

1-20-2014

Applications of Biological Integrity within the National Wildlife Refuge System Region 5

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**Applications of Biological Integrity within the
National Wildlife Refuge System Region 5**

By Katie Lynn Ehlers

A thesis submitted to the Department of Environmental Science and Biology of The
State University of New York College at Brockport in partial
fulfillment of the requirements for the degree of
Master of Environmental Science and Biology

January 20, 2014

Acknowledgements:

I would like to thank my family for their support, encouragement, and patience throughout my educational journey. A special thank you to Michael, who played the role of chauffeur and always tried to keep me focused on the finish line.

I would also like to acknowledge the guidance and support provided by my thesis committee members, Dr. Chris Norment, Dr. Doug Wilcox, and Heidi Kennedy. Specifically, I would like to acknowledge Dr. Norment for his patience and willingness to mentor a non-traditional master's student, as well as his immense effort in shaping this thesis through his always-helpful suggestions and editorial comments.

I am grateful for the insight and opinions shared by the many National Wildlife Refuge System staff members who assisted with various aspects of this project. I wish to express my sincere thanks to those who took the time to share their extensive knowledge about each refuge during my site visits and by answering survey questions. While I would like to give credit to all those who helped by name, I will instead honor the requests of personal/professional anonymity. Specifically, I would like to acknowledge Tom Roster for suggesting biological integrity as a thesis topic and beginning my educational journey on the topic.

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Abstract

The passage of the National Wildlife Refuge System Improvement Act of 1997 (NWRISA) and subsequent implementation of 601 FW 3: Biological Integrity, Diversity and Environmental Health Policy (hereafter, the “Integrity Policy”) represented a groundbreaking paradigm shift for refuge management. NWRISA set forth a “mission for the System, and clear standards for its management, use, planning, and growth (US Fish and Wildlife Service, 1999),” by uniting the eclectic mix of refuges nationwide under the same mission, “to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans” (NWRISA 1997). The act goes on to say that the Secretary of the Interior must “ensure that the biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans (US Fish and Wildlife Service, 1999.)”

NWRISA legally formalized the concept of biological integrity as a refuge management objective, but failed to define it. As a result, field experts and refuge managers struggle to discern applications of the biological integrity concept. Given the difficulties inherent in defining biological integrity, and the ambiguities involved with applying the concept to refuge management, examining how the concept is being applied on local refuges reveals valuable information about its practicality. Ultimately, for the biological integrity concept to shape refuge management, some of the ambiguity surrounding its definition and application must be removed. With outside influences such as surrounding land-use, invasive species, and climate change altering the ecological trajectories, biological integrity, as currently defined by the US Fish and Wildlife Service, proves to be an unattainable goal.

Introduction

The National Wildlife Refuge System (NWRS) has grown significantly in size, responsibility, and complexity since Pelican Island National Wildlife Refuge was created by President Theodore Roosevelt in 1903 (United States Fish and Wildlife Service [USFWS], 1999). Unfortunately, since its inception, the NWRS has functioned under inadequate legislative directives, which focused on how to utilize refuges rather than the functions of the refuge system (USFWS, 1999). Consequently, this created a disjointed system consisting of an eclectic mix of refuges, encompassing a variety of landscapes, and embodying an equally diverse mix of management practices.

Early refuge management goals focused on protecting wildlife and habitat in the public interest, facilitating natural regeneration of degraded land, and acting compatibly with the founding purpose of the refuge (Curtin, 1993). Acts of Congress, donations, and Executive Orders legally established refuges; an estimated 295 refuges (or portions of) were established under the Migratory Bird Conservation Act, “for use as an inviolate sanctuary, or for any other management purpose, for migratory birds” (Schroeder *et al.*, 2004). Thus, the primary management objective for these refuges was to conserve or create habitat for migratory birds, including waterfowl. Management strategies included creation of water-control structures to manipulate open water habitat, planting vegetation to serve as food sources during migration, and developing dense cover for nesting. Creating habitat capable of supporting large waterfowl populations sometimes dramatically altered the original landscape. The selective management style pursued by early National Wildlife Refuges, particularly those formed using “Duck Stamp” dollars, provided critical protection for waterfowl populations. However, this historical management strategy, guided by the idea of managing for a few species, is currently evolving into a contemporary principle that emphasizes utilizing natural processes such as hydroperiods and fire regimes to manage for a multitude of species (Schroeder *et al.*, 2004).

The passage of the National Wildlife Refuge System Improvement Act of 1997 (NWRISA) and subsequent implementation of 601 FW 3: Biological Integrity, Diversity and Environmental Health Policy (hereafter, the “Integrity Policy”) represented a groundbreaking paradigm shift for

National Wildlife Refuge management. NWRSA provides the National Wildlife Refuge System with “a mission for the System, and clear standards for its management, use, planning, and growth” (USFWS, 1999). The eclectic mix of refuges nationwide was united under the same mission, “to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans” (United States Government, 1997). The act orders the Secretary of Interior to “ensure that the biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans” (USFWS, 1999.)

NWRSA legally formalized the concept of biological integrity as a refuge management objective but failed to define it. As a result, field experts and refuge managers struggled to understand how to apply the biological integrity concept. In essence, the concept of biological integrity includes natural, evolutionary, and biogeographic processes (Angermeier *et al.*, 1994). It encompasses an idea of “wholeness,” with complete, functioning ecosystems at all levels, unhindered by human activities. James Karr (2004) wrote, “the healthiest places, those with [biological] integrity, have undergone little or no disturbance at human hands. These places support a balanced, integrated, adaptive biota having the full range of elements or parts (genes, species, assemblages; plants, animals, microbes) and processes (mutation, demography, biotic interactions, nutrient cycling, energy flow, metapopulation dynamics) characteristic of the region and expected in areas with minimal human influence.” The United States Fish and Wildlife Service (USFWS) incorporated some of the above ideas in the Integrity Policy’s (601 FW3) definition of biological integrity: “biotic composition, structure, and functioning at genetic, organism, and community levels comparable with historic condition, including the natural biological processes that shape genomes, organisms, and communities (USFWS, 2001).”

While an adequate definition of biological integrity is warranted, it is more important to have a concept that can be used to guide refuge management decisions (Karr, 2004). According to Karr (2004), lands managed to promote biological integrity can “support a thriving living system, they

retain the capacity to regenerate, reproduce, sustain, adapt, develop, and evolve.” Although the Integrity Policy and NWRSA serve as good management principles, they do not capture all the aspects of biological integrity, nor do they adequately address the complications and contradictions involved with applying such a policy to refuge management programs. The definition of biological integrity needs clarification so that it can evolve from a simple description to a concept useful for the practical purpose of guiding management decisions (Karr, 2004). In addition, implementation of the policy requires a robust analytical framework to track the concepts outlined in the definition of biological integrity (Karr, 2004). Finally, an effective communication forum is required to convey trends and consequences of management initiatives to citizens and policy makers (Karr, 2004). In principle, the Integrity Policy establishes a guiding framework for refuge management by emphasizing an understanding of historical conditions, acknowledging how much current condition has deteriorated, and deciding how to maintain or restore these conditions (Matson, 2004). Thus, refuges that seek to adhere to the Integrity Policy consequently should promote historical conditions (Schroeder *et al.*, 2004). This requires detailed research into what comprised the historical condition, as well as a detailed inventory of the current conditions, placing extensive demands on an organization already fighting resource depletion (Matson, 2004). Historical condition is generally described as the pre-European settlement. Suggested data required to gain an accurate description of historical state include the distribution, abundance, and species composition of flora and fauna, water quality, soil composition, as well as an understanding of ecological processes such as fire and hydrology (Schroeder *et al.*, 2004).

When attempting to formulate ways to measure “historical condition,” it is important to understand that current environmental conditions on any National Wildlife Refuge, no matter how remote, will likely have experienced some form of human impact, including extinctions, climate change, resource use, and facilitation of invasive species. These anthropogenic effects can present obstacles to achieving historical conditions (Meretsky *et al.*, 2006). For example, studies have revealed that while some ecosystems in the Northeast are beginning to resemble historical conditions by moving towards mature forest, the plant and wildlife species composition of these forests is

“culturally conditioned,” and may only vaguely resemble historical conditions (Foster *et al.*, 2002). Given the difficulties with achieving historical condition and biological integrity, however it is defined, it is important to create management strategies that address the environmental repercussions of human influence.

While some may question USFWS’s inclusion of historical condition in its definition of biological integrity, others have focused on alternate ways to define and measure biological integrity. For example, a more realistic approach might use established reference sites as measurable benchmarks for biological integrity, because these sites portray target ecosystem characteristics and are subjected to the same human-induced conditions that may impact a refuge’s ability to achieve, through management efforts, “historical conditions” (Meretsky *et al.*, 2006). Others argue for a practical application, which includes a rigorous sampling and analytical framework of specific predefined parameters. Karr (2004) argues that these “biotic indices” ultimately serve as useful tools of assessment, although some such as Wilcox *et al.*, (2002) have questioned this assertion due to its problematic application in highly variable environments. The ideal process for assessing biological integrity will evaluate the success of management actions that strive to minimize habitat fragmentation, perpetuate natural floral and faunal communities, allow for the continuation of natural processes (i.e. fire and floods), control exotic species while catering to the needs of ecologically important natural species, and maintain areas of uncontaminated land and water (Matson, 2004).

Although restoration of historical conditions is a mandated goal of refuge management, there are several instances where this is not the case. These include situations when there is a conflict with the founding refuge purpose, which requires management for non-historical conditions to achieve the refuge purpose, or when management for non-historical conditions makes a greater contribution to biological integrity on a larger landscape level (Schroeder *et al.*, 2004). Examples of management activities that potentially conflict with the concept of biological integrity include maintaining grasslands on refuges where the ecosystem did not exist historically, or altering the timing of flood/drought cycles to maintain habitat characteristics necessary for targeted species, along with the

construction of dikes. Each of these examples demonstrates how subjective the Integrity Policy can be when applied to refuge management decisions. In addition, some might argue that the Integrity Policy's definition of biological integrity is anti-management, as it promotes the "let nature run its course approach," rather than current management practices that typically enhance integrity by restoring ecological processes and helping native species rebound (Meretsky *et al.*, 2006).

The scientific community, legislation, and newly crafted regulations are reinforcing the commitment of refuges to manage natural landscapes for the long-term benefit of humans (Schroeder *et al.*, 2004). As a result, individual refuges are examining how they fit into the National Wildlife Refuge System, a process mandated by the 1997 National Wildlife Refuge System Improvement Act and documented in the refuge's Comprehensive Conservation Plan (CCP). According to the USFWS, a refuge's CCP "describes the desired future conditions of a refuge or planning unit; provides long-range guidance and management direction to achieve the purposes of the refuge; helps fulfill the mission of the Refuge System; maintains and, where appropriate, restores the ecological integrity of each refuge and the Refuge System; helps achieve the goals of the National Wilderness Preservation System; and meets other mandates (USFWS, 2000)." This long-range planning document captures the evolutionary change that the USFWS's refuge philosophy has undergone, as it has shifted from species-specific management to utilizing natural processes to manage for many species (Schroeder *et al.*, 2004). The NWRSA and the Integrity Policy have laid the groundwork for the CCP process. However, refuge managers must confront the ambiguity of the legislation and regulations, and decide how the Integrity Policy applies to their individual refuge.

Given the difficulties inherent in defining biological integrity and applying the concept to refuge management, it is important to evaluate its effectiveness by analyzing how this policy is utilized. The objective of my research is to examine how the concept of biological integrity is applied to refuge management decisions by examining case studies of six refuges within Region 5 of the NWRS, in the northeastern United States. I will discuss how the concept of biological integrity has been applied on individual refuges, including how "historical condition" has been interpreted, how

refuges justify maintaining non-historical conditions, how refuges are fitting the presence of invasive species into their model of historical condition, and how surrounding land-use impacts the process of managing for biological integrity. This discussion will then lead to the development of recommendations to improve the NWR's implementation of the biological integrity concept.

Methods

Survey

I developed a survey on issues concerning biological integrity with constructive input from staff at Iroquois National Wildlife Refuge and the College of Brockport (Appendix 1). Questions were designed to gather information on current management perspectives related to biological integrity at target refuges, including those enhancing biological integrity, factors affecting biological integrity, and the potential for reverting to historical conditions. Surveys were distributed to staff at all the refuges that were included as case studies. The refuge manager or wildlife biologist was the intended recipient of the survey.

Site Visits

In conjunction with the survey questionnaire, I conducted site visits at six refuges in the National Wildlife Refuge System Region 5, including Erie (August 2011), Montezuma (September 2011), Iroquois (May 2011), Canaan (July 2012), Missisquoi (July 2012), and Rachel Carson (July 2012). Site visits included a comprehensive tour of the refuge led by either the wildlife biologist or the refuge manager. Interviews were conducted during each site visit with questions aimed at determining current managerial practices on the refuge, opportunities for future improvements, examples of how the perceived principles of biological integrity were currently being implemented, and how the policy could be improved. Discussion revolved around current management practices, future projects, and the state of the existing CCP.

Analysis

My thesis incorporates a qualitative analysis of current refuge management practices as they apply to the concept of biological integrity. Observations from site visits, data from survey answers, information from each refuge's CCP, and an extensive literature review, helped to formulate a picture of how the NWRS incorporates biological integrity into management decisions and actions. I have extracted "best practices" from this case study analysis, and I recommend alternative suggestions for implementing the concept of biological integrity into useful management strategies.

Study Areas

The National Wildlife Refuges that were included as case studies are all located within the System's Region 5 (Figure 1). This region encompasses the northeastern United States.

Iroquois National Wildlife Refuge (NWR) is located in upstate New York between Buffalo and Rochester. It contains some highly managed habitats, including grassland and impounded wetlands. Erie NWR, located in Guys Mills, PA, is similarly managed. Montezuma NWR is another refuge that contains a similar mix of managed habitats, but it is situated further east, between Rochester and Syracuse, NY. Continuing to move geographically east, Missisquoi NWR is on the eastern shore of Lake Champlain, in Franklin County, Vermont. Located on the Missisquoi River Delta, this refuge contains primarily riverine wetland habitats. The Rachel Carson NWR contains mostly saltwater marsh habitats at various locations along the coastline of Maine. Finally, Canaan Valley, located in West Virginia, is the southernmost refuge that I studied. Canaan Valley contains primarily upland forests and forested wetlands. All six refuges compose a diverse sampling of Region 5 National Wildlife Refuges, which adequately reflects the challenges and successes of applying biological integrity within a variety of habitat types and landscapes.

Refuge Descriptions and Analysis

Iroquois National Wildlife Refuge

Location, history, and mission

Iroquois National Wildlife Refuge is situated between the western New York cities of Buffalo and Rochester, in Basom, NY. Referred to by locals as the “Alabama Swamps,” it is a 10,828 acre (4382 ha) tract of land that once was part of the historic Oak Orchard Swamp (Iroquois NWR Staff, 2011). This area historically contained oak forest and swamplands, which were populated by many wildlife species (Iroquois NWR Staff, 2011). Attracted by the area’s rich resources, Native Americans were the first to manipulate the land through drainage and forest clearing (Iroquois NWR Staff, 2011). European settlement followed the American Revolutionary War, enabled by the transportation provided by the natural network of rivers and the Erie Canal, and enticed by the rich hardwood forests that supported a logging industry (Iroquois NWR Staff, 2011). Development of logging and agriculture required development of artificial drainage for swamp areas. Eventually noticeable declines in wildlife led to calls for protection of the swampland. Consequently, Iroquois National Wildlife Refuge was formally established in 1958, under the Migratory Bird Conservation Act, “...for use as an inviolate sanctuary, or any other management purposes, for migratory birds” (Iroquois NWR Staff, 2011).

Important habitats and management issues

To fulfill its founding purpose, Iroquois Wildlife National Refuge has employed a wide range of management techniques to provide productive habitats for migratory birds. Combinations of dikes and water-control structures form 19 impoundments, which support the refuge’s goal of providing high quality wetlands for migrating waterfowl (Iroquois NWR Staff, 2011). To attract birds using the Atlantic Flyway, a major north/south route for migrants traveling between wintering ground and spring nesting sites, refuge impoundments are flooded to coincide with the timing of migration (Iroquois NWR Staff, 2011). Through artificial means, manipulated water levels attempt to mimic natural hydroperiods, with strategically timed drawdown periods to allow for vegetative growth. The result is

an available, high-energy food source for migrating waterfowl and open water habitat to support feeding and nesting requirements.

While dikes and open water pools require much of the refuge's management focus due to their use by migratory waterfowl, there are other important habitats and ecosystems within the refuge (Figure 2). The New York Natural Heritage Program identified deep emergent marsh, hemlock-northern hardwood forest, and beech-maple mesic forest as three ecologically significant communities within Iroquois Wildlife Refuge (Iroquois NWR Staff, 2011). With designation from the Heritage Program, these select ecosystems are primary examples of natural, indigenous ecosystems, and therefore prime areas in which to cultivate biological integrity.

While deep emergent marsh has Heritage Program designation and occurs naturally in the area, the majority of these areas occur at Iroquois because of the use of impoundments. Despite how the wetlands were created, emergent marsh is a dominant ecosystem at Iroquois NWR. As palustrine systems, Iroquois NWR wetlands have hydric soils, obligate and/or facultative wetland vegetation, and permanent or seasonal flooding (Reschke, 1990). Vegetation is dictated by water depth but can include reed canary grass (*Phalaris arundinacea*), and bulrush (*Scirpus cyperinus*), as well as emergent aquatics such as cattails (*Typha latifolia* and *T. angustifolia*), arrowleaf (*Peltandra virginica*), and pond lily (*Nuphar luteum* and *Nymphaea odorata*) (Reschke, 1990). Areas experiencing disturbance contain invasive, weedy exotics such as purple loosestrife (*Lythrum salicaria*) and common reed (*Phragmites australis*). While impounded wetlands make up 4,000 acres (1620 ha) of refuge habitat, natural (not impounded) marsh occurs along Oak Orchard Creek east of Sour Springs Road (Iroquois NWR Staff, 2011). Here, the only impediments to hydrology are occasional beaver dams and the constrictions resulting from Sour Springs Road (Iroquois NWR Staff, 2011). The Iroquois CCP lists emergent marsh as a high priority habitat because it benefits several wildlife species that are characterized as resources of concern, including the American bittern (*Botaurus lentiginosus*), least bittern (*Ixobrychus exilis*), black tern (*Chlidonias niger*), pied-billed grebe (*Podilymbus podiceps*), Virginia rail (*Rallus limicola*), American black duck (*Anas rubripes*), blue-winged teal

(*Anas carolinensis*), Northern pintail (*Anas acuta*), Atlantic-Southern James Bay Canada goose (*Branta canadensis*), least sandpiper (*Calidris minutilla*), pectoral sandpiper (*Calidris melanotos*), semipalmated sandpiper (*Calidris pusilla*), Wilson's snipe (*Gallinago delicata*), and bald eagle (*Haliaeetus leucocephalus*) (Iroquois NWR Staff, 2011).

Hemlock-northern hardwood forest is another ecologically significant habitat, which occurs in moist, well-drained fringes around swamps (Reschke, 1990). It is a widely distributed community characterized by the co-dominant hemlock species, with at least one of the following tree species also occurring: American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), black cherry (*Prunus serotina*), white pine (*Pinus strobus*), yellow birch (*Betula alleghaniensis*), black birch (*Betula lenta*), red oak (*Quercus rubra*) and basswood (*Tilia americana*) (Reschke, 1990). Dense canopy cover combined with sparse groundcover foster populations of wild turkey (*Meleagris gallopavo*) and pileated woodpecker (*Dryocopus pileatus*) (Reschke, 1990). A prime example of Hemlock-northern hardwood forest is preserved in the Milford Posson Resource Natural Area (RNA), which contains 15 acres (6 ha) of old growth northern hardwoods (Iroquois NWR Staff, 2011). RNA's are established to fulfill three objectives: "first, to participate in the national effort to preserve adequate examples of all major ecosystem types or other outstanding physical or biological phenomena; second, to provide research and educational opportunities for scientists and others in the observation, study, and monitoring of the environment; and third, to contribute to the national effort to preserve a full range of genetic and behavioral diversity for native plants and animals, including endangered or threatened species" (Missisquoi NWR Staff, 2007). Natural processes operate uninterrupted in these RNAs, as they are exemplary representations of the array of North American ecosystems (USFWS, 2012). Wood duck (*Aix sponsa*) and cerulean warbler (*Dendroica cerulean*) are designated resources of concern that utilize forested wetland habitats of the refuge (Iroquois NWR Staff, 2011).

