.444444444	2

Management Activity Scoring for Connectivity

	Culvert Removal/Upgrade		Installation of Fish Ladders/Passages		Education Programs		Removal of Dams, Weirs, or Levees		Restoration of Channel Shape, Size, or Sinuosity		Riparian Buffer Restoration and Creation		Total	Normalized Score	Category
Gaylord	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Not applicable		Rarely	1	9	0.571428571	3
Atlanta	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Not applicable		Rarely	1	9	0.571428571	3
Pigeon River Country	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Not applicable		Rarely	1	9	0.571428571	3
Grayling State Forest Area	Occasionally	2	Rarely	1	Occasionally	2	Occasionally	2	Rarely	1	Occasionally	2	10	0.714285714	3
Manistee National Forest	Often	3	Never		Often	3	Rarely	1	Rarely	1	Occasionally	2	10	0.714285714	3
Huron National Forest	Often	3	Never		Often	3	Rarely	1	Rarely	1	Occasionally	2	10	0.714285714	3
Traverse City	Often	3	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Rarely	1	12	1	4
Cadillac	Often	3	Rarely	1	Occasionally	2	Occasionally	2	Occasionally	2	Rarely	1	11	0.857142857	4
Manistee River State Game Area	Rarely	1	Occasionally	2	Occasionally	2	Never		Occasionally	2	Occasionally	2	9	0.571428571	3
Fisherman's Island State Park	Rarely	1	Not applicable		Occasionally	2	Not applicable		Not applicable		Occasionally	2	5	0	1
Wilderness State park	Rarely	1	Not applicable		Occasionally	2	Never		Rarely	1	Occasionally	2	6	0.142857143	1

Management Activity Scoring for Physical Habitat and Energy Regime

	Culvert Removal/Upgrade		Erosion Control Methods		Education Programs		Post Disturbance Re-vegetation		Promotion of Forest BMPs		Reduction of Impervious Surfaces		Removal of Dams, Weirs, or Levees		Restoration of Channel Shape, Size, or Sinuosity		Instream Habitat Practices		Stormwater Management		Streambank Stabilization		Wetland Restoration		Total	Normalized Score	Category
Gaylord	Occasionally	2	Occasionally	2	Occasionally	2	Rarely	1	Often	3	Rarely	1	Occasionally	2	Not applicable		Occasionally	2	Never		Rarely	1	Rarely	1	17	0.375	2
Atlanta	Occasionally	2	Rarely	1	Occasionally	2	Rarely	1	Often	3	Rarely	1	Occasionally	2	Not applicable		Occasionally	2	Never		Occasionally	2	Rarely	1	17	0.375	2
Pigeon River Country	Occasionally	2	Rarely	1	Occasionally	2	Rarely	1	Often	3	Rarely	1	Occasionally	2	Not applicable		Occasionally	2	Never		Often	3	Never		17	0.375	2
Grayling State Forest Area	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Often	3	Occasionally	2	Occasionally	2	Rarely	1	Often	3	Occasionally	2	Occasionally	2	Occasionally	2	25	0.875	4
Manistee National Forest	Often	3	Often	3	Often	3	Often	3	Often	3	Never		Rarely	1	Rarely	1	Often	3	Never		Occasionally	2	Occasionally	2	24	0.8125	4
Huron National Forest	Often	3	Often	3	Often	3	Often	3	Often	3	Never		Rarely	1	Rarely	1	Often	3	Never		Occasionally	2	Occasionally	2	24	0.8125	4
Traverse City	Often	3	Often	3	Occasionally	2	Occasionally	2	Often	3	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Rarely	1	Often	3	Rarely	1	26	0.9375	4
Cadillac	Often	3	Often	3	Occasionally	2	Occasionally	2	Often	3	Occasionally	2	Occasionally	2	Occasionally	2	Often	3	Rarely	1	Often	3	Rarely	1	27	1	4
Manistee River State Game Area	Rarely	1	Occasionally	2	Occasionally	2	Occasionally	2	Often	3	Rarely	1	Never		Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	21	0.625	3
Fisherman's Island State Park	Rarely	1	Occasionally	2	Occasionally	2	Occasionally	2	Occasionally	2	Not applicable		Not applicable		Not applicable		Never		Not applicable		Occasionally	2	Not applicable		11	0	1
Wilderness State park	Rarely	1	Occasionally	2	Occasionally	2	Often	3	Not applicable		Occasionally	2	Never		Rarely	1	Never		Not applicable		Occasionally	2	Not applicable		13	0.125	1