Finally, beech-maple mesic forest is the third ecologically significant community at Iroquois NWR, as identified by the New York Natural Heritage Program (Iroquois NWR Staff, 2011). It is

characterized by well-drained and acidic soils, which are populated by sugar maple and American beech, the codominant tree species (Reschke, 1990). American redstart (*Setophaga ruticilla*), red-eyed vireo (*Vireo olivaceus*), and red-bellied woodpecker (*Melanerpes carolinus*) are bird species common to the beech-maple mesic forest (Reschke, 1990). The Iroquois CCP lists wood thrush (*Hylocichla mustelina*), black-billed cuckoo (*Coccyzus erythrophthalmus*), cerulean warbler, and American woodcock (*Scolopax minor*) as resources of concern that utilize upland forest habitats (Iroquois NWR Staff, 2011).

Additional important habitats that are actively managed at Iroquois NWR include grasslands and early successional shrublands (Iroquois NWR Staff, 2011). The grassland habitat at Iroquois NWR contains managed warm season grasses such as switchgrass (*Panicum virgatum*), indiagrass (*Sorghastrum nutans*), and big bluestem (*Andropogon gerardii*), as well as a mix of cool season grasses such as orchard-grass (*Dactylis glomerata*), timothy (*Phleum pratense*), smooth brome (*Bromus inermis*), and redtop (*Agrostis gigantea*), along with forbs such as goldenrod (*Solidago* spp.), milkweed (*Asclepias* spp.), and bird's-foot trefoil (*Lotus corniculatus*) (Iroquois NWR Staff, 2011). Many of these species, including smooth brome, timothy, orchard grass, and redtop, are non-native species introduced to North America to provide forage for livestock; however, they currently may provide quality habitat for obligate grassland breeding birds, which are declining in the Northeast (Norment, 2002). Grassland bird species such as the sedge wren (*Cistothorus platensis*), bobolink (*Dolichonyx oryzivorus*), eastern meadowlark (*Sturnella magna*), savannah sparrow (*Passerculus sandwichensis*), and grasshopper sparrow (*Ammodramus savannarum*) utilize the managed grassland habitat (Norment *et al.*, 1999 and Iroquois NWR Staff, 2011). Data from the Breeding Bird Survey has shown that grassland breeding species like the eastern meadowlark, bobolink, and grasshopper sparrow are declining throughout the eastern United States (Figure 3; Sauer *et al.*, 2012). Therefore, to help manage for these types of species, protecting and maintaining habitat currently utilized by obligate grassland breeding birds would need to be prioritized (Sauer *et al.*, 2012). Grassland areas

require a large resource investment, as prescribed burns and periodic mowing are required to prevent encroachment by woody species and maintain early succession habitat (Iroquois NWR Staff, 2011).

Like grassland habitats, shrubland areas also require management intervention to maintain the early succession stages. Much of the shrubland is succeeding to forested habitats, requiring the use of chemical spraying and mechanical removal to maintain the early successional habitat (Iroquois NWR Staff, 2011). As a result, these areas are under scrutiny by refuge staff to determine which ones will be better utilized as forest, and those that should be maintained as shrubland (Iroquois NWR Staff, 2011). Common shrubland plants found at Iroquois NWR include native species such as dogwoods (*Cornus* spp.) and viburnums (*Viburnum* spp.), and exotics such as honeysuckle (*Lonicera tatarica*), buckthorn (*Rhamnus cathartica*), Russian olive (*Elaeagnus angustifolia*), and multiflora rose (*Rosa multiflora*). Common shrubland birds include the song sparrow (*Melospiza melodia*), yellow warbler (*Setophaga petechia*), gray catbird (*Dumetella carolinensis*), eastern towhee (*Pipilo erythrophthalmus*), and common yellowthroat (*Geothlypis trichas*) (Klees 2008).

While it is important to inventory the existing habitat and species composition on the refuge, it is also important to note the potential haven these areas could provide for state and/or federally threatened or endangered species. Federally listed threatened or endangered species do not currently exist on the refuge (Iroquois NWR Staff, 2011). However, bog turtles (*Glyptemys muhlenbergii*), Hine's emerald dragonfly (*Somatochlora hineana*), and the eastern massasauga rattlesnakes (*Sistrurus catenatus catenatus*) were previously noted on the refuge and have the possibility to be supported again based on the refuge's current habitat compositions (Iroquois NWR Staff, 2011). Bald eagles, recently delisted from the federal threatened and endangered species list, remain a species of concern at Iroquois. In addition, there are several New York State listed endangered or threatened species that occur on the refuge, including the short-eared owl (*Asio flammeus*), northern harrier (*Circus cyaneus*), black tern, Henslow's sparrow (*Ammodramus henslowii*), sedge wren, Golden Eagle (*Aquila chrysaetos*), and peregrine falcon (*Falco peregrines*), (Iroquois NWR Staff, 2011).

For the refuge to offer a safe haven to such a variety of important species, it must deal with many factors that may affect management actions. These challenges include surrounding/historical land-use, climate change, and invasive species. Prior to European settlement, the refuge area contained thousands of acres of continuous wetland habitat (emergent marsh and forested wetland), which continuously flooded (Iroquois NWR Staff, 2011). Agricultural development altered the hydrology of the area so that the land was inundated in the spring, but was usually dry in fall (Iroquois NWR Staff, 2011). This change in hydrology prompted the refuge's need to rely on impoundments as a tool to manipulate water levels for optimal waterfowl habitat (Iroquois NWR Staff, 2011). In addition, runoff, particularly animal waste, negatively affects water quality by causing increases in algal growth (Iroquois NWR Staff, 2011). Climate change is a recently recognized threat to the implementation of biological integrity. In the face of this uncertainty, the refuge can only manage for healthy, connected, genetically diverse populations as a way to mitigate the projected temperature and precipitation changes (Iroquois NWR Staff, 2011). Finally, the presence of exotic species on the refuge is a threat to the biological integrity, as invasive species typically out-compete native species for important resources. Exotic invasive species present at Iroquois include multiflora rose, garlic mustard (*Alliaria petiolata*), buckthorn, purple loosestrife (*Lythrum salicaria*), Eurasian milfoil (*Myriophyllum spicatum*), European starling (*Sturnus vulgaris*), and mute swans (*Cygnus olor*). The common carp (*Cyprinus carpio*) is one of the most destructive invasive species, as it destroys wetland vegetation and causes poor water quality by increasing the turbidity levels (Iroquois NWR Staff, 2011).

Comprehensive Conservation Plan and Biological Integrity

When considered in the context of biological integrity, those habitats within Iroquois NWR that possess special classifications by the New York Natural Heritage Program, or those designated as NRA's, assume particular importance. Areas that are not of the same caliber, in an ecological sense, may lack certain aspects of biological integrity, including essential ecosystem functions or characteristics, and may be possible targets for improvement projects. Finally, areas that are non-historical, and contain non-"natural" habitats, like grasslands and impounded wetlands, appear to violate the biological integrity policy. However, these same areas fill an important management

function at a landscape level because they support “at risk” species or ecosystems. In the Northeast, maintaining and creating grasslands are often justified using this very logic, as these areas are composed of primarily exotic species but are vital to protecting “at risk” grassland bird species (Norment, 2002).

Iroquois NWR has a variety of habitat types, and managing several of them involves possible conflicts with the concept of biological integrity, as defined by the Integrity Policy of the USFWS. Therefore, analyzing the goals that pertain to biological integrity can provide insight on how the refuge implements, or intends to implement, biological integrity in its management decisions. Goals in the Iroquois NWR CCP that incorporate the concept of biological integrity include:

- **Goal 1:** Provide high quality freshwater wetland migration stopover and breeding habitat for waterfowl, marsh birds, shorebirds, and bald eagles in refuge impoundments through water-level control.
- **Goal 2:** Maintain the environmental health and integrity of Oak Orchard Creek and associated bottomland floodplain forests and wetlands as a natural, free-flowing habitat with a diverse assemblage of native plants and animals.
- **Goal 3:** Provide a diverse mix of grassland, shrub land, and forested upland habitats arranged to reduce fragmentation and edge effects, and enhance habitat quality for priority species of conservation concern.

Given the USFWS’s responsibility for ensuring that biological integrity is maintained, it is surprising that goal 2 provides the only mention of the key term, “integrity.” Semantics aside, Goal 2 focuses on maintaining the integrity of the Oak Orchard Creek Marsh National Natural Landmark as a free-flowing habitat (Iroquois NWR Staff, 2011) Listing “free-flowing” in the statement of the goal is consistent with biological integrity as defined by the USFWS, as it includes maintaining natural hydrology and allowing other ecological processes to occur unobstructed. The CCP describes this area as a pristine stretch along a meandering creek, with low, flat terrain and populated by broad-

leaved cattails, buttonbush (*Cephalanthus occidentalis*), water willow (*Justicia*), swamp rose (*Rosa palustris*), purple nightshade (*Solanum xanti*), and forested swamp areas dominated by silver maple (*Acer saccharinum*), green ash (*Fraxinus pennsylvanica*), and swamp white oak (*Quercus bicolor*) (Iroquois NWR Staff, 2011). To achieve this objective, the refuge plans to “maintain and restore where necessary, the water quality, natural flow regimes, and biological integrity of Oak Orchard Creek in the eastern portion of the refuge, relying on natural processes when possible” (Iroquois NWR Staff, 2011). “Relying on natural process” encompasses a foundational principle of the biological integrity policy. Although not unaltered, the Oak Orchard Creek provides a significant riparian habitat for a variety of fish and wildlife species at minimal cost due to the refuge’s decision to allow natural processes to dictate hydrological and ecological sequencing (Iroquois NWR Staff, 2011). This riparian habitat is one in which biological integrity is clearly a good guiding principle. While there are currently few management actions directed at facilitating natural hydrologic shifts and the cascading environmental processes that follow, some management action may be required to mitigate the negative impacts from nonpoint pollution sources. A problem is that these sources of nonpoint pollution lie beyond the refuge boundaries and consequently outside refuge management control.

At first glance, Goal 1 appears to contradict the USFWS’s definition of biological integrity, as it mentions providing quality wetland habitat in impoundments (which contradicts the Integrity Policy’s emphasis on historical conditions) through water-control (which contradicts the Integrity Policy’s emphasis on natural processes). Given their presence on the refuge and the substantial wetland habitat they provide, it would not be feasible to remove the impoundments because the natural hydrology is no longer there to support the desired habitat. Instead, the refuge objectives outlined to achieve goal 1 describe actions necessary for improving the biological integrity (as much as possible within the confines of a manmade system) so that the vegetation takes on an increasingly historical composition. For example, Oneida Pool is currently an impounded wetland habitat consisting of large areas of open water and other areas containing dense monotypic stands of cattail. Neither of these qualities is very beneficial to priority migratory bird species, nor does its description generate thoughts of biological integrity (Iroquois NWR Staff, 2011). Consequently, subdividing the pool will create

smaller, more manageable impoundments and facilitate the desirable wetland conditions (Iroquois NWR Staff, 2011). While increasing the amount of manipulation and control again seems to defy the biological integrity concept, subdividing Oneida Pool is actually a reflection of a management strategy that applies biological integrity principles. Restoring natural hydrology is almost impossible because the fundamental ecological processes are constrained by human development in the surrounding landscape, so it is up to refuge management to apply actions that mimic natural ecological processes.

The management actions described above also may promote biological integrity at the landscape or regional level. The foundation for Goal 1 is rooted in the goals and objectives of the Atlantic Coast Joint Venture (ACJV). This organization brings together public, private, and conservation groups focused on conserving native bird species in the Atlantic Flyway region (Atlantic Coast Joint Venture, 2009). The ACJV created several focus areas, which are “discrete and distinguishable habitats or habitat complexes that are regionally important for one or more priority species during one or more life history stages” (Iroquois NWR Staff, 2011). Rehabilitation of Mohawk and Oneida Pools is a high priority project within the Tonawanda-Iroquois-Oak Orchard Focus Area, to provide improved wetland habitat on the Iroquois Refuge (Iroquois NWR Staff, 2011). While promoting a highly managed, impounded wetland may seem counterproductive to the concept of biological integrity, this habitat is necessary to support natural, historical migration patterns along the Atlantic Flyway. Therefore, management activities in Iroquois NWR help ensure the availability of stopover habitat during essential time periods and ultimately expand the benefits of refuge’s wetland habitat from a limited local scale to larger landscape or regional levels (Iroquois NWR Staff, 2011).

Goal 3 fulfills biological integrity in a similar fashion by supporting the conservation of grassland habitat and its species at the landscape or regional scale. The Northeast region is important for grassland birds, given their continental decline and habitat loss in the Midwest, the core of their range (Norment, 2002). Iroquois NWR has been identified as an important area in Bird Conservation Region (BCR) 13, lies within a NY state Grassland bird focus area, and is important for the conservation of bobolink, Henslow’s sparrow, sedge wren, and northern harrier (Iroquois NWR Staff,

2011). Roughly, half of the upland habitat on Iroquois is maintained as early successional habitat using mowing or burning in grasslands, and mechanical or chemical treatments in shrublands (Iroquois NWR Staff, 2011). In addition, grasslands could also serve as prime habitat for reintroduction of the Karner blue butterfly (*Lycaeides melissa samuelis*), a federally endangered species that was once common in New York but does not currently reside on Iroquois NWR (Iroquois NWR Staff, 2011).

My analysis of Iroquois NWR CCP goals suggests that management and maintenance of upland grasslands, shrublands, and impounded wetlands (Goals 3 and 1) partially conflict with the concept of biological integrity as defined by the USFWS because there is not a direct management correlation to biological integrity for these habitats. For example, these habitats require intensive management to maintain their desired characteristics and ecological functions. Grasslands require mowing and burning to keep woody growth from invading, while impoundments require careful control over water to generate the desired mix of vegetation and open water (Iroquois NWR Staff, 2011). Strict interpretation of the Integrity Policy's definition of biological integrity would fault both goals for encouraging non-historical, unnatural habitats. However, current refuge personnel describe the policy as helping "drive management decisions, without having extremely rigid requirements (Personal communication, refuge staff, Iroquois National Wildlife Refuge)."

In regards to survey questions concerning biological integrity, refuge staff felt that altered hydrology, contamination by surrounding land-use, and invasive species make it difficult to achieve historical conditions (Personal communication, refuge staff, Iroquois National Wildlife Refuge). It is important to recognize that regional and/or continental management goals, such as those of the Atlantic Coast Joint Venture, are more consistent with the biological integrity approach than the goal of restoring historical conditions (Personal communication, refuge staff, Iroquois National Wildlife Refuge). Ultimately, by looking at the refuge system as a whole, both the wetland impoundments and early successional habitats (grasslands and shrublands) may benefit landscape and regional management objectives, and thus are at least partly consistent with the concept of biological integrity. In addition, the refuge can attempt to collaborate with its neighbors to improve conditions that affect

Iroquois NWR, but ultimately, it has little or no control of the sources of contamination or hydrological alterations that originate outside of the refuge's boundaries (Personal communication, refuge staff, Iroquois National Wildlife Refuge).

The management staff at Iroquois NWR considers the alternatives and limitations of potential actions when making management decisions, ultimately choosing the path that best benefits the natural resources (Personal communication, refuge staff, Iroquois National Wildlife Refuge). Although management actions should always strive for biological integrity, it sometimes is not achievable due to surrounding land-use, invasive species, climate change, and specific production objectives (Personal communication, refuge staff, Iroquois National Wildlife Refuge). Although some may argue that biological integrity is a subjective, ineffective policy, it is important to note that the Integrity Policy holds the refuge to a higher standard of accountability by demanding stronger justification and rationale to accompany management actions (Personal communication, refuge staff, Iroquois National Wildlife Refuge).

Missisquoi National Wildlife Refuge

Location, History, and Mission

The 6,592 acre (2642 ha) Missisquoi National Wildlife Refuge (NWR) is located on the eastern shore of Lake Champlain, in Franklin County, Vermont (Missisquoi NWR Staff, 2007). The refuge sits at the mouth of the Missisquoi River, which flows through the refuge and into Lake Champlain, and includes most of the river delta (Missisquoi NWR Staff, 2007; Figure 4). The delta's physical structure consists of a small number of distributaries, along with a narrow strip of delta straddling the river, which is located upstream away from the point of branching, much the same as the Mississippi River Delta (Missisquoi NWR Staff, 2007). Despite the construction of hydrology-changing dams and the resulting alteration in flow and sedimentation rates, the delta is continuing to expand northward (Missisquoi NWR Staff, 2007). The river delta is the largest wetland complex in the Lake Champlain Basin, and as a result, 90 percent of the refuge is wetland or open water habitat (Missisquoi NWR Staff, 2007).

The last continental glacial event peaked about 18,000 years ago and greatly affected the geological characteristics of landscape in and around Missisquoi National Wildlife Refuge. As the ice sheet began receding, melt water went through a gradual transition from a saltwater to a brackish and then freshwater environment, resulting in thick clay deposits mixed with sand deposits, which produced a very productive soil foundation (Missisquoi NWR Staff, 2007). The river deltas and sand-gravel margins facilitated a unique mosaic of plant communities, found in few other places in New England (Missisquoi CCP, 2007). Historically, silver maple floodplain forest, red maple black-ash swamp, mesic oak hardwood forest, and sugar maple-beech-birch forest would have dominated the region, with pitch pine-scrub oak woodlands, emergent marsh, and large river systems spread throughout (Missisquoi, 2007).

Little of the historical landscape remains, due mostly to anthropogenic impacts. The Missisquoi region has a long history of human activity, with exploration of the area beginning as early as 7500 BC (Missisquoi NWR Staff, 2007). Minimal environmental impacts stemmed from the early peoples' subsistence living, which included hunting and gathering, during the Early, Middle, and Late Archaic Periods. The Late Woodland Period (1000-1650 AD) saw human-caused environmental disturbance expand with corn, bean, and squash horticulture (Missisquoi NWR Staff, 2007). Human disturbance has subsequently increased exponentially since European settlement during the late 1600s (Missisquoi NWR Staff, 2007).

It was not until 1943 that Missisquoi National Wildlife Refuge was founded under the Migratory Bird Act as "an inviolate sanctuary. . . . for migratory birds" (Missisquoi NWR Staff, 2007). The refuge hosts over 200 different species of birds, with fall populations of waterfowl topping 20,000 (Missisquoi NWR Staff, 2007). This waterfowl focus helped drive management decisions. For instance, reed canary grass and birdsfoot trefoil were planted to create grassland habitats and increase nesting habitat for blue-winged teal (*Anas discors*) and mallard ducks (*Anas platyrhynchos*) (Missisquoi NWR Staff, 2007). The refuge mission statement details the refuge's "role in maintaining the ecological integrity of the river delta, providing breeding, staging, and migration habitat for

thousands of waterfowl and other fish and wildlife.” Accomplishing this goal ultimately “relies on continued understanding of the past and present biological processes and human influences that created and maintain this large wetland complex (Missisquoi NWR Staff, 2007).”

Important habitats and management issues

Many of the ecosystems observed on the refuge result from the area’s integral relationship to the Missisquoi River, as 90% of the refuge contains wetland or open water habitat (Missisquoi NWR Staff, 2007). As the Missisquoi River flows through the refuge, it passes through high quality silver maple floodplain forest (Missisquoi NWR Staff, 2007). This ecosystem contains a mix of silver maple, eastern cottonwood (*Populus deltoides*), swamp white oak, green ash, American elm (*Ulmus americana*), and an understory of sensitive fern (*Onoclea sensibilis*). Covering more than 1,000 acres (405 ha), the refuge’s silver maple floodplain forest is the largest continuous example of this ecosystem type in Vermont (Missisquoi NWR Staff, 2007). Spring flooding of the Missisquoi River inundates the forest and leaves behind seeds and fertile soil when the water recedes (Missisquoi NWR Staff, 2007). The rich vegetation supports a variety of bird species at different stages in their life cycles. Migratory songbirds such as wood thrush, black-billed cuckoo, and Baltimore oriole (*Icterus galbula*) utilize the area in spring and fall for nesting, foraging, and migratory stopover (Missisquoi NWR Staff, 2007). Cavity nesters like wood duck and common goldeneye (*Bucephala clangula*) nest within hollow floodplain trees (Missisquoi NWR Staff, 2007). The CCP document categorizes this habitat type as a high priority, based on its connections to the Integrity Policy and the large number of impacted trust species (Missisquoi NWR Staff, 2007). The biggest threats to maintaining this area’s integrity include water contamination and invasive species (Missisquoi NWR Staff, 2007).

In addition, various emergent marsh habitats comprise a significant portion of Missisquoi’s total area. These areas are found on organic muck soils and experience seasonal flooding each spring, ultimately being covered by 5 to 12 inches (12.7 to 30.5 cm) of standing water (Missisquoi NWR Staff, 2007). A total of 702 acres (284 ha) of sedge meadow habitat is located along the edge of the floodplain and the buttonbush colonies, and is dominated by tussock sedge (*Carex stricta*), giant bur

reed (*Sparganium eurycarpum*), broad-leaved cattail, and wild rice (*Zizania palustris*) (Missisquoi NWR Staff, 2007). Wild rice meadow covers 664 acres (269 ha) of Missisquoi's total area and contains the indicator species wild rice and giant bur reed (Missisquoi NWR Staff, 2007). Buttonbush and wild rice are present in the buttonbush swamps, which account for 614 acres (248 ha) of the refuge's total area. Buttonbush swamp habitat was identified as a "significant natural community" by the Vermont Nongame and Natural Heritage Program (Missisquoi NWR Staff, 2007). Combined, the emergent marsh habitats of sedge meadow, buttonbush swamp, and wild rice meadow, cover 1,980 acres (801 ha) of the refuge and consequently make up a significant portion of the refuge's landscape.

In addition to harboring multiple emergent wetland habitats, Missisquoi National Wildlife Refuge contains two Resource Natural Areas (RNA), located in Maquam Bog and Shad Island. Maquam Bog is an 890 acre (360 ha) sphagnum bog, which hosts a large array of diverse plant species including rhodora (*Rhododendron canadense*), high bush blueberry (*Vaccinium corymbosum*), sedges, and pitch pine (*Pinus rigida*) (Missisquoi NWR Staff, 2007). It contains three community types: pitch pine woodland bog, dwarf shrub bog, and mixed sedge shrub bog (Missisquoi NWR Staff, 2007). Each contains a unique blend of flora and fauna, most of which are uncommon in the state of Vermont (Missisquoi NWR Staff, 2007). Importantly, this ecosystem also supports a large population of the state-listed threatened plant species, Virginia chain fern (*Woodwardia virginica*) (Missisquoi NWR Staff, 2007).

The second RNA is located at the northern end of the refuge. Shay Island has escaped many of the detrimental historical land-use practices and, therefore, supports a mix of silver maple, swamp white oak, green, and cottonwoods (Missisquoi NWR Staff, 2007). The most notable feature of this 120 acre (48.6 hectare) plot of land is a great blue heron (*Ardea herodias*) rookery, which is the largest in Vermont (Missisquoi NWR Staff, 2007). This area was recently evaluated (and found unsatisfactory) under criteria to designate it a wilderness area. Although Shay Island is "primarily

affected by the forces of nature;” nearby lands and adjacent waters were not (Missisquoi NWR Staff, 2007).

Missisquoi National Wildlife maintains many natural communities with little direct management action. However, grassland is a habitat type present on the refuge that requires significant resources to maintain. Mixed grasslands account for 3%, or 223 acres (90 ha) of the refuge’s total area, but this small collective area of land requires direct management actions of burning, haying, and mowing to maintain its desirable habitat characteristics (Missisquoi National Wildlife Refuge Staff, 2007). Indicator species include reed canary grass, rice cut grass (*Leersia oryzoides*), and bluejoint grass (*Calamagrostis canadensis*), (Missisquoi NWR Staff, 2007). Some of the areas currently utilized as grassland were floodplain forest located along the Missisquoi River (Missisquoi NWR Staff, 2007). Management focus is now shifting away from perpetuating the intensive management actions required to maintain the grassland habitats and has embraced limiting the scope of those management actions to only those fields proven to benefit grassland birds (Missisquoi NWR Staff, 2007). The CCP lists grassland as a moderate priority habitat type because of the low number of priority species present (Missisquoi NWR Staff, 2007).

Another habitat on the refuge that requires extensive management intervention is impounded wetlands. These areas employ dikes to impound managed areas and allow for control over water levels. This water-management strategy affects approximately 1,250 acres (506 ha) in two water-management units: Goose Bay-Big Marsh Slough and Cranberry Pool (Missisquoi NWR Staff, 2007). Completed by the 1970s, these projects intended to turn low quality wetland habitat into more productive waterfowl habitat (Missisquoi NWR Staff, 2007). Since then, these managed wetland communities have become high priority management targets because they fulfill the refuge purpose for migrating waterfowl, contain a large number of focal species, and have applications under the Integrity Policy (Missisquoi NWR Staff, 2007). The largest factors influencing management success in these

habitat types include invasive species, contamination, siltation, and water quality/quantity (Missisquoi NWR Staff, 2007).

No known federally listed threatened or endangered species currently occur at Missisquoi. However, it is home to several state-listed species, including the Virginia chain fern and few-seeded sedge (*Carex microglochin*), which are state-threatened and occur in Maquam Bog. In addition, there are seven species of state threatened or endangered freshwater mussels present, including the Black Sandshell (*Ligumia recta*), Cylindrical papershell (*Anodontooides ferussacianus*), Fluted-shell (*Lasmigonacostata*), Fragile papershell (*Leptodea fragilis*), Giant floater (*Pyganodon grandis*), Pink heelsplitter (*Potamilus alatus*), and pocketbook (*Lampsilis ventricosa*). Finally, the state endangered lake sturgeon (*Acipenser fulvescens*) is present on the refuge but is not common.

While the refuge supports numerous species of concern, there are also several invasive species that require direct, preventative management action. Phragmites, Eurasian watermilfoil, purple loosestrife, water chestnut (*Trapa natans*), Japanese knotweed, and reed canary grass are common invasive species on the refuge (Missisquoi NWR Staff, 2007). Herbicide applications control most of the invasive species. Although other refuges in Region 5 have found success in controlling purple loosestrife by introducing phytophagous insects (*Gallerucella* sp. beetles and a weevil, *Hylobius transversovittatus*), these insects have not had the same impacts on Missisquoi NWR because the flood regime kills the over-wintering eggs of the *Gallerucella* beetles (Missisquoi NWR Staff, 2007). Plants are not the only exotic threats to Missisquoi NWR. Zebra mussels (*Dreissena polymorpha*) and sea lamprey (*Petromyzon marinus*) are exotic animal species that pose potential threats to the Missisquoi NWR (Missisquoi NWR Staff, 2007).

In addition to invasive species threatening the biological integrity of the refuge, Missisquoi NWR must also attempt to mitigate surrounding land-use impacts. The Pike and Rock rivers are two major tributaries, which empty into Missisquoi Bay after flowing through a mix of privately owned and state owned property. As a result, the bay contains some the highest concentrations of

phosphorous within Lake Champlain (Missisquoi NWR Staff, 2007). These elevated phosphorous levels degrade water quality and increase the occurrences of algal blooms. Ninety percent of the phosphorous comes from nonpoint sources such as runoff from lawns, farms, and urban areas. Point sources for phosphorous include wastewater treatment plants. Additional water quality concerns include the presence of mercury, pesticides, and the spread of invasive species (Missisquoi NWR Staff, 2007). Finally, upstream land-uses like agriculture increase stream bank erosion runoff, resulting in increased sedimentation into sensitive refuge areas like wetlands, fish spawning grounds, and mussel beds (Missisquoi NWR Staff, 2007).

Comprehensive Conservation Plan and Biological Integrity

Numerous mandates, policies, and plans are weighed in refuge management actions. The Missisquoi CCP is one of the few refuge CCP documents that specifically isolates the concept of biological integrity and describes how that concept is being applied directly to management directives as a way to identify priority resources of concern, and develop the habitat goals and objectives at the Missisquoi refuge. The Missisquoi CCP (2007) states that, “given the continually changing environmental conditions and landscape patterns of the past and present (e.g., rapid development, climate change, sea-level rise), relying on natural processes is not always feasible nor always the best management strategy for conserving wildlife resources.” The CCP (2007) goes on to say that, “uncertainty about the future requires that the Refuge manage within a natural range of variability rather than emulating an arbitrary point in time. This maintains mechanisms that allow species, genetic strains, and natural communities to evolve with changing conditions, rather than necessarily trying to maintain stability.” This approach is evident when examining the refuge’s CCP goals that pertain to biological integrity, which include:

- **Goal 1** Maintain the ecological integrity of the Missisquoi River delta to ensure a healthy and diverse river and wetland ecosystem providing a full range of natural processes, community types, and native floral and faunal diversity.

- **Goal 2** Provide diverse upland habitats for Federal trust species including migratory birds and other species of conservation concern in all seasons.

According to refuge personnel, “what is not written is perhaps as important as what is written, as there is no mention of cutting, diking, or otherwise changing the floodplain forest from natural trajectories of succession and hydrologic cycles (Personal communication, refuge staff, Missisquoi National Wildlife Refuge).” This perspective seems to represent a noticeable shift in management thinking, as historical actions favored more direct actions such as impounding wetlands to create desirable waterfowl habitat. “Many refuges will list a strategy to “maintain floodplain forest” or the “shrub swamp community,” essentially meaning that no physical manipulation will be targeted in those communities, allowing natural processes to occur (Personal communication, refuge staff, Missisquoi National Wildlife Refuge).” While “maintain” does not exactly exclude physical manipulation, it does appear to limit intensive, drastic management action that would alter the current state of the habitat. This shift in management philosophy appears to favor the underlying principles of the Integrity Policy.

Goal 1 of Missisquoi’s CCP document captures the essence of the biological integrity concept by emphasizing the role natural processes take in maintaining a valuable riverine system. Functioning hydrology is one of the most important natural processes that occurs within the Missisquoi Delta. There is a seasonal fluctuation in water levels, where flooding occurs in the spring as snow melts, and water levels recede during the hot summer months. It is this “seasonal pattern of flooding that stimulates and maintains the dynamic structure of the delta and its inhabitants (Missisquoi NWR Staff, 2007).” Runoff pollutants affecting water quality and invasive species pose the biggest hindrance to achieving goal 1. While the USFWS has little to no authority to affect runoff pollutants, it is important that the refuge place precedence on the importance of the natural systems and wildlife habitats over competing interests among recreational users (Missisquoi NWR Staff, 2007).

In contrast, Goal 2, as outlined in the Missisquoi CCP document, fails to make a direct connection to biological integrity. The goal emphasizes diversity of upland habitat for focal species but fails to prioritize natural, intact process or habitats. As opposed to Goal 1, this goal appears to be

emphasizing quantity over quality. However, Goal 2 emphasizes habitats that contribute to the diversity on the refuge and support bobolink, eastern meadowlark, and woodcock, which are species of concern.

In addition, refuge personnel recognize that, “policies developed take time to become integrated into the language of the organization, and indeed take time to be fully explored and tested for their strengths, weaknesses, and applicability to each individual refuge (Personal communication, refuge staff, Missisquoi National Wildlife Refuge).” While it may be easier to continue to view refuge management through the lens of a refuge’s founding purpose rather than attempting to implement biological integrity, there has been an observable shift to incorporate regional thinking when making management decisions (Personal communication, refuge staff, Missisquoi National Wildlife Refuge). While there has been a shift in management approach, there fails to be a system which empirically demonstrates the impacts such phylosphical changes have on the managed environments. “Develop(ing) a way to evaluate the success of managing for biological integrity...in a meaningful and cost-effective way (Personal communication, refuge staff, Missisquoi National Wildlife Refuge),” is one of the greatest challenges a refuge faces in implementing the Integrity Policy.

Montezuma Wildlife Refuge

Location, history, and mission

Montezuma National Wildlife Refuge is located between the western New York cities of Syracuse and Rochester. Situated at the north end of Cayuga Lake, it lies within Seneca, Wayne, and Cayuga Counties (Montezuma NWR Staff, 2012). Established in 1938 as “a refuge and breeding ground for migratory birds and other wildlife,” the refuge has expanded to 9,184 acres (3717 ha) (Montezuma NWR Staff, 2012). When combined with surrounding state-owned lands, lands held by private land-owners, and land owned by conservation groups, the Montezuma NWR forms a portion of the Northern Montezuma wetland Complex, which is considered hold global significance due to its role as a staging and breeding area along the Atlantic Flyway (Montezuma NWR Staff, 2012). Lands acquired through the Migratory Bird Conservation Act were intended “for use as an inviolate

sanctuary, or for any other management purpose, for migratory birds” (Montezuma NWR Staff, 2012). The refuge has succeeded in supporting its founding mission by enhancing the natural resources within its boundaries to provide stopover and foraging habitat for large concentrations of migratory birds (Montezuma NWR Staff, 2012).

Glaciations, ecological processes, and human disturbance have influenced both the historical and current conditions on the refuge (Montezuma NWR Staff, 2012). Glaciations contributed oval-shaped hills (drumlins) as well as a series of long narrow lakes that eventually developed into extensive marshes (Montezuma NWR Staff, 2012). The resulting landscape consisted of continuous wetland habitat in lower elevations, while dominant upland forest types consisted of beech-maple-linden and hemlock-beech forests (Marks *et al.*, 1992).

Human disturbance in the Montezuma area began with the Native Americans’ subsistence lifestyle of hunting, harvesting, and building settlements. Increasingly detrimental to the area’s biological integrity, human disturbance continued through the 1900s with the agricultural exploitation of natural muck soils, and construction of both the Erie Canal System and the NYS Thruway (Montezuma NWR Staff, 2012). The result is a wetland complex where water levels are managed by the New York State Canal Cooperation, and where the possibility of restoring abandoned or marginal agricultural lands to high quality wetlands is high (Montezuma NWR Staff, 2012).

Important habitats and management issues

Despite the substantial anthropogenic impacts on the biological integrity of the refuge, Montezuma contains a diverse range of habitats (Figure 5) (Montezuma NWR Staff, 2012). Comprised of rooted herbaceous plants such as cattails (*Typha* spp.), smartweed (*Polygonum* spp.), and phragmites, emergent marsh is the primary habitat on the refuge, covering 46.9% or 4,307 acres (1743 ha) (Montezuma NWR Staff, 2012). Historically, weather was the primary factor influencing these habitats. Wet years resulted in a greater proportion of open water, and drier years yielded more vegetation. This natural variation is currently mimicked using impoundments, which allow refuge staff to control water levels in an effort to reproduce natural hydroperiods (Montezuma NWR Staff,

2012). Important wildlife species found in emergent marsh include American bittern, least bittern, Virginia rail, blue-winged teal, common merganser (*Mergus merganser*), northern pintail, tundra swan (*Cygnus columbianus*), river otter (*Lutra canadensis*), and peregrine falcon (*Falco peregrinus*) (Montezuma CCP 2012). In addition, the American black duck and pied-billed grebe are freshwater emergent wetland focal species, and the black tern and short-eared owl are both state endangered species (Montezuma NWR Staff, 2012). With altered natural hydrology, dikes and impoundments are required to manipulate water levels and maintain the desired habitat (Montezuma NWR Staff, 2012). Consequently, refuge staff need to mitigate dense monotypic cattail stands, maintain water-control structures, control muskrat (*Ondatra zibethicus*) populations, and monitor water inflow from the canal for contamination and undesirable species (Montezuma NWR Staff, 2012). Despite requiring intensive management, emergent marsh habitat is uncommon regionally and provides valuable breeding ground for priority species and foraging ground for migrating waterfowl (Montezuma CCP, 2012).

Ranked second in management priority, the mudflats of Montezuma are another valuable habitat located on the refuge, as they are designated critical inland habitat for shorebird migration (Montezuma NWR Staff, 2012). Like emergent marsh, this habitat requires the careful manipulation of water levels to create an area of mostly open water of less than 2 inches (5 cm) deep and sparse emergent vegetation (Montezuma NWR Staff, 2012). Species found here include the focal species short-billed dowitcher (*Limnodromus griseus*), along with other species of concern such as the green-winged teal, least sandpiper (*Calidris minutilla*), pectoral sandpiper, and Wilson's snipe (Montezuma NWR Staff, 2012).

In addition, a management priority habitat and the second most abundant habitat type, covering 18 % of the refuge, is forested wetland (Montezuma NWR Staff, 2012). These areas are dominated by red maple, silver maple green ash, and swamp white oak (Montezuma NWR Staff, 2012). These areas support a native forest community, and important wildlife species include Cooper's hawk (*Axzipiter cooperii*), red-headed woodpecker (*Melanerpes erythrocephalus*), scarlet tanager (*Piranga olivacea*), willow flycatcher (*Empidonax taillii*), silver-haired bat (*Lasionycteris noctivagans*), blue-spotted salamander (*Ambystoma laterale*), and the wood turtle (*Clemmys insculpta*)

(Montezuma NWR Staff, 2012). The cerulean warbler and wood thrush are designated focal species for forested habitat (Montezuma NWR Staff, 2012). Riparian corridors provide connectivity between habitats, as well as providing summer habitat for bats (Montezuma NWR Staff, 2012). Refuge management must mitigate water-control issues, altered hydrology, invasive species, and over browsing by white-tailed deer, all of which place pressure on integrity of forested wetland habitat (Montezuma NWR Staff, 2012).

While the priority habitats previously mentioned require directed management activities, there are several exemplary, intact ecosystem types, identified as Research Natural Areas (RNAs) within Montezuma NWR: Beech-Maple Knoll and Swamp Woods (Montezuma NWR Staff, 2012). The Beech-Maple Knoll is “a prime example of a mature, northern hardwood beech-maple forest cover type,” (Montezuma NWR Staff, 2012). The beech-maple forest community type exists throughout New York on moist, well-drained soils, where sugar maple and American beech co-dominate (Reschke, 1990). Swamp Woods is a remaining example of woodland swamp, which would have been widespread in the area prior to extensive draining of the Montezuma Marsh complex (Montezuma NWR Staff, 2012). Black ash (*Fraxinus nigra*), American elm, red maple, and white oak (*Quercus alba*) are dominant species thriving on the indigenous muck soils (Montezuma NWR Staff, 2012). Swamp Woods is a part of the Montezuma Marshes National Natural Landmark (NNL), a designation given to the area because of its significance in representing the area’s natural history (Montezuma NWR Staff, 2012). Other characteristics of the area original condition include vast expanses of cattail marsh broken by old river channels and ponds (Montezuma NWR Staff, 2012). However, the New York State Thruway (I-90) forms the northern border to this NNL and threatens its integrity by introducing fragmentation and pollution (Montezuma NWR Staff, 2012).

Other issues directly affecting the ability of the Montezuma NWR to fulfill its management obligation to promote biological integrity successfully include surrounding land-use and invasive species. Detrimental surrounding land-use activities can fragment the landscape, introduce disturbance, and consequently establish point sources for invasive species. Surrounding land-use, mainly consequences from intensive agriculture practices, have dramatically altered the vegetative

landscape so that it is difficult to detect the historical state (Montezuma NWR Staff, 2012). Another major surrounding land-use negatively affecting the refuge is the proximity of the New York State Thruway, which bisects the refuge. In addition to resulting in direct mortality of animals attempting to cross the road, populations also become isolated as individuals are deterred from crossing roads. Montezuma's CCP states, "we will consider constructing wildlife underpasses or mitigate the impacts of roads in other ways feasible (Montezuma NWR Staff, 2012)." In addition, canals and levees in the surrounding areas have altered the natural hydrology on the refuge. As a result, the refuge will need to study ground and surface hydrology to understand water quantity and availability to the refuge and consequently adjust current management plans (Montezuma NWR Staff, 2012). Finally, exotic and/or invasive species are a threat to all habitat types on the refuge. Montezuma's management action plan for addressing threats from invasive species includes preventing invasion, eradicating small infestations, and finally controlling or containing large infestations (Montezuma NWR Staff, 2012). These actions are required to protect the large, intact native habitats. These problems stemming from surrounding land-use and exotic species need mitigation for successful implementation of biological integrity.