Management Activity Scoring for Biotic Composition

Protected Area	Acid Mine Drainage Remediation	Culvert Removal/ Upgrade	Erosion Control Methods	Fishing Regulations Enforcement	Installation of Fish Ladders/Passages	Installation of Levee Bypasses	Education Programs	Invasive Species Management	Post Disturbance Re-vegetation	Prohibition of Species Extractions (non-fish)	Promotion of Forest BMPs	Reduction of Impervious Surfaces	Removal of Dams, Weirs, or Levees	Restoration of Channel Shape, Size, or Sinuosity	Riparian Buffer Restoration and Creation	Road Construction and Maintenance BMPs	Instream Habitat Practices	Recovery of Native Species	Stocking of Native Species	Stormwater Management	Streambank Stabilization	Upgrade of Septic Systems to Performance Standards	Use of Physical Barriers to Prevent Exotic Colonization	Wetland Restoration	Total	Normalized Score	Category
Gaylord	Not applicable	Occasionally	Occasionally	Occasionally	Occasionally	Not applicable	Occasionally	Often	Rarely	Unsure	Often	Rarely	Occasionally	Not applicable	Rarely	Occasionally	Occasionally	Occasionally	Rarely	Never	Rarely	Unsure	Never	Rarely			
		2	2	2	2		2	3	1		3	1	2		1	2	2	2	1		1			1	30	0.222222222	1
Atlanta	Not applicable	Occasionally	Rarely	Occasionally	Occasionally	Not applicable	Occasionally	Often	Rarely	Unsure	Often	Rarely	Occasionally	Not applicable	Rarely	Occasionally	Occasionally	Rarely	Rarely	Never	Occasionally	Unsure	Rarely	Rarely			
		2	1	2	2		2	3	1		3	1	2		1	2	2	1	1		2		1	1	30	0.222222222	1
Pigeon River	Not applicable	Occasionally	Rarely	Often	Occasionally	Not applicable	Occasionally	Often	Rarely	Unsure	Often	Rarely	Occasionally	Not applicable	Rarely	Occasionally	Occasionally	Occasionally	Never	Never	Often	Unsure	Never	Never			
		2	1	3	2		2	3	1		3	1	2		1	2	2	2			3				30	0.222222222	1
Grayling	Unsure	Occasionally	Occasionally	Often	Rarely	Rarely	Occasionally	Occasionally	Occasionally	Occasionally	Often	Occasionally	Occasionally	Rarely	Occasionally	Often	Often	Occasionally	Occasionally	Occasionally	Occasionally	Unsure	Rarely	Occasionally			
		2	2	3	1	1	2	2	2	2	3	2	2	1	2	3	3	2	2	2	2		1	2	44	1	4
Manistee	Not applicable	Often	Often	Not applicable	Never	Never	Often	Often	Often	Not applicable	Often	Never	Rarely	Rarely	Occasionally	Often	Often	Occasionally	Not applicable	Never	Occasionally	Occasionally	Rarely	Occasionally			
		3	3				3	3	3		3		1	1	2	3	3	2			2	2	1	2	37	0.611111111	3
Huron	Not applicable	Often	Often	Not applicable	Never	Never	Often	Often	Often	Not applicable	Often	Never	Rarely	Rarely	Occasionally	Often	Often	Occasionally	Not applicable	Never	Occasionally	Occasionally	Rarely	Occasionally			
		3	3				3	3	3		3		1	1	2	3	3	2			2	2	1	2	37	0.611111111	3
Traverse	Not applicable	Often	Often	Occasionally	Occasionally	Not applicable	Occasionally	Occasionally	Occasionally	Rarely	Often	Occasionally	Occasionally	Occasionally	Rarely	Often	Occasionally	Rarely	Rarely	Rarely	Often	Rarely	Rarely	Rarely			
		3	3	2	2		2	2	2	1	3	2	2	2	1	3	2	1	1	1	3	1	1	1	41	0.833333333	4
Cadillac	Not applicable	Often	Often	Occasionally	Rarely	Not applicable	Occasionally	Occasionally	Occasionally	Rarely	Often	Occasionally	Occasionally	Occasionally	Rarely	Often	Often	Rarely	Rarely	Rarely	Often	Rarely	Not applicable	Rarely			
		3	3	2	1		2	2	2	1	3	2	2	2	1	3	3	1	1	1	3	1		1	40	0.777777778	4
Manistee River State Game Area	Not applicable	Rarely	Occasionally	Often	Occasionally	Unsure	Occasionally	Occasionally	Occasionally	Rarely	Often	Rarely	Never	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Unsure	Unsure	Occasionally			
		1	2	3	2		2	2	2	1	3	1		2	2	2	2	2	2	2	2			2	37	0.611111111	3
Fisherman's Island	Not applicable	Rarely	Occasionally	Rarely	Not applicable	Not applicable	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Not applicable	Not applicable	Not applicable	Occasionally	Often	Never	Occasionally	Often	Not applicable	Occasionally	Not applicable	Not applicable	Not applicable			
		1	2	1			2	2	2	2	2				2	3		2	3		2				26	0	1
Wilderness	Not applicable	Rarely	Occasionally	Occasionally	Not applicable	Not applicable	Occasionally	Often	Often	Often	Not applicable	Occasionally	Never	Rarely	Occasionally	Occasionally	Never	Never	Never	Not applicable	Occasionally	Often	Not applicable	Not applicable			
		1	2	2			2	3	3	3		2		1	2	2					2	3			28	0.111111111	1