Comprehensive Conservation Plan and Biological Integrity

When examining the implementation the Integrity Policy, it is important to review the CCP document to see how the policy drives management action. Cited goals in the Montezuma NWR CCP concerning aspects of biological integrity include:

- **Goal 1:** Provide, enhance, and restore where possible, freshwater emergent marsh, open water wetland, and mudflat habitats to benefit native wildlife and plant communities, particularly migrating waterfowl, shorebirds, and breeding marsh birds.
- **Goal 2:** Restore and maintain forested wetlands, riparian forests along the Seneca and Clyde Rivers, and upland forests to benefit priority native species, including songbirds, bats, and important plant communities.

- **Goal 3:** Manage grassland and shrubland habitats primarily to benefit bird species of conservation concern.

Although not mentioned directly, each goal reflects how Montezuma NWR applies biological integrity to its management actions. While goals 1 and 3 seem to conflict with the basic principle defining biological integrity (that of historical conditions), goal 2 allows for an easy, direct application of the Integrity Policy's definition of biological integrity. Goal 2, targets areas with RNA designation, along with other specific habitat types that were present historically. As a result, these areas align with the biological integrity definition of containing "biotic composition, structure, and functioning at genetic, organism, and community levels comparable with historic condition, including the natural biological processes that shape genomes, organisms, and communities (USFWS, 2001)." However, white-tailed deer populations are exceeding the current carrying capacity due to the historical eradication of their natural predators and habitat change. As a result, management action is required to maintain an appropriate deer population to reduce the negative impacts to forest regeneration resulting from deer overpopulation and over-browsing (Montezuma NWR Staff, 2012). Other management actions promoting biological integrity in this area include allowing natural tree falls to create a multi-layer forest structure, as well as promoting reforestation of artificial forest opening to create more forest interior (Montezuma NWR Staff, 2012).

Goals 1 and 3 of Montezuma's CCP do not directly align with the FWS definition of biological integrity and consequently result in a more complex implementation strategy because, although wetland impoundments and grasslands were not part of the historical condition, they provide substantial habitat to numerous species of concern. In the case of impounded wetlands, the refuge was forced to construct impoundments as a direct result of the canal system forcing an artificially low water table, along with past NWR policy. With the inability to restore natural hydrology, it is almost impossible for these habitats to return to an "as comparable to historical state." Therefore, management actions focus on enhancing natural qualities of the given habitats. For instance, the refuge management carefully times drawdowns and flooding of impoundments to mimic natural

hydroperiods, while maintaining necessary habitat for the numerous species of concern. While this action is necessary to maintain the desired emergent marsh habitat, the refuge is investigating the feasibility of restoring hydrologic connectivity at Knox-Marsellus Marsh, Puddler Marsh, and the Stowell Property by connecting directly to the canal system (Montezuma NWR Staff, 2012). This will require understanding and working with the canal system in order to create efficient water-control strategy (Montezuma NWR Staff, 2012).

Goal 3's management focus is on grassland habitats. Interestingly, the CCP outlines a reduction in acreage because "grassland habitat takes more resources to maintain and larger patches of grassland habitat are more valuable to wildlife than smaller patches." As a result, the refuge plans to focus on maintaining larger, higher quality patches of grassland habitat while allowing the smaller patches to become shrubland or mature forest (Montezuma NWR Staff, 2012). This management decision aligns with biological integrity in two ways. First, allowing unproductive grassland habitat to revert to a more accurate portrayal of the historical condition, such as shrubland or mature forest. Secondly, by reducing grassland to a few concentrated areas allows management action to focus on providing the best habitat for grassland bird species. Grassland habitat within its natural range is quickly diminishing, so it is important to accommodate grassland bird species that have found suitable habitat on refuge land (Norment, 2002). Reducing fragmentation also reduces the "edge effect" and high rates of invasion by non-native and invasive species, as well as changes in microclimate (Montezuma NWR Staff, 2012). As with Iroquois NWR, grassland habitats at Montezuma NWR remain important for grassland bird species, given their continental decline and habitat loss in their core Midwestern ranges (Norment, 2002).

Refuge personnel stated that when "defining biological goals at the individual refuge level, staff should always consider refuge habitats and wildlife populations in a landscape context. An individual plot of land may not be restored to historic conditions but may be managed to provide a habitat that was once present but is now lacking in the surrounding landscape (Personal communication, refuge staff, Montezuma National Wildlife Refuge)." This is often the case when managing for focal species. Goal 3 reflects this statement as it details managing grassland and

shrubland for bird species, habitats that are considered non-historical. Grasslands are managed with plantings of non-native cool and warm season grasses. Overlooking the non-historical habitat, these habitats fill a hole in the landscape habitat composition by providing extremely valuable habitat to the grassland bird species whose continued existence depends on it. At Montezuma NWR, managing for conditions other than the historical state is often the case, as “there are greater habitat needs in the landscape (Personal communication, refuge staff, Montezuma National Wildlife Refuge).” Ultimately, the refuge used a “combination of factors to determine refuge goals and objectives including historic habitat conditions, landscape context, and species of conservation concern (Personal communication, refuge staff, Montezuma National Wildlife Refuge).” It seems that biological integrity is only one of many factors that affects the decision-making process for management actions on the refuge.

Canaan Valley National Wildlife Refuge

Location, History, and Mission

Situated within the Alleghany Mountains, Canaan Valley NWR is located in Tucker County, West Virginia (Canaan Valley NWR Staff, 2011). The cool and moist climate of the Canaan Valley NWR is a reflection of its geography and elevation (Canaan Valley NWR Staff, 2011). Bordered by the Allegheny Mountains and up to 3,200 feet (975 m) above sea-level in a high plateau zone, cool moist air settles in the valley, allowing frost even in the summer months (Canaan Valley NWR Staff, 2011). The mountains also force orographic lifting, causing increased precipitation within the valley as compared to surrounding areas (Canaan Valley NWR Staff, 2011). This unique climate set the stage for facilitating an equally unique composition of ecosystems.

Historical reports on Canaan Valley include descriptions of “impenetrable spruce forest and rhododendron swamp” (Canaan Valley NWR Staff, 2011). Large dead trees covered in moss were found within forests dominated by red spruce (*Picea rubens*), eastern hemlock, yellow birch, which contained sparse ground cover of mosses, and lycopodiums (Canaan Valley NWR Staff, 2011). During the late 1800s and early 1900s, this idyllic setting was marred by severe ecological disturbances. The logging industry clear-cut forests, while human-caused fires intended to facilitate hunting and

agriculture burned off the topsoil and seed banks (Canaan Valley NWR Staff, 2011). Erosion of the bare hillsides further exacerbated soil degradation. In addition, elevated grades resulting from an obsolete logging railroad continue to impede natural hydrology (Canaan Valley NWR Staff, 2011). These anthropogenic actions drastically altered the plant communities of the Canaan Valley (Canaan Valley NWR Staff, 2011).

In 1994, as the 500th established refuge, Canaan Valley was created with a mere 86 acres (35 ha) (Canaan Valley NWR Staff, 2011). Since then, it has grown to include over 16,000 acres (6475 hectares), 65% of which is upland habitat, with 34% of the area classified as freshwater wetland (Figure 6). Less than 1 percent of the refuge is classified as open water and riverine habitat even though the refuge serves as a steward of a substantial portion of the Blackwater River headwaters (Canaan Valley NWR Staff, 2011). Canaan Valley National Wildlife Refuge was established “to ensure the ecological integrity of Canaan Valley and the continued availability of its wetland, botanical, and wildlife resources to the citizens of West Virginia and the United States (Canaan Valley NWR Staff, 2011).” Land for the refuge has been acquired through the Fish and Wildlife Act of 1956 [16 U.S.C. 742f(a)(4)], the Emergency Wetlands Resources Act of 1986 [16 U.S.C. 3901b], and the Migratory Bird Conservation Act of 1926 [16 U.S.C. 715d]. These legislative directives strongly influence the management priorities at Canaan Valley. As a result, the CCP lists additional refuge purposes to include, “for use as a inviolate sanctuary...for migratory birds (Migratory Bird Conservation Act of 1929)”, for “the conservation of the wetlands of the Nation (Emergency Wetland Resources Act of 1986),” and “for the development, advancement, management, conservation, and protection of fish and wildlife resources (Fish and Wildlife Act of 1956)” (Canaan Valley NWR Staff, 2011).

Important Habitats and Management Issues

Canaan Valley NWR contains 5,407 acres (2188 ha) of freshwater wetland habitat, more finely classified as shrub wetlands, herbaceous wetlands, and open water (Canaan Valley NWR Staff, 2011). Only about 166 acres (67 ha) are open water and riverine habitat (Canaan Valley NWR Staff,

2011). The 10,481 acres (4242 ha) of upland habitat are comprised of shrubland, old-field, managed grasslands, northern hardwood forest, and conifer (spruce) forest (Canaan Valley NWR Staff, 2011).

The Blackwater River is the primary water body within Canaan Valley, which combined with numerous springs and seeps, forms extensive wetlands complexes (Canaan Valley NWR Staff, 2011). The Blackwater River and its tributaries are considered low gradient streams, but they combine to create the largest area of wetlands in West Virginia (Canaan Valley NWR Staff, 2011). Scrub swamps, peatlands, and wet meadows create habitat for a variety of species. The northern harrier, swamp sparrow (*Melospiza georgiana*), southern bog lemming (*Synaptomys cooperi*), Indiana bat (*Myotis sodalis*), black duck American woodcock, American bittern, and Virginia rail benefit from the presence of this type of habitat.

Upland habitats cover parts of the Canaan Valley NWR not inundated with water. Northern hardwood forest, conifer (spruce)/mixed forest, managed grassland, old field, and shrubland comprise the variety of upland habitats, and occur on a low sandstone ridge extending into the center of the refuge and along the borders of the wetland complexes (Canaan Valley NWR Staff, 2011). Forests provide habitat for general forest songbirds, including brown creeper (*Certhia americana*), black-billed cuckoo, and hermit thrush (*Catharus guttatus*), as well as white-tailed deer (*Odocoileus virginianus*) and black bear (*Ursus americanus*) (Canaan Valley CCP 2011). The saw-whet owl (*Aegolius acadicus*), yellow-rumped warbler (*Setophaga coronata*), West Virginian flying squirrel (*Glaucomys sabrinus fuscus*), and the Cheat mountain salamander (*Plethodon nettingi*) utilize the upland spruce habitat (Canaan Valley NWR Staff, 2011).

Forested wetlands cover about 2 percent of the refuge (Canaan Valley NWR Staff, 2011). Identified as rare “because of their current paucity within the Allegheny Mountain Section” and “because they contain rare plant species,” these areas occur on low-lying sections and along major riparian sections (Canaan Valley NWR Staff, 2011). These areas are characterized by dominant species such as red spruce, balsam fir (*Abies balsamea*), and eastern hemlock (Canaan Valley NWR Staff, 2011). The balsam fir population in the Canaan Valley is genetically unique, and efforts have

been made to perpetuate this genotype by keeping it genetically isolated (Canaan Valley Site Visit, 2012). Co-dominants in the forested wetland habitat include red maple, black ash, serviceberry (*Amelanchier*), black cherry, yellow birch, and mountain ash (*Sorbus aucuparia*) (Canaan Valley NWR Staff, 2011).

Areas within Canaan Valley have received special land-status designation denoting the refuge's unique and noteworthy attributes. A total of 24,763 acres (10021 ha) of Canaan Valley is designated as National Natural Landmark (NNL), including 16,054 acres (6499 ha) in Canaan Valley NWR (Canaan Valley NWR Staff, 2011). This classification denotes a nationally significant area, as the valley holds relict northern boreal communities and unique wetlands with respect to their elevation, size, and diversity (Canaan Valley NWR Staff, 2011). The NNL designation carries no legal obligations, but refuge management has a responsibility to uphold such high quality habitat (Canaan Valley NWR Staff, 2011). In addition, the Blackwater River is currently under consideration for a National Wild and Scenic River designation (Canaan Valley NWR Staff, 2011). While the river appears to possess the scenic, fisheries, and recreational qualities necessary to satisfy requirements to be a National Wild and Scenic River, the final determination will be determined by the Congress or the Secretary of the Interior (Canaan Valley NWR Staff, 2011).

In addition to areas of land receiving special classifications, several animal species have prioritization over others. The flying squirrel, Cheat Mountain salamander, and Indiana bat are species Canaan Valley closely monitors due to their special designations. Recently removed from the federal endangered species list, the flying squirrel remains a priority species, as it serves as an indicator to quality spruce habitat (Canaan Valley NWR Staff, 2011). Another recently delisted species, the bald eagle, frequents the refuge during the winter months and migration remains a refuge priority species (Canaan Valley NWR Staff, 2011). The federally threatened Cheat Mountain salamander occurs in high elevation spruce and hardwood forests (Canaan Valley NWR Staff, 2011). Finally, the Indiana Bat, listed as federally endangered in 1967, is thought to use the valley lands during migration or during the summer months as a maternity colony (Canaan Valley NWR Staff, 2011).

Refuge management concerns stem from numerous sources, including surrounding land-use. The nearby Blackwater and Canaan Valley state parks, along with the Timberline Four Seasons Resort, extract considerable ground and surface water (Canaan Valley NWR Staff, 2011). This and future development in the area will continue to reduce the water quantity of Blackwater River and may lead to low water flow, increased water temperatures, and direct loss of habitat for certain aquatic species (Canaan Valley NWR Staff, 2011). Another concern is the contamination associated with current and future wells and/or mines, as the federal government owns the lands of Canaan Valley NWR but not the associated mineral rights (Canaan Valley NWR Staff, 2011). A secondary concern is the pollution, acid rain, and overall atmospheric degradation stemming from mining industry activities (Canaan Valley NWR Staff, 2011).

Exotic and invasive species typically are a formidable threat to biological integrity that refuge management must mitigate. Fortunately, the current threat at Canaan Valley NWR is low (Canaan Valley NWR Staff, 2011). Despite its current low risk level, Canaan Valley has plans to extract any invasive species by hand and/or apply herbicides to ensure that no new invasive species become established (Canaan Valley NWR Staff, 2011). Current exotic and invasive threats include multiflora rose, yellow iris (*Iris pseudacorus*), Japanese stilt grass, and garlic mustard (Canaan Valley NWR Staff, 2011).

Comprehensive Conservation Plan and Biological Integrity

The Canaan Valley NWR completed its CCP document in February 2011. It is now currently working on step-down plans to begin implementing the goals and objectives identified in the CCP (Personal communication, refuge staff, Canaan National Wildlife Refuge). Several projects are underway that strive to promote biological integrity, including red spruce restoration, utilizing a wetland ecological integrity index, along with decommission and obliteration of the logging road and rail grade that pass through the refuge (Personal communication, refuge staff, Canaan National Wildlife Refuge). Despite being actively engaged in promoting biological integrity, Canaan Valley

NWR still recognizes the difficulty of implementing such a policy because of the impacts from the area's logging history, as well as the unknown impacts from climate change.

Within its CCP document, Canaan Valley NWR lists its management goals as:

- **Goal 1:** Maintain and perpetuate the ecological integrity of the Canaan Valley wetland complex to ensure a healthy and diverse wetland ecosystem providing a full range of natural processes, community types, and native floral and faunal diversity.
- **Goal 2:** Perpetuate the ecological integrity of upland northern hardwood and northern hardwood-conifer forests to sustain native wildlife and plant communities including species of conservation concern, to develop late-successional forest characteristics, and to perpetuate the biological diversity and integrity of upland forest ecosystems.
- **Goal 3:** Provide and promote through active management a diversity of successional habitats in upland and wetland-edge shrublands, grasslands, old fields, and hardwood communities to sustain early successional and shrubland specialists such as golden-winged warbler, American woodcock, brown thrasher, eastern towhee, field sparrow, and other species of concern.

These well-defined management goals clearly attempt to incorporate the concept of biological integrity. Specifically, Goal 1 cites, “providing a full range of natural processes” as a way to maintain the ecological integrity of the refuge's wetland complexes, which embodies the key functional component of the FWS biological integrity definition. Goal 2 names “late-successional characteristics” as its benchmark for perpetuating ecological integrity, with no mention of historical conditions. It is interesting to note that the refuge chose to name a different target in place of the FWS's definition of biological integrity, “as comparable to historical conditions.” Finally, goal 3 describes providing necessary habitat for “at risk” species, despite the fact that these habitats may be in conflict with the idea of historical conditions.

Current conflicts with implementing the Integrity Policy at Canaan Valley NWR stem from wildlife dynamics and land-use. Current wildlife dynamics may prevent the refuge from achieving historical conditions. Canaan Valley NWR has been trying to mitigate white-tailed deer

overpopulation due to habitat changes and the extinction of their natural predators. Increased numbers of deer are now affecting the fecundity of balsam fir due to excessive browsing on saplings (Personal communication, refuge staff, Canaan National Wildlife Refuge), which will dramatically influence forest composition in the years to come. Another issue is conflicting land-use on the refuge. Ski trails may be creating impassable barriers for the threatened Cheat mountain salamander (Personal communication, refuge staff, Canaan National Wildlife Refuge). These man-made barriers may exacerbate the genetic isolation of different populations of the Cheat mountain salamander (Personal communication, refuge staff, Canaan National Wildlife Refuge). It seems that the location of these ski trails has a negative impact of the natural processes of genetic exchange, and therefore, they are in conflict with biological integrity.

According to refuge personal, it is hard to understand what historical conditions were like in the Canaan Valley (Personal communication, refuge staff, Canaan National Wildlife Refuge). Accounts from the logging industry have provided an incomplete understanding of Canaan Valley's historical condition, demonstrating that the "historical context" of biological integrity is subject to interpretation (Personal communication, refuge staff, Canaan National Wildlife Refuge). This is problematic for the refuge because the specific enabling legislation for a refuge and regional directives may conflict with the goal of managing for historical conditions under the biological integrity policy (Personal communication, refuge staff, Canaan National Wildlife Refuge). For instance, legislation dictates that the National Wildlife Refuge System needs to provide recreational activities such that the people can interact with the natural world. This typically results in increased disturbance and can be detrimental to the overall goals of the refuge management teams, as demonstrated in the previously mentioned case of Cheat Mountain salamander populations.

Lacking a standardized means to quantify biological integrity, refuges are left searching for individual solutions rather than following a prescribed protocol (Personal communication, refuge staff, Canaan National Wildlife Refuge). The refuge is looking into developing a biological index for wetland communities, which may standardize assessment of integrity for that specific habitat type

(Personal communication, refuge staff, Canaan National Wildlife Refuge). However, establishing such a matrix is labor-intensive and controversial (Wilcox *et al.*, 2002 and Euliss *et al.*, 2008). It will be up to the refuge to weigh the pros and cons before deciding on implementation of such a tool.

Rachel Carson Wildlife Refuge

Location, history, mission

Located within the Gulf of Maine watershed, the multiple divisions of the Rachel Carson Wildlife Refuge dot the Maine coastline (Rachel Carson NWR Staff, 2007). Stretching 50 miles (80km) between the counties of York and Cumberland, the refuge totals 5,293 acres (2142 ha) (Rachel Carson NWR Staff, 2007). Originally named the Coastal Maine National Wildlife Refuge, the refuge was formed in 1966 under the Migratory Bird Act as “an inviolate sanctuary, or any other management purpose, for migratory birds,” to preserve and protect migratory waterfowl habitat and migration routes (Rachel Carson NWR Staff, 2007). Additional refuge purposes include recreational development, conservation of wetlands, and conservation of natural resources (Rachel Carson NWR Staff, 2007). Renamed Rachel Carson National Wildlife Refuge, the refuge is now comprised of 10 divisions (Figure 7): Brave Boat Harbor, Moody, Lower Wells, Upper Wells, Mousam, Goose Rocks, Little River, Biddleford Pool, Goosefare Brook, and Spurwink River Divisions (Rachel Carson NWR Staff, 2007). Initially, each division was formed to protect an estuary or tidal river resource; later, land was acquired to protect water quality, wetlands, and/or valuable wildlife habitat (Rachel Carson NWR Staff, 2007).

Historical records show that Maine’s estuary habitats were teeming with wildlife during the mid-1800s, which supported the developing fishing and hunting industries (Rachel Carson NWR Staff, 2007). Recreational use of the Maine coastline increased after the arrival of the railroad in 1842, which resulted in seasonal and vacation homes being constructed on the edge of the native salt marsh habitats (Rachel Carson NWR Staff, 2007). The dense coastal population is detrimental to the variety of ecosystems, and proves to be a challenge for refuge management.

Important habitats and management issues

Rachel Carson NWR contains a variety of diverse habitats; 35% of the total area is comprised of tidal habitats (beach, dune, dune grassland, river, rocky shore, estuarine, bay, and salt marsh), 10% freshwater habitat (cattail marsh, bog, emergent shrub-scrub wetland, pocket swamp, red maple swamp, and floodplain forest), and 55% upland habitat (mixed oak and pine forests, grasslands, thickets) (Rachel Carson NWR Staff, 2007). The Rachel Carson NWR staff utilized the Integrity Policy, legal mandates, and USFWS Trust Resources to identify habitats that required prioritized management actions. These areas include dune grassland (beach, rocky shore, sub tidal, intertidal), salt marsh, and tidal rivers (Rachel Carson NWR Staff, 2007).

Factors leading to dune grassland habitat prioritization include its utilization by the federally threatened piping plovers (*Charadrius melodus*) during the breeding season. These birds nest above the tide line on open sand and feed in the “splash zone” (Rachel Carson NWR Staff, 2007). The least tern (*Sternula antillarum*) is another species of concern that requires similar breeding areas. Finally, dune grassland habitats serve as feeding and roosting habitat for migrating waterfowl (Rachel Carson NWR Staff, 2007). Dune grasslands are a naturally functioning habitat and make up 1,100 acres (445 hectares) of the refuge (Rachel Carson NWR Staff, 2007). Dune grass (*Ammophila breviligulata*) dominates these areas, which anchors the otherwise exposed sand dunes (Rachel Carson NWR Staff, 2007). This habitat is threatened by climate change and the consequential sea-level rises. In addition, invasive species, development, and overuse by the public pose threats to the biological integrity of this priority habitat due to their affects on the nesting, foraging, and roosting areas of several species of concern (Rachel Carson NWR Staff, 2007).

Rachel Carson NWR contains 3,844 acres (1556 hectares) of valuable salt marsh habitat, with a mix of high and low salt marsh vegetation (Rachel Carson NWR Staff, 2007). Identified as a priority habitat, saltmarsh benefits the numerous priority species that utilize these important areas. The salt marsh sharp-tailed sparrow (*Ammodramus caudacutus*) breeds almost exclusively in salt marsh habitats, nesting in medium high cord grass near the mean high-tide line (Rachel Carson NWR Staff, 2007). Currently estimated to have a global population of 30,000 and 50,000 individuals, the salt

marsh sharp-tailed sparrow is identified as a species of conservation concern by numerous agencies, including Partners in Flight, BirdLife International, and the American Bird Conservancy (Bayard and Elphick, 2011). The salt-marsh sparrow, along with other marsh-nesting birds, is threatened by projected rises in sea-level because of the detrimental impacts to the sensitive salt marsh habitat (Bayard and Elphick, 2011). The black duck uses salt marsh habitat exclusively during the winter (Rachel Carson NWR Staff, 2007). The North American Breeding Bird Survey identified the black duck as a declining species with a negative population trend between 1966 and 2001. More recent data reveal a non-significant trend between 2001 and 2011 in the Northeast (Sauer, *et al.*, 2012). Finally, salt marsh areas serve as feeding grounds for both the common tern and the federally endangered roseate tern (*Sterna hirundo* and *Sterna dougallii*, respectively) (Rachel Carson NWR Staff, 2007). It is clear that marsh habitat serves a variety of species during various life history stages.

Since its inception, Rachel Carson NWR has been dedicated to salt marsh restoration by plugging ditches to mitigate the damage to pools and salt pans from the parallel-grid-ditches once used for mosquito control (Rachel Carson NWR Staff, 2007). These restored salt marsh habitats are now threatened by climate change and consequential sea-level rises. Sea-level rise and climate change are direct threats to the biological integrity of the refuge, with the Northeast a designated hot spot. Additional threats, including invasive species, development, and environmental contamination may affect the biological integrity of this priority habitat (Rachel Carson NWR Staff, 2007).

Tidal rivers are another prioritized habitat at Rachel Carson, as the refuge was established around a series of these critical habitats. Several federal trust species are present within the tidal river systems, including alewife (*Alosa pseudoharengus*), American eel (*Anguilla rostrata*), blueback herring (*Alosa aestivalis*), rainbow smelt (*Osmerus mordax*), bluefish (*Pomatomus saltatrix*), and Atlantic menhaden (*Brevoortia tyrannus*) (Rachel Carson NWR Staff, 2007). Threats to water quality and quantity include development, environmental contamination, and siltation affect the integrity of the tidal river ecosystems (Rachel Carson NWR Staff, 2007).

In addition to the numerous habitat types conserved within Rachel Carson NWR, specific divisions house unique natural communities. For example, the Brave Boat Harbor division was

nominated to be included in the Maine Ecological Reserve Program. This designation is used to maintain a community in a natural condition, establishing a benchmark against which environmental change can be measured against, and to protect sufficient habitat (Maine Department of Agriculture, Conservation, and Forestry, 2010). This area is classified as “oak-pine forest with vernal pools and old field upland habitats surrounding salt marsh and estuary habitat (Rachel Carson NWR Staff, 2007).”

White wood aster (*Aster divericatus*), wild coffee (*Triosteum aurantiacum*), and dwarf glasswort (*Salicornia bigelovii*) are listed as rare plant species occurring within this division (Rachel Carson NWR Staff, 2007). In addition, species such as bayberry (*Myrica pensylvanica*), high bush blueberry, and spirea (*Spirea latifolia*) make up the understory in the upland habitats (Rachel Carson NWR Staff, 2007).

Other notable habitats and their respective divisions include one of the largest salt marshes in the state and a historic barrier beach, which is located in the Lower Wells Division (Rachel Carson NWR Staff, 2007). Black duck and Nelson’s sharp-tailed sparrows (*Ammodramus nelsoni*) use this division (Rachel Carson NWR Staff, 2007). The Upper Wells Division is home to several pairs of nesting piping plovers and least terns (Rachel Carson NWR Staff, 2007). The upland forests of this division are populated with pitch pine, white pine, red maple, and red oak. The Biddeford Division protects some of the state’s most important estuarine habitats, including salt marsh, coastal shrublands, grasslands, and some pitch pine forest (Rachel Carson NWR Staff, 2007).

Despite harboring numerous critical species and habitats, the relatively intact biological integrity of Rachel Carson NWR is in jeopardy. Encroaching development and impacts from climate change are the two greatest threats. Thermal steric expansion through heat uptake in combination with glacial melt water are two contributing factors increasing sea-level (Jeffress, 2013). The duration and depth of tides influence the coastal wetland vegetation; consequently, species have adapted to tolerate a certain level of salinity and tidal influence (Glick *et al.*, 2013). To persist, salt marsh habitat must migrate inland or increase in elevation by accretion at a pace that matches the rise in sea-level (Glick *et al.*, 2013). Rachel Carson NWR is concerned that projected sea-level rises will occur at a faster rate than salt marsh accretion, resulting in the habitat becoming too flooded and contributing to plant

mortality, peat erosion, and loss of elevation (Rachel Carson NWR Staff, 2007). Effects from climate change have the potential to convert salt marshes to mudflats or open water, which would harm the numerous species that rely on salt marsh habitat for critical biological processes (Rachel Carson NWR Staff, 2007). Development along the coastline may magnify the decline of salt marsh in the face of climate change. In the face of potential sea-level rise, salt marsh habitat may be “squeezed” out if its retreat is constricted by steep elevation changes, particularly those imposed by sea walls and other shoreline structures (Rachel Carson NWR Staff, 2007). Other anthropogenic impacts that threaten the biological integrity of the refuge and surrounding areas include habitat conversion to urban and suburban uses, agriculture, gravel pits, and fragmentation from roadways (Rachel Carson NWR Staff, 2007).

Another potential threat to the biological integrity of the Rachel Carson NWR comes from exotic species. Remarkably, given the amount of historical disturbance, many divisions of the refuge are relatively free from invasive species, and are estimated to be 90% “clean” (Rachel Carson NWR Staff, 2007). The CCP (2007) states that, “the refuge appears to be quite clean...that is largely due to our abundant, clean salt marsh habitats.” Phragmites and purple loosestrife appear to be less of a problem on Rachel Carson NW Refuge than on other refuges in Region 5, as they have invaded less than 15 acres (6 ha) and 3 acres (1 ha), respectively. In contrast, Asiatic bittersweet (*Celastrus orbiculata*), bush honeysuckle (*Lonicera sp.*), common barberry (*Berberis vulgaris*), glossy buckthorn (*Frangula alnus*), Japanese barberry (*Berberis thunbergii*), and reed canary grass have invaded more than 20 acres (8 ha) (Rachel Carson NWR Staff, 2007). Rachel Carson National Wildlife Refuge’s approach to managing invasive species aligns with most northeastern refuges, as they systematically identify, locate, and map invasive species, which are then integrated into a response plan of control, monitoring, and evaluation projects (Rachel Carson NWR Staff, 2007). The refuge pledges to promote alternative, environmentally benign pest-management practices in recognition of the refuge’s namesake (Rachel Carson CCP, 20007).

Comprehensive Conservation Plan and biological integrity

To protect the biological integrity of these valuable coastal ecological communities, Rachel Carson NWR defined the following goals within their CCP document:

- **Goal 1:** Perpetuate the biological integrity and diversity of coastal habitats to sustain native wildlife and plant communities, including species of conservation concern.
- **Goal 2:** Perpetuate the biological integrity and diversity of freshwater habitats to sustain native wildlife and plant communities, including species of conservation concern.
- **Goal 3:** Perpetuate the biological integrity and diversity of upland habitats to sustain native wildlife and plant communities, including species of conservation concern.

Rachel Carson NWR has been very explicit in integrating the concept of biological integrity into their CCP document. This is evident in the fact that three of the refuge's goals specifically identify biological integrity, a rarity when comparing Rachel Carson's CCP goals to those of the five other refuges that I used as case studies. Rachel Carson NWR has completely aligned its goals with the Integrity Policy for all of its major habitat types. Again, this approach is unique to Rachel Carson NWR, as other refuges in my study typically identify one or two habitat types for which biological integrity (or similar concepts) is a management goal.

Rachel Carson NWR has made the commitment to restore or mimic natural processes wherever possible. However, in light of changing environmental conditions and landscape patterns (climate change, land development, etc.), always relying on natural process may not be the best management policy. Instead, Rachel Carson NWR seeks to manage its habitats within a range of environmental variability rather than precisely emulating any particular historical states (Rachel Carson NWR Staff, 2007). More importantly, the CCP (2007) states that, "rather than maintain stability, we will maintain mechanisms that allow species, genetic strains, and natural communities to evolve to changing conditions." According to refuge staff, "this station takes our responsibility to achieve the refuge purpose and system mission very seriously, and the BIDEH (Integrity Policy) policy helps focus our efforts," but recognizes that the policy, "provides an approach, not an answer" (Personal communication, refuge staff, Rachel Carson National Wildlife Refuge). Acknowledging the

ambiguity and difficulty in implementing the Integrity Policy, refuge staff said, “we do much better with populations than we do with food webs, better with populations than with genetic recombination, and perhaps best with community succession (Personal communication, refuge staff, Rachel Carson National Wildlife Refuge).”

The refuge system has a strong history of identifying populations in decline and launching initiatives as a way to increase those threatened populations. By understanding community succession, managers are able to construct habitats most needed to harbor at-risk populations of species. Populations and succession are integral components of refuge management and support implementable principles of the Integrity Policy in areas they can observe, measure, and interact with directly. Focusing on these tangible components of biological integrity indirectly supports the more difficult to quantify elements that make up biological integrity, such as genetic processes. Rachel Carson NWR has applied this approach as it attempts to facilitate the recovery of the New England cottontail (*Sylvilagus transitionalis*). Current populations of the New England cottontail span only 75% of its historical range, from the Hudson River in NY, through the New England states of Connecticut, Rhode Island, Massachusetts, Vermont, and into southern Maine (USFWS, 2006). Loss of the New England Cottontail’s desired thicket habitat, combined with food competition from white-tailed deer and the eastern cottontail, has resulted in declining populations (O’Brien, 2009). Rachel Carson NWR is one (of two) refuges that have New England cottontails present on the refuge (O’Brien, 2009). Therefore, Rachel Carson NWR is taking steps to increase the amount of edge habitat, which directly supports more individuals of New England cottontail. Indirectly, the refuge’s actions will be facilitating other biological integrity principles including increasing the genetic pool of the refuge population. Efforts to sustain the New England cottontail and other species of concern are complicated by potential impacts from climate change, as refuge staff acknowledges that sea-level rise endangers coastal refuges (Personal communication, refuge staff, Rachel Carson National Wildlife Refuge).

Erie Wildlife Refuge

Location, history, mission

Erie National Wildlife Refuge is the only refuge used as a case study that has not finished its CCP document, which has an anticipated completion date of year end 2013. There is limited information available, as only a draft of the goals and mission are currently available to the public. As a result, my research was limited to information gathered during the site visit, survey response, and what was available on the fws.gov website for Erie NWR.

Erie National Wildlife Refuge is located in Crawford County, Pennsylvania, about 35 miles (56.3 km) south of the city of Erie, PA, and contains two separate land divisions separated by about 10 miles (16.1 km) (USFWS, 2013). The Sugar Lake division is located 10 miles (16.1 km) east of Meadville, and the Seneca division lies about 4 miles (6.4 km) southeast of Cambridge Springs, PA (Figure 8) (USFWS, 2013).

Established in 1959, lands for the refuge were purchased with funds from the Migratory Bird Hunting and Conservation Stamps (aka “Duck” stamps.) Consequently, the refuge’s primary objective is to provide nesting, brooding, and feeding habitat for migrating waterfowl (USFWS, 2011)). The refuge contains 5206 acres (2107 ha) of open water creeks and connected marshland, with are bordered by forested slopes and interspersed with grassland and wet meadows habitat (USFWS, 2011).

Important habitats and management issues

Located entirely within the nationally significant French Creek Watershed, Erie NWR is home to a diverse number of habitats, including riparian, wetland, shrubland, grassland, and forested habitats. Riparian habitats encompass water bodies and the surrounding riparian zones, which typically include wetlands, shrublands, and forests (USFWS, 2011). Wetland habitats on the Sugar Lake Division are manipulated using 16 impoundments (USFWS, 2011). The resulting hydrologic structure results in flooding in the spring and fall, with drawdowns during the late spring/summer months to facilitate vegetation growth (USFWS, 2011).

A total of 3,487 acres (1411 ha) of forested habitat occur within Erie NWR (USFWS, 2011). Red maple, striped maple (*Acer pensylvanicum*), mountain maple (*Acer spicatum*), white ash, and

black cherry occur in these upland forest areas and help create breeding habitat for bird species that prefer the forest interior, such as the cerulean warbler and scarlet tanager (USFWS, 2011). Managed to prevent the areas from reverting to forest, the refuge's shrubland requires mowing as a form of disturbance (USFWS, 2011). This is necessary to provide the desired habitat requirements for species like the woodcock and blue-winged warbler (*Vermivora cyanoptera*) (USFWS, 2011).

Erie NWR attracts more than 230 species of birds, and it has earned a designation as an Important Bird Area (USFWS, 2011). Bird species that frequent the refuge include the recently delisted bald eagle, osprey (*Pandion haliaetus*), and the American kestrel (*Falco sparverius*) (USFWS, 2011). Migrating waterfowl species include wood ducks, mallards, blue-winged teal, and the hooded merganser (*Lophodytes cucullatus*) (USFWS, 2011). In addition, there are shore and marsh birds that frequent the refuge, including lesser yellowlegs (*Tringa flavipes*), and great blue herons (USFWS, 2011).

Common mammals on the refuge include the white-tailed deer, beaver, muskrat, and woodchuck (*Marmota monax*) (USFWS, 2011). Several species of turtle are found on the refuge, including the box (*Terrapene carolina*), mud (*Kinosternon subrubrum*), and snapping (*Chelydra serpentina*) turtles (USFWS, 2011). Common fish species include black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavescens*), and largemouth bass (*Micropterus salmoides*). Other important aquatic species on the refuge include two federally endangered species of mussels. The endangered northern riffleshell (*Epioblasma torulosa rangiana*) and clubshell (*Pleurobema clava*) mussels reside in French Creek. Although these species have lost almost 95% of their range, the individuals remaining in French Creek are some of the best examples of their species (USFWS, 2011).

Mitigating water quality concerns from agricultural run-off and limiting the impact of invasive species are the two primary management concerns. Invasive species on the refuge include garlic mustard, honeysuckle, and multiflora rose (USFWS, 2011).

Comprehensive Conservation Plan and biological integrity

Erie's final draft of the CCP remains unavailable. Two of the draft goals, extracted from the refuge's released draft vision and goals, are rooted in the Integrity Policy (USFWS, 2011). These include:

- **Goal 1:** Restore and maintain the biological diversity, integrity, and environmental health of the riverine and riparian ecosystems of the Seneca Division, including streams, scrub-shrub habitat, wetlands, riparian and upland forests, and other rare plant communities.
- **Goal 2:** Restore and maintain a healthy and dynamic riverine and riparian ecosystem in the Sugar Lake Division, including streams, scrub-shrub habitat, wetlands, riparian and upland forests, open lands, and other rare plant communities.

It is evident that while the refuge has not decided on a course of action for steering its future management direction, it is examining ways to increase the "naturalness" of the refuge by emphasizing biological integrity within both divisions. A significant step towards achieving the above draft CCP goal includes a hydrogeomorphic study that was being conducted to examine the potential impacts of removing some of the impoundments and determining if a more natural hydrology could be restored (Erie Survey Responses, 2012).

Discussion

The responsibility for conserving, protecting, and enhancing the fish and wildlife populations of the United States has been entrusted to a number of federal agencies, including the USFWS (US Government Accountability Office, 1981). In 1981, the US Government Accountability Office (GAO) reported that the FWS had not provided necessary oversight to the NWRS and urged the agency to refocus on conserving and managing wildlife resources (US Government Accountability Office, 1981). According to the GAO (1981), improper oversight had allowed detrimental land-use to occur within refuge boundaries, while some refuges held little wildlife value (US Government Accountability Office, 1981). Lacking a unified management plan, many refuges acted autonomously, while the management objectives of individual refuges were subjective (US Government Accountability Office, 1981). Protecting fish and wildlife is the primary focus of NWRS, but allowing the NWRS to operate

haphazardly may have facilitated the degradation of species and/or ecosystems entrusted to its protection.

The National Wildlife Refuge System Improvement Act (NWRISA) and the USFWS' Biological Integrity, Diversity and Environmental Health Policy (Integrity Policy) addressed the major concerns cited in the GAO report by uniting the refuge system under a common mission with detailed system objectives. NWRISA states that the Secretary of the Interior must "ensure that the biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans (USFWS, 1999.)" The Integrity Policy (601FW 3) defines biological integrity as "biotic composition, structure, and functioning at genetic, organism, and community levels comparable with historic condition, including the natural biological processes that shape genomes, organisms, and communities" (USFWS, 2001). Biological integrity should be evaluated "by examining the extent to which biological composition, structure, and function has been altered from historic conditions" (USFWS, 2001). However, the USFWS also acknowledges that no landscape "retains absolute biological integrity," (USFWS, 2001) as human impacts and other influences have forever altered natural systems.