Appendix 8: Average of all stressors affecting Water Quality response variable point catchments are displayed to see the components used to create a catchment condition score (Ag=agriculture; RC = riparian corridor 100meter buffer).. This catchment condition score is specific to each study PA for Water Quality data points. (sample size)

PA (Sample size of response variable data points)	Roads Meters per sqm of Catchment	# of Road Crossings per sqm of Catchment	Population of Urban Center(s) per sqm of Catchment Area	Dam density	Catchment % Ag	Catchment % Impervious	RC% Ag	RC% Impervious
Atlanta State Forest Area (33)	0.07	0.03	0.00	0.10	19.83%	6.40%	2.46%	11.40%
Cadiliac State Forest Area (36)	0.13	0.07	0.04	0.14	12.99%	2.73%	4.75%	3.10%
Gaylord State Forest Area (76)	0.13	0.02	0.01	0.08	8.49%	3.28%	8.88%	2.76%
Grayling State Forest Area (14)	0.13	0.09	0.02	0.17	3.88%	2.48%	4.73%	1.09%
Huron National Forest (12)	0.09	0.17	0.03	0.27	4.00%	1.62%	13.17%	1.36%
Manistee National Forest (123)	0.22	0.09	0.06	0.06	18.92%	3.65%	11.35%	4.15%
Manistee State Game Area (60)	0.11	0.75	0.15	0.09	2.33%	5.75%	4.12%	1.00%
Pigeon River County State Forest Area (21)	0.10	0.02	0.03	0.08	3.08%	2.09%	6.69%	0.89%
Traverse City State Forest Area (28)	0.11	0.03	0.02	0.02	30.68%	1.83%	2.59%	1.73%

An average of all stressors affecting Biotic Composition response variable point catchments are displayed to see the components used to create a catchment condition score (Ag=agriculture; RC = riparian corridor 100meter buffer).. This catchment condition score is specific to each study PA for Biotic Composition data points. (sample size)

PA (Sample size of response variable data points)	Large Scale Withdrawals per sqm of Catchment	Roads Meters per sqm of Catchment	Wells per sqm of Catchment	# of Road Crossings per sqm of Catchment	Population of Urban Center(s) per sqm of Catchment Area	Catchment % Ag	RC% Ag	Dam Density	Catchment % Impervious	RC% Impervious
Atlanta State Forest Area (5)	0.09	0.23	0.12	0.04	0.00	4.22%	1.17%	31.46%	1.05%	0.75%
Cadiliac State Forest Area (8)	0.59	0.80	0.29	0.07	0.10	9.92%	6.42%	70.52%	2.88%	11.99%
Gaylord State Forest Area (8)	0.31	0.46	0.17	0.08	0.05	7.01%	3.66%	51.08%	1.96%	7.56%
Grayling State Forest Area (0)	na	na	na	na	na	na	na	na	na	na
Huron National Forest (9)	0.35	0.62	0.15	0.50	0.10	0.70%	6.81%	3.57%	1.11%	1.22%
Manistee National Forest (23)	0.28	0.64	0.08	0.37	0.34	22.43%	6.02%	50.04%	6.02%	1.30%
Manistee State Game Area (14)	0.12	0.45	0.29	0.31	0.06	8.46%	2.13%	59.77%	12.30%	1.19%
Pigeon River County State Forest Area (0)	na	na	na	na	na	na	na	na	na	na
Traverse City State Forest Area (5)	0.44	0.83	0.38	0.03	0.00	6.39%	5.63%	74.89%	3.55%	1.63%

An average of all stressors affecting Physical Habitat and Energy Regime response variable point catchments are displayed to see the components used to create a catchment condition score (Ag=agriculture; RC = riparian corridor 100meter buffer).. This catchment condition score is specific to each study PA for Physical Habitat/Energy Regime data points. (sample size)

PA (Sample size of response variable data points)	TRI Sites per m^2	NPDES Facilities per m^2 of Catchment	Large Scale Withdrawals per sqm of Catchment	Roads Meters per sqm of Catchment	Wells per sqm of Catchment	# of Road Crossings per sqm of Catchment	Population of Urban Center(s) per sqm of Catchment Area	Dam Density	Catchment % Ag	Catchment % Impervious	RC% Impervious	RC% Ag
Atlanta State Forest Area (34)	0.02	0.03	0.01	0.13	0.27	0.21	0.01	0.24	10.06%	1.50%	1.26%	3.96%
Cadiliac State Forest Area (11)	0.13	0.19	0.18	0.22	0.59	0.20	0.13	0.20	11.69%	2.14%	1.20%	5.10%
Gaylord State Forest Area (15)	0.00	0.29	0.13	0.25	0.23	0.08	0.01	0.11	9.98%	3.80%	0.79%	8.54%
Grayling State Forest Area (16)	0.02	0.03	0.07	0.18	0.12	0.28	0.04	15.21	1.01%	1.25%	1.13%	8.20%
Huron National Forest (16)	0.02	0.02	0.06	0.18	0.13	0.26	0.04	0.35	1.37%	1.41%	1.20%	7.77%
Manistee National Forest (68)	0.00	0.15	0.06	0.19	0.66	0.05	0.01	0.11	25.01%	7.57%	1.02%	4.13%
Manistee State Game Area (8)	0.00	0.04	0.08	0.19	0.44	0.06	0.01	0.17	8.43%	1.66%	0.72%	1.75%
Pigeon River County State Forest Area (0)	na	na	na	na	na	na	na	na	na	na	na	na
Traverse City State Forest Area (23)	0.20	0.44	0.09	0.32	0.76	0.11	0.05	0.07	28.98%	2.71%	1.63%	12.00%