The Integrity Policy represents an intent to manage refuges holistically by balancing biological integrity, diversity, and environmental health (USFWS, 2001). As a result, the Integrity Policy outlines directives but includes qualifying "escape" clauses as a way to allow acceptable exceptions, based primarily upon professional judgment (USFWS, 2001). For instance, the Integrity Policy states, "where it is not appropriate to restore ecosystem function, our refuge management will mimic these natural processes including natural frequencies and timing to the extent this can be accomplished" (USFWS, 2001). However, the policy goes on to say, "We may find it necessary to modify the frequency and timing of natural processes at the refuge scale... for example, we may flood areas more frequently and for longer periods of time than they were flooded historically" (USFWS, 2001).

Another example of “escape clauses” within the Integrity Policy concerns the assessment of biological integrity. The policy states that biological composition, structure, and function factor into biological integrity assessments. 601 FW 3 states that, “biological composition refers to biological components such as genes, populations, species, and communities. Biological structure refers to the organization of biological components, such as gene frequencies, social structures of populations, food webs of species, and niche partitioning within communities. Biological function refers to the processes undergone by biological components, such as genetic recombination, population migration, the evolution of species, and community succession.” The Policy then clarifies this statement by saying that “maintaining biological integrity may entail managing for a single species or community at some refuges and combinations of species or communities at other refuges” (USFWS, 2001). This juxtaposition of seemingly contradictory statements has led to confusion about the intent of the policy and left room for ambiguous interpretation. Examples cited in these “escape clauses” are consistent with current refuge management practices and/or founding refuge purposes, which might otherwise be in conflict with the goals and objectives of the Integrity Policy. The resulting ambiguity seems to contradict the unifying purpose of NWRSA.

To understand the effectiveness of the Integrity Policy, it is important to analyze its current use on individual refuges. Region 5 case studies reveal how local refuges are trying to muddle through the ambiguous wording of the Integrity Policy, especially in regard to creating Comprehensive Conservation Plans. Because the Integrity Policy is relatively new, as is the concept of managing for biological integrity, its application to the management strategy of the NWRSA is still unclear. Hopefully, practice and application will shape the Integrity Policy into a useful guiding principle that will help unite the refuge system. However, confusion surrounds the definition and implementation of biological integrity as it relates to historical conditions, non-native species, and impacts from surrounding land-use and climate change, as well as how biological integrity fits within founding missions and active management practices of individual refuges.

The ambiguity mentioned above is reflected in the CCPs of the NWRS refuges used as case studies. The CCP is intended to guide long range management decisions, and while biological integrity is now a mandate, relatively few refuge goals directly acknowledge integrity. Of the six case studies, only Rachel Carson utilized the key vocabulary word, biological integrity, in the stated goals. Erie, Missisquoi, Iroquois, and Canaan Valley NWRs mentioned integrity or ecological integrity. Montezuma's goals failed to use any derivation of biological integrity, but instead used "restore and maintain" to describe its management actions. Missisquoi states that its primary goal is to maintain the ecological integrity of the Missisquoi River Delta (Missisquoi NWR Staff, 2007). Because this refuge sits at the mouth of the Missisquoi River and includes most of the river delta, maintaining the ecological integrity of the River Delta results in refuge-wide impacts and promotes a sustaining management philosophy (Missisquoi NWR Staff, 2007). Other refuge goals describe the desirable characteristics of biological integrity they wish to maintain but fail to use the term to incorporate the "wholeness" of an ecosystem.

The opinions of refuge personnel reflect the ambiguity of the Integrity Policy. A member of the Missisquoi Refuge staff noted that implementation of the Integrity Policy occurs on a case-by-case basis, as refuges apply the concept in select areas of the refuge and not others (Personal communication, refuge staff, Missisquoi National Wildlife Refuge). This observation holds true for every refuge used as a case study. For instance, Missisquoi was "established for waterfowl with impoundments which are being maintained to meet the purposes of why the refuge was established (Personal communication, refuge staff, Missisquoi National Wildlife Refuge)" Therefore, Missisquoi has one large impoundment for waterfowl but then manages other wetland/forested habitat for biological integrity purposes (Personal communication, refuge staff, Missisquoi National Wildlife Refuge)." Iroquois NWR and Montezuma NWR operate under similar circumstances; se refuges essentially are subdivided into highly manipulated areas and low maintenance areas where natural process are allowed to operate. In these instances, the result is a divided management focus. A Canaan Valley NWR staff member shared similar sentiments by stating, "When defining biological

goals at the individual refuge level, staff should always consider refuge habitats and wildlife populations in a landscape context. An individual plot of land may not be restored to historic conditions but may be managed to provide a habitat that was once present but is now lacking in the surrounding landscape. This is often the case when managing for focal species (Personal communication, refuge staff, Canaan National Wildlife Refuge).”

While refuge goals show a lack of uniformity regarding management based upon the concept of biological integrity, and the attitudes of refuge staff towards the policy varied, all the CCP documents examined did acknowledge existing areas of biological integrity. Each refuge used as a case study possessed key areas with special designations, such as the Natural Research Areas (NRA) where natural, indigenous habitats are allowed with little to no management interventions. These areas currently embody the definition of biological integrity. It is obvious from analyzing the CCP documents that these areas are easily managed under the biological integrity policy, as they require little direct management action and allow for a simplified approach to implementing Integrity Policy directives.

All case study refuges displayed some level of biological integrity inherent to the refuge. However, some refuges will have an easier time implementing a management strategy rooted in biological integrity, given the current make-up of the refuge and surrounding landscape. Refuges like Canaan Valley and Rachel Carson contain relatively intact ecosystems, which require little management intervention, as opposed to refuges like Iroquois and Montezuma, which rely heavily on water-control structures to maintain the desired habitat characteristics. In addition to water impoundments, there are certain habitats, like grasslands, that are not easily managed under the Integrity Policy because they require intensive maintenance activities. All case study refuges maintained some grassland habitat, despite the fact that extensive patches of warm season and non-native cool season grasses may or may not have existed naturally in these areas. This type of habitat fails to satisfy some of the foundation principals of biological integrity, even though it may support at-

risk grassland bird species of management concern. Habitat types that lie outside of the definition of biological integrity lack a clear implementation strategy, and result in variability in applications.

Finally, from examining the Region 5 case study refuges, it is clear that the definition of biological integrity as it relates to historical conditions does not have universal implementation strategies due to complications from non-native species, impacts from surrounding land-use and climate change, as well as how biological integrity fits within founding missions and active management practices of individual refuges. Using the USFWS' definition of biological integrity implies that a refuge adhering to the policy would ultimately promote historical conditions (Schroeder *et al.*, 2004). Refuge management would then emphasize understanding historical conditions, acknowledging deterioration within the current state, and working to maintain or restore these historic conditions (Matson, 2004). An ecosystem possessing historical characteristics would then embody biological integrity. With historical condition stressed in the USFWS definition of biological integrity, all NWRS Region 5 refuges used as case studies have attempted to describe possible historical conditions within their CCP documents. This allows insight about the factors that have influenced current states, as well as analyses of how much divergence from historical state has occurred. However, using historical conditions as a reference point for making these assessments is misleading because it excludes external forces affecting the modern environment, such as climate change, invasive species, and effects of surrounding land-use. While processes such as climate change and anthropogenic influences have been around for a long time, their magnitude has changed since the "historical condition" benchmark. These are important factors, which dramatically alter environmental trajectories, and may be impossible to counteract. For example, Foster and his colleagues have described concurrent patterns of land-use change and wildlife population trajectories in New England from 1600 until the present, as accompanied by static physical environmental changes (Foster *et al.*, 2002). Foster *et al.*, (2002) conclude that while the current landscape is coming to resemble historical conditions circa 1600, the current wildlife species composition is culturally conditioned and only broadly analogous to historical conditions. This situation results from species range extensions, abiotic

changes due to climate change, and the introduction of non-native species. The question then becomes; does attempting to manage for a view of biological integrity based on historical conditions set a refuge up for failure? If climate change, invasive species, and surrounding land-use have strong influences on environmental trajectories, then they may render historical conditions unachievable and unrealistic for refuges.

In addition to Foster's research, studies concerning grassland birds further support the idea that historical conditions are mostly irrelevant for certain refuge management actions. For example, many grassland bird species did not begin their range expansion eastward, or regional population increases, until the late 1800s and early 1900s when extensive forest clearing cultivated desirable habitat (Foster *et al.*, 2002, Norment, 2002) and therefore should not be considered part of "historical state" under the strict definition of biological integrity. Therefore, if management actions in these habitats were to promote historical conditions, they would be removing essential habitat for species that are experiencing continental declines due to habitat loss in their native Midwest range (Norment, 2002). Foster *et al.*'s (2002) research and examples using grassland birds lend support to the idea that historical conditions may not be a relevant tool for current management policy to assess biological integrity against because of modern-day affects, such as habitat loss and climate change.

Another modern-day reality of refuge management involves dealing with species' diverse habitat preferences and life histories, some of which may be experiencing range changes initiated by climate change, new food sources (trash, birdseeds), and changes in land cover (Foster *et al.*, 2002). For example, geographic range shifts are increasingly related to climate change, a phenomenon observed in a number of bird populations. Temperature increases and precipitation changes associated with climate change translate to shifts in migration arrival dates, advances in nesting dates, and northward expansion of wintering and breeding grounds (Matthews *et al.*, 2011). In recent years, Canaan Valley has observed an increase of 1.5° F (.83°C), coupled with a general trend toward warmer, less snowy winters, earlier arrivals of spring, and hotter summers (Canaan Valley NWR Staff, 2011). Consequently, there has been a noticeable shift in the phenology of various species, birds are

migrating earlier, and frogs initiate their breeding calls almost two weeks earlier than previously observed (Canaan Valley NWR Staff, 2011).

In refuges like Canaan Valley, where climate change is influencing the ecological timetables, restoration to historical conditions may not be possible. As abiotic factors affecting environmental trajectories are altered by climate change, it is irrational to expect that the current ecosystem will remain the same, let alone assume that it can be restored to historical conditions. Using historical conditions as a marker for biological integrity could eventually become irrelevant in the face of climate change. The worst-case scenario would be that a misinterpretation of the policy would lead a refuge to attempt mitigating affects of climate change in order to stay within the parameters of historical state. Instead, executing plans to improve habitat resiliency by increasing the connectivity and condition of existing habitat would be more beneficial (Canaan Valley NWR Staff, 2011). Another course of action includes mitigating increases in stream water temperatures by reforesting riparian edges (Canaan Valley NWR Staff, 2011). This strategic plan, while not restoring historical conditions, applies the concepts of biological integrity as it attempts to improve the current conditions while alleviating some of the more detrimental consequences of a warmer climate. Managing for biological integrity in this sense will be beneficial to a refuge because these areas have greater adaptability in the face of climate change and other factors altering environmental trajectory (Karr, 2004). Fostering qualities that assist a habitat's capacity to adapt consequently facilitates "the natural biological processes that shape genomes, organisms, and communities" which is a part of biological integrity.

As climate change alters the ecological phenology, surrounding land-use may also impede the success of any refuge management actions aimed at improving biological integrity. This is another reason why the Integrity Policy's goal of "as comparable to historical conditions" is often unrealistic. Historically, large tracts of untouched land would have created a mosaic of different ecosystems in an area, with an almost seamless blending of ecosystem types. In contrast, present-day landscape's often are crosshatched with highways, sprawling suburbs, neatly partitioned agriculture fields, and contain only isolated fragments of the habitat that once occupied them (Primack, 2006). These fragments

differ from their original habitat by having a greater amount of edge, having the center in closer proximity to edge habitat, and the pieces of habitat have smaller populations, as opposed to continuous habitat with large populations (Primack, 2006). This results in detrimental species impacts. For instance, fragmentation limits a species' potential for dispersal and colonization, alters the microclimate, and increases the vulnerability of the fragment to invasion by exotic species (Primack, 2006). In addition, fragmentation alters microclimate while also limiting division of populations by isolating populations and making them more vulnerable to inbreeding and genetic drift (Primack, 2006) Therefore, each human intrusion has resounding consequences for neighboring refuges.

In refuges like Montezuma NWR, the effects of human use of the surrounding landscape are noticeable. The refuge attempts to mitigate detrimental human land-use activities, including canal systems and interstate highways, both on and off the refuge. The Cayuga-Seneca Canal (which connects the Seneca and Cayuga Lakes to the Erie Canal) has had the most impact on the wetland habitat on the refuge (Montezuma NWR Staff, 2012). The resulting hydrological changes decreased water levels and facilitated the development of more forested upland habitats (Montezuma NWR Staff, 2012). Water-level control lies with the New York State Canal Corporation, whose interests support navigable waters rather than natural hydrology, so there has been a reduction in the water-level variation since its inception (Montezuma NWR Staff, 2012). For this reason, impoundments were constructed to allow manipulation of water levels in wetland habitats on the refuge, to mimic natural hydroperiods (Montezuma NWR Staff, 2012). In addition to canals, another man-made structure affecting the Montezuma NWR is the New York State Thruway, which bisects the refuge (Montezuma NWR 2012). This highway introduces pollution from runoff, habitat fragmentation, and is a point of introduction for invasive species into the refuge (Montezuma NWR Staff, 2012). In both examples, elements of society's infrastructure, which were not part of the historical condition, now have a direct impact on ecological processes on the refuge. Short of removing both the highway and the canal systems, achieving historical conditions would be impossible because the natural hydrology and connectivity among wetlands cannot be restored. Instead, management actions must attempt to

replicate functions hindered by human development and attempt to mimic the natural timing and fluctuations of ecological processes. However, not all of the required functions are achievable in the modern environment. For example, mimicking a large flood event is not feasible if floodwaters jeopardize the Thruway. Therefore, refuges embedded in a landscape in which substantial portions have been altered by human activity require modified management plans to maintain or restore biological integrity because surrounding land-uses have permanently removed or reduced some characteristics of “as comparable to historical state.”

Similar to the way surrounding land-use affects refuge management, non-native and invasive species are altering species composition ratios and threatening biological integrity on refuges (USFWS, 2010 and USFWS 2013). Most refuges, including those in Region 5, face the challenge of managing for biological integrity in the presence of non-native and invasive species. Throughout history, purposeful and/or accidental introductions has resulted in the naturalization and spread of many these non-native species (Foster *et al.*, 2002). Once introduced, only a small proportion of species became naturalized, and an even smaller portion of these naturalizations produce aggressive, highly invasive species (van Kleunen *et al.*, 2011). Qualities that increase the invasiveness of a species include possessing a wide niche breadth, the ability to tolerate stressful environments, and the ability to exploit benign environments (van Kleunen *et al.*, 2011). Research has shown that disturbance directly facilitates invasive species by reducing the presence of native/established species, consequently reducing the interspecies competition for resources (Firn *et al.*, 2008). Indirectly, disturbance can alter abiotic factors to the extent that they are no longer suitable for native species (Firn *et al.*, 2008). Both non-native and invasive species alter the species composition of an ecosystem and create a formidable “enemy” for refuge management.

In Region 5 CCP documents, non-native and native invasive species are highlighted all the refuges used as case studies. These species do not conform to the FWS definition of biological integrity but are an almost constant presence on refuges. The Iroquois CCP labels common carp as its most invasive animal species and lists its negative attributes as destroying wetland vegetation and

reducing water quality by causing high turbidity (Iroquois NWR Staff, 2011). Iroquois NWR also notes detrimental effects by exotic bird species, such as the European starling (*Sturnus vulgaris*), house sparrow (*Passer domesticus*), and rock pigeon (*Columba livia*), as they compete with native species for nesting sites and other resources (Iroquois NWR Staff, 2011). Similar situations occur on refuges throughout Region 5. Like climate change and surrounding land-use, non-native and invasive species are modern day factors that influence ecosystem trajectories and fail to meet the criteria of “comparable to historical conditions” because they alter ecosystem processes and reduce biodiversity (Montezuma NWR Staff, 2012). Refuges like Montezuma NWR employ costly mitigation actions, which detail plans to eradicate invasive species, or minimize their damage to native plant communities (Montezuma NWR Staff, 2012). Canaan Valley and Rachel Carson are exceptions, as non-native and invasive species are uncommon, which may be attributed to its unique climate and elevation, as well as low levels of disturbance (Canaan Valley NWR Staff, 2011 and Rachel Carson NWR Staff, 2007).

While native species can become invasive, it is typically the non-native species that receive the attention as invasive threats. However, there are several instances where non-native species introductions have occurred through purposeful management actions. One such example is the introduction of non-native species are related to the current management strategy for purple loosestrife. Purple loosestrife is an exotic wetland plant that is turning prime wetland habitat into monoculture stands (Malecki *et al.*, 1993). Thriving in areas of disturbance and lacking natural predators, purple loosestrife effectively replaces native plant species and reduces biological diversity (Malecki *et al.*, 1993). In this scenario, the presence of a non-native invasive plant is destructive to an ecosystem’s overall biological integrity. By “fighting fire with fire,” the refuge management system successfully uses two non-native beetle species, *Galerucella pusilla* and *G. californiensis*, to control purple loosestrife (Grevstad, 2006). Cost-benefit analysis of this management action revealed that these non-native controls were the best option to combat the explosive expansion of purple loosestrife. This management strategy, although contradictory to the idea of historical conditions, also can be viewed as promoting biological integrity because it prevents the invasive species from monopolizing

resources that otherwise would go towards supporting native ecosystems. This example reiterates the argument that “historical condition” should not be linked to the definition of biological integrity because such necessary management actions may directly oppose opposition to the concept.

In some instances, entire non-native ecosystems, such as grasslands, have been purposefully created and maintained on wildlife refuges. While historical grassland habitats existed in the Northeastern region, they were concentrated on the coastal plains of Long Island and Rhode Island, and the “blueberry barrens” along the Maine coast or resulted from periodic disturbances by fire and beaver (Norment, 2002, Askins *et al.*, 2007). Land survey records and palynological data suggest that most of the Northeast was forested during the pre-Columbian time period (Foster *et al.* 2002, Norment, 2002). These naturally occurring grasslands were dominated by warm season grasses and limited to maritime areas and sandy plains (Norment, 2002). Conversely, many of the present-day managed northeastern grassland habitats are comprised of introduced cool season grasses, which are prevalent in anthropogenic habitats like pastures and hayfields (Norment, 2002). As a result, maintaining these early successional habitats is labor-intensive because of the need to introduce frequent disturbance to fight forest succession (Norment, 2002, Askins *et al.*, 2007). Obligate grassland breeding birds in the northeast prefer low-stature, less dense cool season grasslands (Norment, 2002). To promote grassland bird populations, refuge managers should “encourage the growth of non-native cool-season grasses, perhaps in mixtures with native warm-season grasses of lower stature” (Norment, 2002). This management philosophy appears to be in direct conflict with the Integrity Policy’s definition of biological integrity.

Managing for non-native species appears to be in conflict with the concept biological integrity because of the obvious conflict with “historical conditions.” These new species have not evolved with the ecosystem, and consequently do not have an established niche. Ultimately they monopolize resources that would otherwise go to native species, as in the examples previous noted within the Iroquois CCP (Iroquois CCP 2011). They also conflict with how biological integrity is evaluated by

altering the “biological composition, structure, and function” from historic conditions. Refuge 5 examples of this occur at both the species and ecosystem levels.