Average of all stressors affecting Connectivity are displayed to see the components used to create a catchment condition score. This catchment condition score is specific to each PA of interest for Connectivity data points. (sample size)

PA (Sample size of response variable data points)	Large Scale Withdrawals per sqm of Catchment	Roads Meters per sqm of Catchment	# of Road Crossings per sqm of Catchment	Dam Density
Atlanta State Forest Area (38)	0.06	0.20	0.05	0.05
Cadiliac State Forest Area (17)	0.12	0.33	0.08	0.08
Gaylord State Forest Area (36)	0.19	0.27	0.03	0.03
Grayling State Forest Area (28)	0.08	0.29	0.07	0.07
Huron National Forest (18)	0.09	0.30	0.11	0.11
Manistee National Forest (31)	0.03	0.33	0.12	0.12
Manistee State Game Area (5)	0.07	0.32	0.28	0.28
Pigeon River County State Forest Area (9)	0.37	0.26	0.02	0.02
Traverse City State Forest Area (14)	0.09	0.31	0.04	0.04

Average of all stressors affecting hydrologic regime are displayed to see the components used to create a catchment condition score (Ag=agriculture; RC = riparian corridor 100meter buffer). This catchment condition score is specific to each PA of interest for hydrologic regime data points (sample size)

PA (Sample size of response variable data points)	Large Scale Withdrawals per sqm of Catchment	Roads Meters per sqm of Catchment	Wells per sqm of Catchment	# of Road Crossings per sqm of Catchment	Population of Urban Center(s) per sqm of Catchment Area	Catchment % Ag	RC% Ag	Dam Density	Catchment % Impervious	RC% Impervious
Atlanta State Forest Area (5)	0.09	0.23	0.12	0.04	0.00	4.22%	1.17%	31.46%	1.05%	0.75%
Cadiliac State Forest Area (8)	0.59	0.80	0.29	0.07	0.10	9.92%	6.42%	70.52%	2.88%	11.99%
Gaylord State Forest Area (8)	0.31	0.46	0.17	0.08	0.05	7.01%	3.66%	51.08%	1.96%	7.56%
Grayling State Forest Area (0)	na	na	na	na	na	na	na	na	na	na
Huron National Forest (9)	0.35	0.62	0.15	0.50	0.10	0.70%	6.81%	3.57%	1.11%	1.22%
Manistee National Forest (23)	0.28	0.64	0.08	0.37	0.34	22.43%	6.02%	50.04%	6.02%	1.30%
Manistee State Game Area (14)	0.12	0.45	0.29	0.31	0.06	8.46%	2.13%	59.77%	12.30%	1.19%
Pigeon River County State Forest Area (0)	na	na	na	na	na	na	na	na	na	na
Traverse City State Forest Area (5)	0.44	0.83	0.38	0.03	0.00	6.39%	5.63%	74.89%	3.55%	1.63%

Appendix 9: Results of Water Quality Response Variable Analysis with resultant quartile scores (1=low, 4=high) and average percent catchment protected by study PA (sample size)

Protected Area	Average $NO_{2+}NO_3$ (mg/L)	$NO_{2+}NO_3$ Quartile Score	Average % Protected for N point catchments	Average Total P (mg/L)	Quartile Score	Avg % protected for P point catchments
Atlanta	0.0492 (25)	4	31.58%	0.0280 (25)	1	31.58%
Cadillac	0.4316 (18)	1	15.71%	0.0222 (19)	2	14.96%
Gaylord	0.4932 (42)	1	28.15%	0.0133 (45)	3	26.31%
Grayling	0.1560 (7)	3	5.35%	0.0119 (7)	4	5.35%
Huron	0.2032 (5)	3	19.47%	0.0112 (5)	4	19.47%
Manistee NF	0.2351 (58)	2	30.5%	0.0261 (58)	1	30.50%
Manistee SGA	0.1300 (1)	3	0.33%	0.0210 (1)	3	0.33%
Pigeon	0.0781 (14)	4	23.58%	0.0227 (14)	2	23.58%
Traverse	0.243 (23)	2	26.55%	0.0154 (22)	4	27.31%