However, the NWRIA and Integrity Policy address this issue of wildlife refuges specifically managing for non-historical conditions, as is the case for most grassland habitat in Region 5. Both policies urge refuges to consider the appropriateness of these non-historical habitats within a landscape context (Scott *et al.*, 2004). The policy states, “On refuges, we typically focus our evaluations of biological diversity at the refuge scale; however, these refuge evaluations can contribute to assessments at larger landscape scales (601 FW 3).” Ideally, the refuge system should collectively represent all the ecosystem types in the United States; however, refuge lands are unevenly distributed throughout the country (Scott *et al.*, 2004). Cultivating a representation of all the country’s ecosystems at a landscape level represents a broad interpretation of biological integrity, especially where grassland habitat is concerned. There is a continental decline of suitable grassland habitat, and in the Midwest, urban development, agriculture, and range management are spurring the loss of the tallgrass and shortgrass prairies (Vickery *et al.* 1999). As a result, some argue that for species such as the Bobolink and Henslow’s Sparrow, which are declining in their historic ranges due to farm abandonment and succession to woodland habitat, decline of hayfield area, and increased hay cropping during the nesting season, northeastern grasslands may provide important habitat (Norment, 2002). Grassland bird species are characterized as area-sensitive, making them vulnerable to habitat loss and fragmentation (Norment, 2002). Therefore, while non-native grasslands in Region 5 appear to conflict with the Integrity Policy by propagating non-native species and non-historical local conditions, managing for these habitats is aligned with the Integrity policy’s goals of maintaining biological integrity at the landscape level

Maintaining grasslands in the Northeast requires long-term maintenance projects such as frequent mowing, herbicide applications, and prescribed burning. Managing for non-native species and the non-historical conditions of current refuge grassland habitat occurs on all refuges analyzed as case studies, including 316 acres (127 ha) at Montezuma NWR, 223 acres (90 ha) at Missisquoi NWR,

1,186 acres (480 ha) at Iroquois, and 512 acres (207 ha) at Canaan Valley NWR. Montezuma and Missisquoi are reevaluating grasslands in their CCP document, demonstrating an observable shift in grassland management strategy. For example, Montezuma will strategically reduce the amount of grassland acreage by allowing the fragmented and unproductive grasslands to revert to shrubland or forest, which maintaining larger cohesive grassland habitats (Montezuma NWR Staff, 2012). Instead of periodic re-planting and intensive management, Missisquoi now favors maintaining those areas that benefit nesting grasslands birds through delayed mowing, while allowing other underutilized areas to revert to shrubland or forest (Missisquoi NWR Staff, 2007). It is clear that refuges are evaluating grassland habitat as it relates to biological integrity and utilizing a cost-benefit analysis on the services this habitat is providing. It would be detrimental to exclude grasslands from Region 5 refuges, given the continental decline of grassland bird species and the destruction of historic grasslands in their native range. However, maintaining small, fragmented, unproductive grasslands does not align with the foundational concepts of biological integrity. Unless utilizing specifically designated focus areas, expanding grasslands may no longer be feasible in light the Integrity Policy. However maintaining the existing, productive grasslands aligns with the ambiguous concept because these non-native grasslands are filling in the landscape mosaic of varied ecosystems.

As previously mentioned, climate change, surrounding land-use change, and non-native/invasive species are factors that interfere with clearly understanding and implementing biological integrity in light of the current FWS definition. These three factors did not have the same type of influence on the “historical condition” of refuges, and most cannot be removed from the current environment. In the case of sensitive habitats like grasslands, removal of non-native species to conform to historical conditions would interfere with the goal of conserving and promoting grassland bird populations. Achieving historical conditions in environments facing climate change, major changes in surrounding land-use, and invasion by non-native species is difficult or impossible and makes evaluations of biological integrity convoluted and potentially impracticable.

While 601 FW 3 uses the disclaimer that “no landscape retains absolute biological integrity...” (USFWS, 2001), the policy fails to present more relevant measures to evaluate biological integrity. The policy states that its implementation processes will “assess historic conditions and compare them to current conditions. This will provide a benchmark of comparison for the relative intactness of ecosystems' functions and processes. This assessment should include the opportunities and limitations of maintaining and restoring biological integrity, diversity, and environmental health” (USFWS, 2001). While the policy requires the assessment of limitations to maintaining and restoring biological integrity, it does not detail best practices, explain how much or little biological integrity is acceptable, give viable alternatives for assessing biological integrity, or even explain how “historical condition” should be determined. The result is an ambiguous policy, which leads to confusion regarding its implementation. While historical conditions may potentially provide benchmarks for evaluating biological integrity, it is important for the policy to give alternative evaluation techniques in light of modern-day issues like climate change, surrounding land-use, and non-native species. The policy needs to facilitate consistency of management policies across the National Wildlife Refuge System, including guidance on applying the landscape management approach. System-identified reference sites, or indexes of biological integrity, may be one practice that enhances application of the Integrity Policy.

The Integrity Policy's reference to historical conditions carries with it an implicit assumption that ecosystems remain static, when in fact they constantly evolve in response to external forces from non-native species, surrounding land-use, climate change, and cultural changes (Graber 1995, Foster *et al.*, 2002). As Donald Graber (1995) has pointed out in reference to prescribed fire in the Sierra Nevada of California, “The logic of attempting to simulate a fire regime produced by a dynamic aboriginal culture operating in a dynamic climatic regime began to fade by the late 1980s.” Rather than using historical conditions as the benchmark for evaluating biological integrity, the refuge system needs to consider other ways to quantify the concept of biological integrity. This is problematic given that biological integrity is more of a qualitative concept, although either reference sites or biological

assessments using an Index of Biological Integrity (IBI) potentially could serve as evaluative tools for refuge managers. The benefit of including reference sites as a measure for biological integrity is that high-quality reference sites may demonstrate achievable integrity (Meretsky *et al.*, 2006). Ideally, sites selected would experience the same unavoidable impacts, but none of the remediable constraints (Meretsky *et al.*, 2006). Specific attributes could then be measured and compared across sites. Unfortunately, not all ecosystems have available reference sites. In these instances, an alternate form of evaluation would be required.

Where reference sites are not available, the possibility exists that an IBI can be utilized to make biological assessments. Originally developed and proven successful for lotic environments (Karr, 1991), experts are now attempting to apply the same IBI concepts to land-management practices. According to Karr (2004), ecosystems that exhibit depleted populations can be assumed to lack integrity, while those ecosystems that support a balanced, integrated structure are capable of adaptive regeneration following disturbance, and therefore encompass the idea of biological integrity). Karr (2004) explains that biological integrity exists along a gradient of biological conditions. At one end is an historical state that has no human impact and continuing to the point where life is unsupportable because of severe degradation (Figure 9, Karr, 2004). While very cautious about how IBIs are created and utilized, Wilcox *et al.*, (2002) describe the IBI process as utilizing metrics that have been successfully tested against the disturbance gradient using dose-response curves, and ideally yield a clear response to increasing disturbance. Scores are assigned and summed, allowing for the categorizations of very poor, poor, fair, good, or excellent quality (Wilcox *et al.*, 2002). Originally developed by James Karr for fish in small streams, IBIs have been applied to other taxa including birds and amphibians, as well as complex ecosystems. For example, Great Lakes coastal wetlands have been evaluated via several long-term, large scale monitoring programs, which facilitated the development of several biological indices including the Water Quality Index (WQI), the Wetland Fish Index (WFI) and the Wetland Macrophyte Index (WMI) (Cvetkovic and Chow-Fraser, 2011). More specifically, the WQI utilizes 12 variables and a series of equations to categorize the magnitude of

water-quality impairment stemming from anthropogenic influences into six categories ranging from highly degraded to excellent (Cvetkovic and Chow-Fraser, 2011). Results from Cvetkovic and Chow-Fraser's research yielded a "confirmation of the high variability in wetland quality that exists in the Great Lakes" as well as providing "baseline information against which impacts of future development may be measured" (2011).

Karr (1991) writes that "the ideal index would be sensitive to all stresses placed on biological systems by human society while also having limited sensitivity to natural variation in physical and biological environments" (Karr, 1991). The benefit of being able to take complex environmental processes and put them in broad, intuitive "buckets," or IBI classifications, allows for simplified and time-efficient comparisons, interpretations, and analysis of environmental data. This approach *potentially* provides a streamlined and universal approach to assessing and implementing biological integrity on wildlife refuges, as it could yield unambiguous performance criteria. The hierarchical nature of the IBI would then allow Refuge System initiatives to target resources to areas of low IBI rankings to improve levels of biological integrity.

However, it is important to emphasize that IBIs are seductive, in that they allow decisions to be made based on simple numerical rules rather than the true biology of systems. This can be misleading if appropriate vetting for applicability is not completed. Limitations of the IBI approach have been demonstrated in ecosystems with high variability (Wilcox *et al.*, 2002, Euliss *et al.*, 2008 Euliss and Mushet 2011,*et al.*), which often fail to have reproducible results using the IBI. Typically this occurs where, "naturally dynamic climate conditions markedly influence the composition of biotic communities (Euliss and Mushet, 2011)." For example, wetlands have plant communities that respond dramatically to lake-level changes, which then translates into radically different IBI scores, depending on where in the hydroperiod the assessment takes place (Wilcox *et al.*, 2002). This problem has the potential to result in misuse or abuse, as data can be collected at times that falsely represent the true integrity of an area and lead to erroneous conclusions (Wilcox *et al.*, 2002). For example, if a developer wants to modify a wetland for commercial use, he or she needs to demonstrate that the area

does not hold significant environmental value in comparison to the economic benefits the development would yield. Luckily, within the Refuge System sacrificing the environmental integrity of an area for commercial gain is rarely an issue. However, the above example does show that IBIs may not have universal applications for measuring biological integrity, as they are only valid within limited temporal and spatial situations. The USFWS should be very cautious about employing IBIs as a tool to assess biological integrity to ensure it is being utilized appropriately.

As previously stated, IBIs are unlikely to work well in environments with high variability. Ecosystems such as wetlands, which notably are important in all of the Region 5 case studies, have a diminished ability to reproduce IBI scores due to the extreme changes in plant communities resulting from fluctuating water levels (Wilcox, *et al.*, 2002). Research has shown that functional IBIs are applicable only to wetlands with relatively stable hydrology (Wilcox *et al.*, 2002). However, refuges like Canaan Valley NWR listed the development of an index of ecological integrity as a way to “to identify, prioritize, and abate...threats to the integrity of the wetland complex” (Canaan Valley NWR, 2011). The Canaan Valley CCP goes on to say that “once created, adaptive management actions will strive to improve the index score over the 15 years of this comprehensive plan (Canaan Valley NWR, 2011).” Canaan Valley has established a lofty goal, but it may be selecting the wrong tool to evaluate the integrity of a wetland complex. Wilcox *et al.* (2002) recommend that “IBI scores not be used (in determining wetland quality) unless the scoring ranges are calibrated for the specific hydrologic history pre-dating any sampling year (Wilcox, 2002).”

Instead of developing an IBI, a refuge such as Canaan Valley might be better served by applying the Hydrogeomorphic Method (HGM). While the IBI focuses on community structure to estimate ecosystem conditions, HGM utilizes ecosystem function (Stevenson and Hauer, 2002). In addition, HGM examines hydrology and abiotic features across a temporal scale (Euliss *et al.*, 2008), which accounts for the variability in the wetland ecosystems that IBIs are not able to quantify accurately. HGM begins with a functional assessment of wetlands, which places the area under evaluation into a hydrogeomorphic class (Stevenson and Hauer, 2002). Next comes a broad-based

functional analysis (surface water storage, nutrient cycling, characteristic plant community, etc.), followed by comparisons to the expected functions in a less disturbed area of the same class (Stevenson and Hauer, 2002). Adaptive management and restoration activities need mechanisms to evaluate performance and effectiveness (Stevenson and Richard, 2002). Although IBIs and HGMs are possible alternatives to using historical condition to gauge biological integrity, it is important to understand their limitations. Careful planning and strategic thinking needs to be utilized to insure the proper measurement systems and mechanisms of analysis are identified, measured, and evaluated.

Targeted instructions for measuring biological integrity are missing from the 1997 NWRSIA legislation, which emphasizes the refuge management's responsibility to "monitor the status and trends of fish, wildlife, and plants in each refuge." While the refuge measurement philosophy continues to evolve, historically refuges have tracked sport species, often marginalizing those species not hunted (Karr, 2004). In addition, refuges operated under the assumption that large populations of priority species resulted from managing for habitats preferred by those species (Karr, 2004). However, population size is rarely a reliable indicator of species success due to its reflexive response to environmental variation (Karr, 2004). Rather than focusing on individual priority species counts, measurements need to be "directly connected to the important dimensions of biological condition (Karr, 2004)." In Karr's opinion, this would include limiting measurements of management actions, like counting the number of permits issued, and utilizing indicator measurements that occur closer to biological condition, such as taxa richness and percentage of taxa belonging to tolerant taxa, which may be more indicative of achieving a desired biological condition (Karr, 2004). When selecting metrics of biological condition, it is important to include diverse dimensions of living systems (taxa richness, relative abundance, individual health, etc.), capture multiple components of biology (biomarkers, population, ecosystem, landscape characteristics), and be sensitive to a range of human impacts (logging, introduction to non-native species, environmental fragmentation, etc.) (Karr, 2004). To define biological integrity, it is important to define these parameters and document how each reacts to human and natural disturbances (Karr, 2004). A successful measurement plan for defining biological integrity would leverage inventory work already being performed on the refuge but focus

the results in useful tabulations to gauge biological integrity. In fact, criteria for assessing ecosystem degradation using IBIs could assist in both inventory and restoration activities (Wilcox *et al.*, 2002). For this to be accomplished, refuges need to limit haphazard surveillance monitoring and invest in more worthwhile pursuits, specifically by shifting to monitoring for active conservation, to more effectively and efficiently utilize limited resources (Nichols and Williams, 2006).

The NWRS has recently reevaluated its policy on Inventory and Monitoring (I&M) and has stated that the I&M should help “the Service lead in developing approaches to inventory and monitor biological integrity, biological diversity, and environmental health (USFWS 2010).” The USDA Forest Inventory & Analysis Program (FIA), EPA National Aquatic Resource Surveys (NARS), and the NRCS Natural Resource Inventory (NRI) are three existing federal programs that could be leveraged to gather the desired data on a continental scale (USFWS, 2010). The Inventory and Monitoring 7 Year Plan: 2013-2020 (USFWS, 2013) details plans for gathering and synthesizing data to evaluate the effectiveness of policy initiatives. Prioritized projects include abiotic data, adaptive management, baseline biotic inventories, invasive species monitoring, water resources inventory and monitoring, and wildlife health, among others (USFWS, 2013). These initiatives are all ways the NWRS can focus its monitoring practices into an effective and efficient information gathering strategy.

Effective monitoring and assessment programs contain four key processes: classification of environment types, sampling biota, integrating analytical procedures, and communicating results (Karr, 2004). Indicators and measurable attributes should be organized in a unified framework for ecological assessment and implemented on all refuges (Stevenson and Hauer, 2002). The above suggestions for constructing measurement programs are on the radar of refuge staff as they construct Habitat Management Plans and Species Inventory and Monitoring Plans. These plans are “vital for implementing habitat management actions and measuring success in meeting the objectives (Canaan Valley NWR Staff, 2011). Employing standard methods across the NWR System allows shareable information for synthesizing individual or multiple studies (Stevenson and Hauer, 2002). Standardization will allow for an integrated analysis of biological integrity on multiple scales, so that

contributions made on individual refuges, as well as assessments of landscape level integrity, can be understood.

Conclusion

The NWRIA demands that the refuge system, “ensure the biological integrity...for present and future generations.” The legislative wording does not qualify this statement by adding “where appropriate” or “to the degree practicable” (Fischman, 2004). Therefore, the new directive shifts management perspective from being primarily species-directed to refocusing on the “biotic composition, structure, and function” across multiple levels of varying ecological complexity. Biological integrity is the over-arching concept that encompasses the needs of a well functioning landscape (Fischman, 2004). Ecosystems that support a balanced, integrated structure are capable of adapting to and regenerating following disturbances, which is the epitome of biological integrity (Karr, 2004). A refuge’s founding mission, bird conservation regions, and other management directives are singular components of integrity, which may flourish on solid foundations resulting from integrity-based management policy practices.

For the biological integrity concept to shape refuge management, some of the ambiguity surrounding its definition and application must be removed. With outside influences such as surrounding land-use, invasive species, and climate change altering the ecological trajectories, historical conditions proves to be an unattainable goal. The refuge system operates in a highly manipulated landscape, and often requires intensive management practices to achieve the needs of various focal species. In addition, some ecosystems, like grasslands, are so vulnerable to habitat loss in their native range that the NWRS has made a concerted effort to support them in locations outside of their natural/historical range. It is clear that “historical condition” is not broadly applicable to the numerous goals of the National Wildlife Refuge System, and should be removed from the definition. Suggestions for clarifying the use and applications of biological integrity include:

- 1.) Rewording the USFWS definition of biological integrity so that the statement “as comparable to historical conditions” is removed to allow for other, more appropriate assessments of biological integrity.
- 2.) Reference sites and hydrogeomorphic assessments should be identified as potentially valuable tools available to refuge managers to assess biological integrity. The policy should identify these as standard practices to establish uniform procedures across the System and ensure their proper applications.
- 3.) IBI’s should be used with caution and scrutiny to ensure its application is appropriate and accurate.

The National Wildlife Refuge System Improvement Act of 1997 was created to unify the NWR System under a common mission. By clarifying the Integrity Policy and its applications, the NWR system can truly be unified in both practice and mission. This is a crucial step for the NWR system. As stated by an Iroquois NWR staff member, “in the past, management might have been done just because that is what someone wanted to do, with no consideration for the overall ecosystem...now there seems to be a more thoughtful process that ensures we are accountable for what we do.” This accountability that will drive the future success of the National Wildlife Refuge System.

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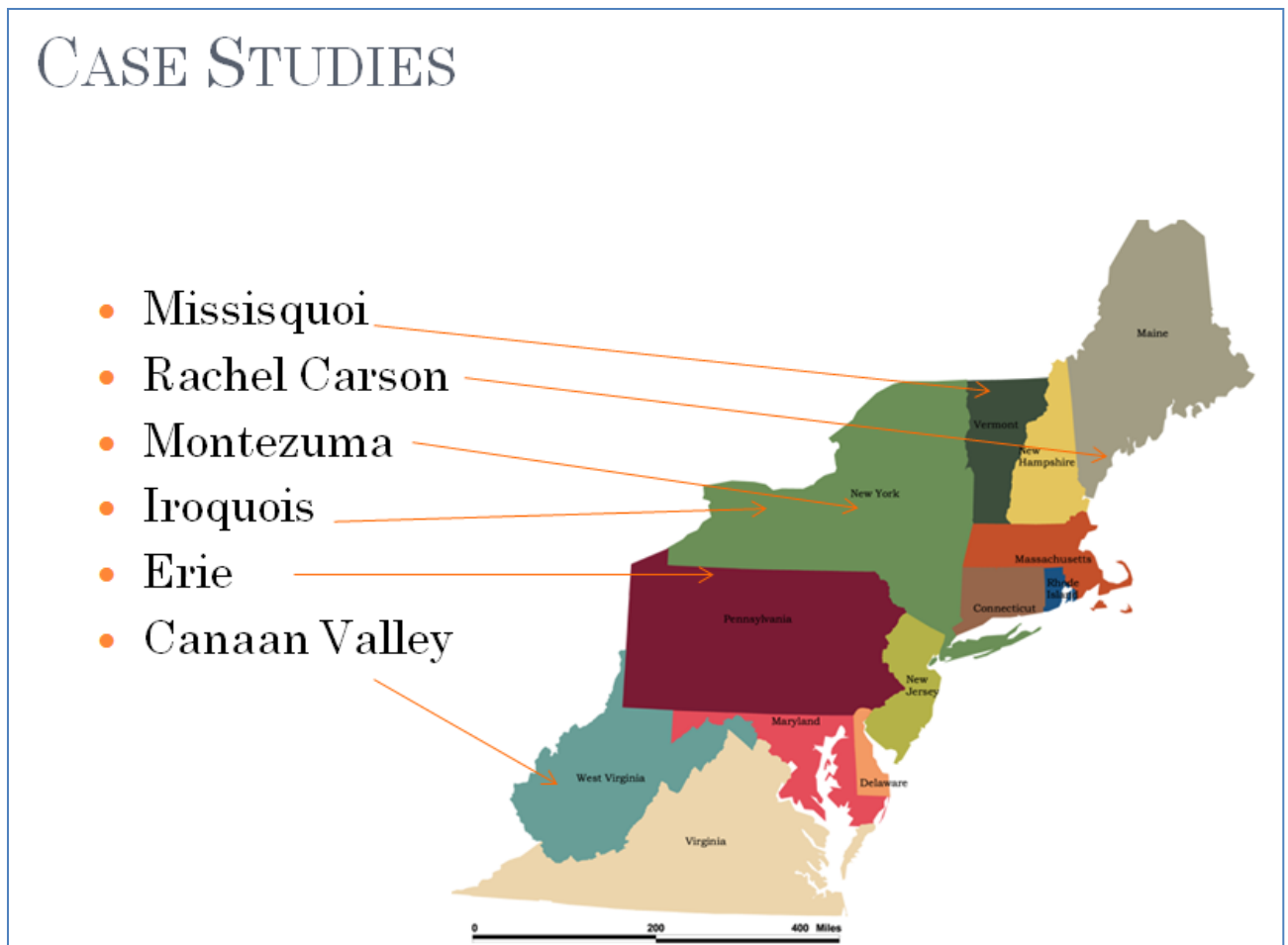


Figure 1: Map of the NWR Region 5 states along with relative locations of the case study locations.