Results of Biotic Composition Variable analysis with resultant quartile score (1=low, 4=high) and average percent protected by study PA for data point catchments (sample size)

Protected Area	Average FIBI Score	Quartile Score	Avg % Protected for FIBI point catchments	% Intolerant	Quartile Score	Avg% Protected for % Intol point catchments
Atlanta	65.20 (22)	2	20.89%	32.34 (22)	3	20.89%
Cadillac	63.00 (8)	2	21.04%	21.12 (7)	1	21.04%
Gaylord	79.73 (10)	4	45.17%	63.10 (10)	4	45.17%
Grayling	50.71 (7)	1	15.63%	48.93 (6)	3	15.63%
Huron	47.59 (12)	1	53.93%	31.55 (12)	2	53.93%
Manistee NF	65.81 (30)	3	25.26%	27.76 (30)	1	25.26%
Manistee SGA	n/a (0)	n/a	n/a	n/a (0)	n/a	n/a
Pigeon	n/a (0)	n/a	n/a	n/a (0)	n/a	n/a
Traverse	65.95 (19)	3	33.87%	32.16 (20)	2	32.26%

Results of Hydrologic Regime Variable analysis with resultant quartile scores, and average % protected by study PA for data point catchments (sample size)

Protected Area	Average Rate of Flow Response	Quartile Score	Avg % Protected for RR point catchment	Low Flow Expectation Deviation	Quartile Score	Avg % Protected for LF point catchments
Atlanta	6.00 (2)	4	27.97%	23.91 (2)	3	27.97%
Cadillac	6.31 (2)	4	10.71%	38.19 (2)	3	10.71%
Gaylord	12.09 (8)	3	13.07	54.90 (8)	2	13.07
Grayling	26.46 (6)	2	28.16%	266.86 (6)	2	28.16%
Huron	38.56 (4)	1	14.02%	340.92 (4)	1	14.02%
Manistee NF	15.29 (6)	3	17.4%	85.10 (6)	2	17.4%
Manistee SGA	162.50 (1)	1	15.41%	396.43 (1)	1	15.41%
Pigeon	16.50 (2)	2	12.50%	11.14 (2)	4	12.50%
Traverse	7.25 (2)	3	29.60%	23.32 (2)	4	29.60%

Results of Physical Habitat and Energy Regime Variable analysis, with quartile score (1=low, 4=high) and average percent protected by study PA for Habitat data point catchments used (sample size).

Protected Area	p51 Habitat Score	Quartile Score	Avg % Protected for Habitat point catchments
Atlanta	n/a (0)	n/a	n/a
Cadillac	71.58 (11)	1	19.43%
Gaylord	104.62 (12)	3	30.12%
Grayling	93.13 (7)	3	22.65%
Huron	81.78 (8)	2	34.22%
Manistee NF	86.94 (33)	2	26.13%
Manistee SGA	n/a (0)	n/a	n/a
Pigeon	n/a (0)	n/a	n/a
Traverse	111.00 (12)	4	23.81%

Results of Connectivity analysis, with resultant quartile scores (1=low, 4=high) and average % protected by study PA for catchments used in the quantification (sample size).

Protected Area	Dams per stream meter (m)	Quartile Score	Average % Protected
Atlanta	17161.15 (40)	1	27.78%
Cadillac	22672.80 (33)	2	16.58%
Gaylord	32653.51 (43)	4	18.54%
Grayling	43497.96 (27)	4	19.31%
Huron	18647.68 (25)	1	24.58%
Manistee NF	29159.24 (103)	3	22.49%
Manistee SGA	25009.71 (1)	3	0.33%
Pigeon	20113.95 (14)	2	22.76%
Traverse	22624.41 (38)	2	30.43%

Appendix 10: External threats identified by interviewed PA managers with indications of high, moderate, low, or no alteration to freshwater conditions