Source: <http://www.fws.gov/northeast/offices.html>

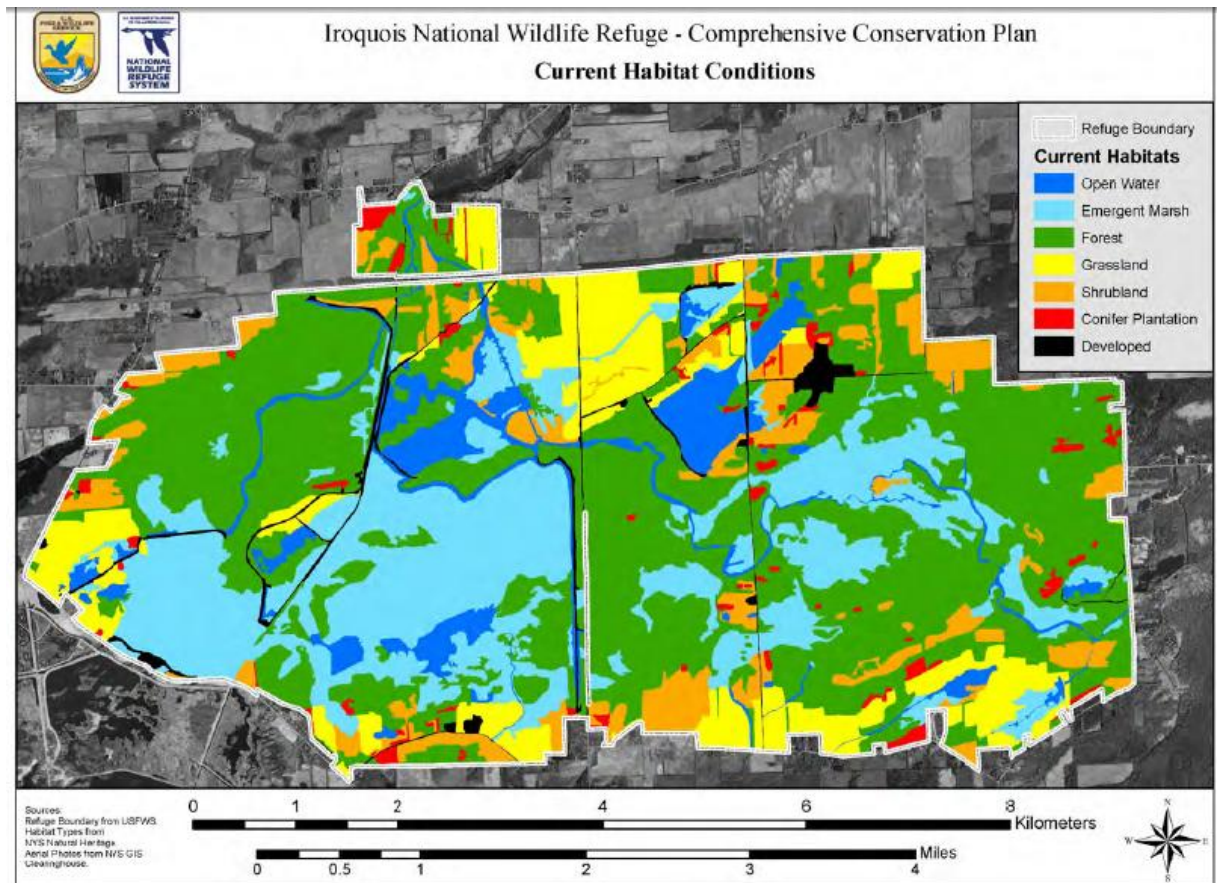


Figure 2: Map detailing the current habitat conditions at Iroquois NWR.

Source: Iroquois NWR Staff. 2011. Comprehensive Conservation Planning, Final. USFWS, Basom, NY. Available at: <http://www.fws.gov/northeast/planning/Iroquois/finalCCP.html>.

Declining Species:				
Species	Adjusted Trend	N routes	(Unadjusted Trend [2.5% CI, 97.5%CI])	

Significant trends (P less than 0.05):				
Western Meadowlark	-4.4	388	-4.4	(-6.8 -1.7)
Eastern Meadowlark	-3.4	1803	-3.4	(-3.8 -3.0)
Grasshopper Sparrow	-3.3	1141	-3.3	(-4.3 -2.2)
Bobolink	-2.6	1115	-2.6	(-3.3 -2.0)
Savannah Sparrow	-2.0	1252	-2.0	(-2.8 -1.0)
Horned Lark	-1.4	1040	-1.4	(-2.3 -0.4)

Figure 3: Declining breeding grassland bird species in the Eastern BBS (Breeding Bird Survey) Region.

Source: Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2012. *The North American Breeding Bird Survey, Results and Analysis 1966 - 2011. Version 12.13.* 2011 USGS Patuxent Wildlife Research Center, Laurel, MD



Figure 4: Map detailing Missisquoi NWR.

Source: Missisquoi National Wildlife Refuge Staff. 2007. Comprehensive Conservation , Final. USFWS, Hadely, MA. Available at: <http://www.fws.gov/northeast/planning/missisquoi/finalccp.html>.

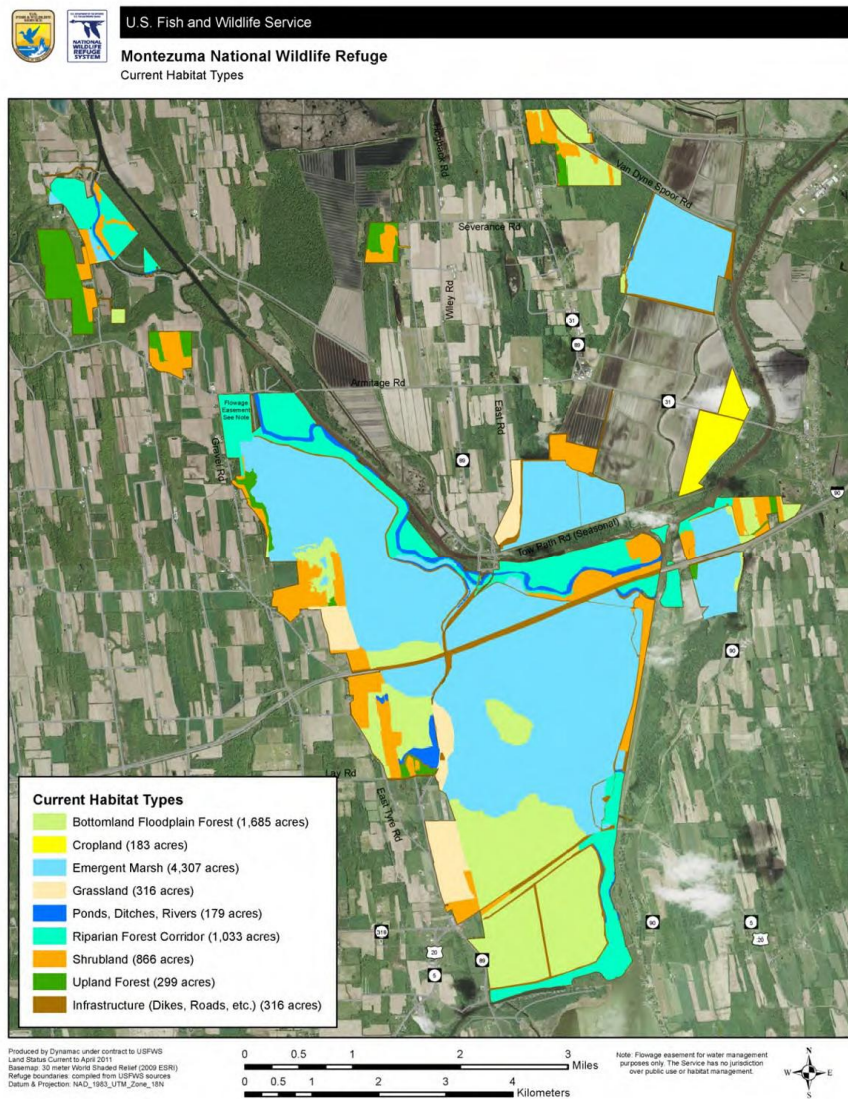


Figure 5: Map detailing current habitat conditions at Montezuma NWR.
Source: Montezuma National Wildlife Refuge Staff. 2012. Comprehensive Conservation Plan and Ecological Assessment, Draft. USFWS, Seneca Falls, NY. Available at: <http://www.fws.gov/northeast/planning/Montezuma/ccpchapters.html>.

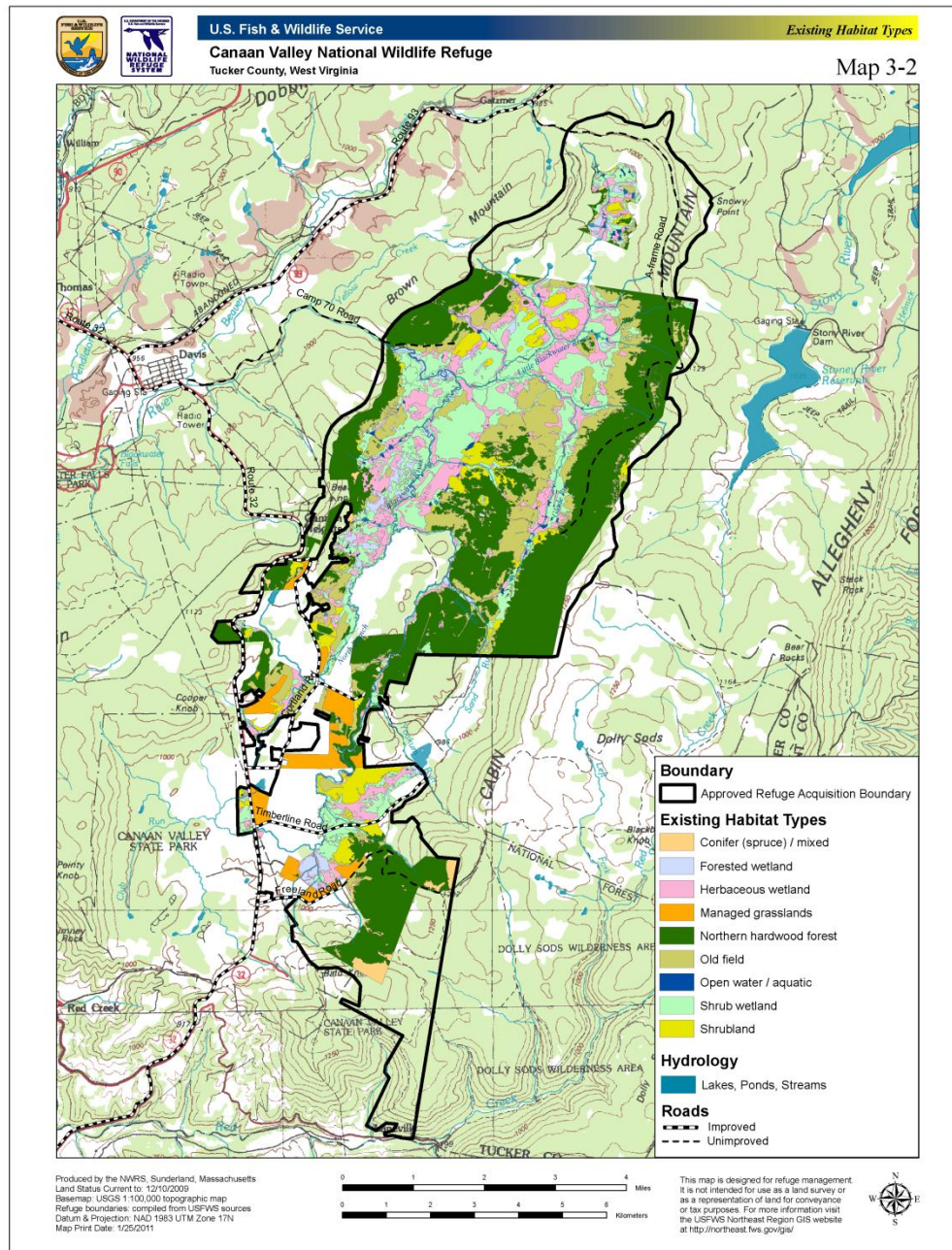


Figure 6: Existing habitat types on Canaan Valley NWR.
 Source: Canaan Valley NWR Staff. 2011. Canaan Valley National Wildlife Refuge Comprehensive Conservation Plan, Final. USFWS, Davis, WV. Available at: <http://www.fws.gov/Northeast/planning/Canaan%20Valley/fianlccp.html>



Figure 7: Map of Rachel Carson NWR division locations.

Source: Rachel Carson NWR Staff. 2007. Rachel Carson National Wildlife Refuge Comprehensive Conservation Plan, Final. USFWS, Hadley, MA. Available at: <http://www.fws.gov/northeast/planning/rachel%20carson/finalccp.html>.

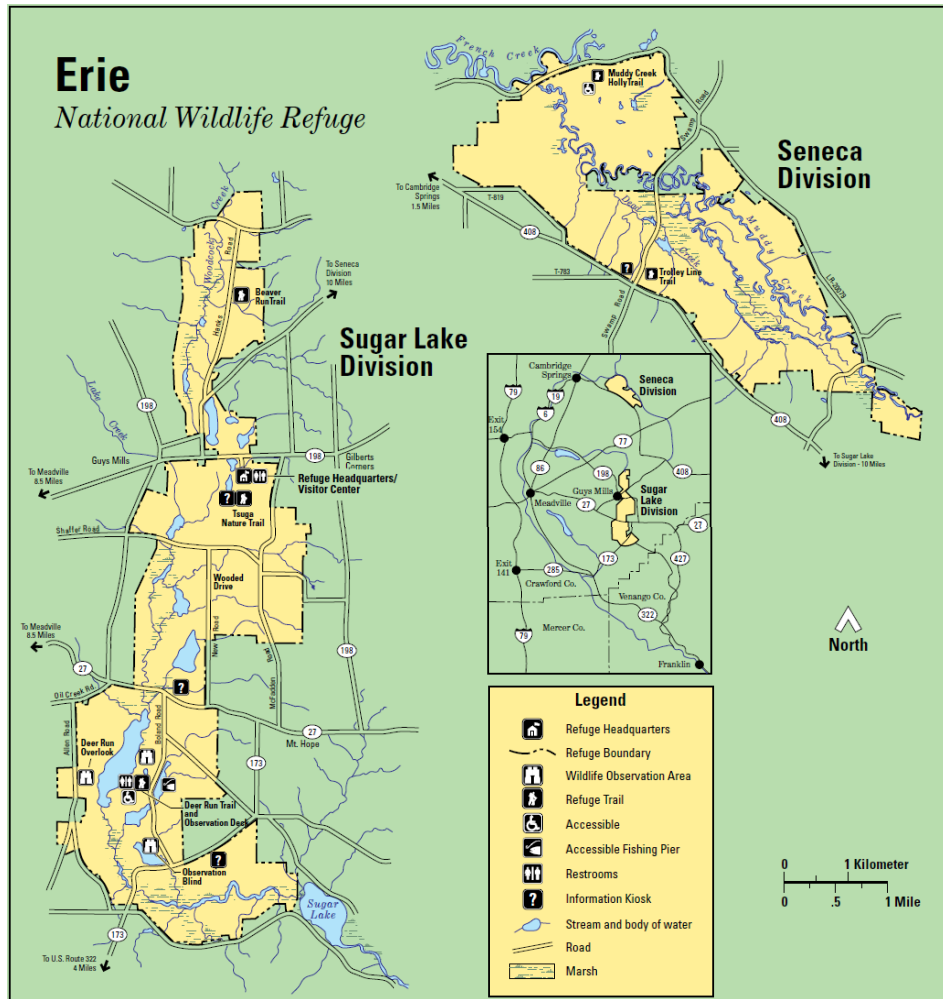


Figure 8: Map of the Seneca and Sugar Lake Divisions at Erie National Wildlife Refuge.
 Source: US Fish and Wildlife Service. 2011. Erie National Wildlife Refuge Brochure. Available at:
<http://www.fws.gov/refuge/erie/about.html>.

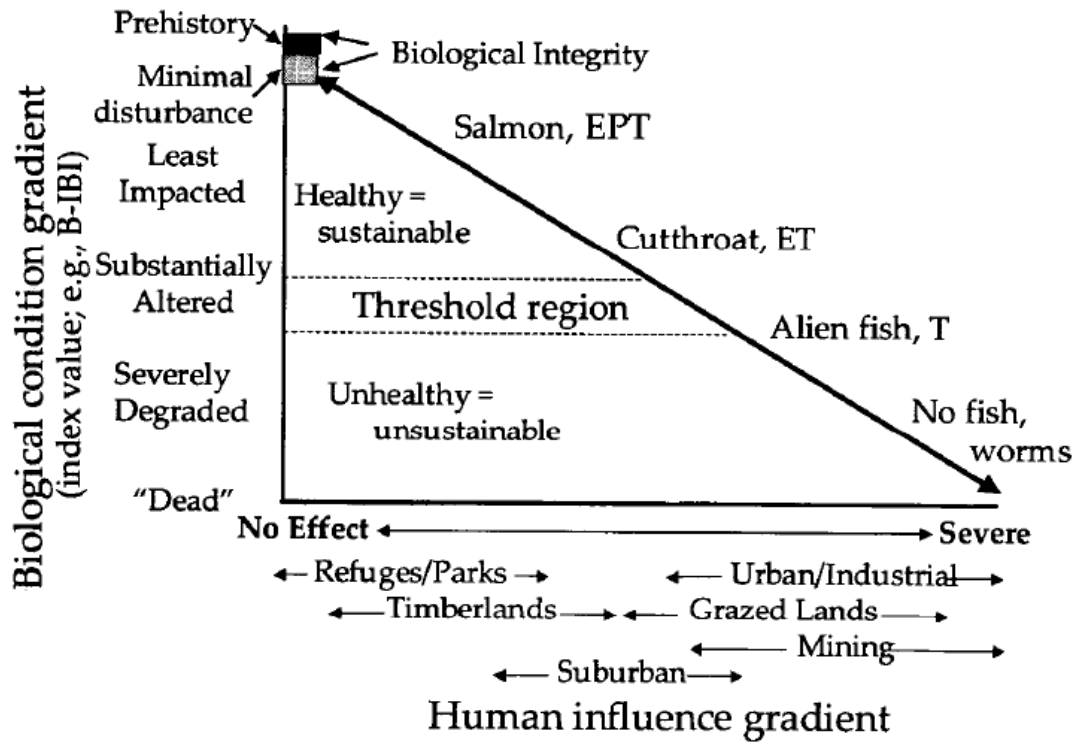


Figure 9: Biological condition's relationship to human influence.

Source: Karr, J.R. 2004. Beyond definitions: Maintaining biological integrity, diversity, and environmental health in nation wildlife refuges. *National Resources Journal* 44: 1067-1092