How Much Habitat is Enough?

A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern

Second Edition

Environment Canada
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About the Canadian Wildlife Service

The Canadian Wildlife Service, part of Environment Canada, manages wildlife matters that are the responsibility of the federal government. These include protection and management of migratory birds, nationally-significant habitat and endangered species, as well as work on other wildlife issues of national and international importance. In addition, the Canadian Wildlife Service does research in many fields of wildlife biology and provides incentive programs for land stewardship and donation.

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Executive Summary

How Much Habitat is Enough?: A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (the *Framework)* provides science-based information and general guidelines to assist government and non-government restoration practitioners, planners and others involved in natural heritage conservation and preservation in ensuring there is adequate wetland, riparian and forest habitat to sustain minimum viable wildlife populations and help maintain selected ecosystem functions and attributes. The *Framework* provides 18 wetland, riparian and forest habitat guidelines and accompanying rationales. Within Great Lakes Areas of Concern (AOCs), the *Framework* can be used to assist in the setting and achievement of delisting criteria concerning fish and wildlife habitat beneficial-use impairments, and post delisting can provide further guidance on habitat restoration.

A 2002 assessment of the *Framework* (first edition) showed it was well-used both within and outside of AOCs. It was used as originally envisioned as a guide to set restoration targets and locate restoration projects, and also as a science-based reference for agencies protecting habitat and identifying natural heritage systems. To ensure that the *Framework* is based on the most current science this second edition incorporates a review of the relevant new literature that has appeared since the first edition was published in 1998. Two guidelines, *Amount of Natural Vegetation Adjacent to a Wetland* and *Percent of an Urbanized Watershed that is Impervious*, have changed since the first edition and four guidelines have been modified to a minor extent – *Wetland Size, Wetland Shape, Total Suspended Sediments* and *Fragmented Landscapes and the Role of Corridors.*

To illustrate application of the *Framework* within AOCs a summary of its use in the Severn Sound AOC is provided. An outline is also provided of the Terrestrial Natural Heritage Strategy being developed in Toronto that moves beyond the general *Framework* guidelines to consider local conditions and the effect on habitat of the matrix of land-uses in a landscape. Key to providing adequate wildlife habitat is the protection of existing habitat and, in acknowledgement, the second edition provides suggestions on use of the *Framework* in land-use planning.

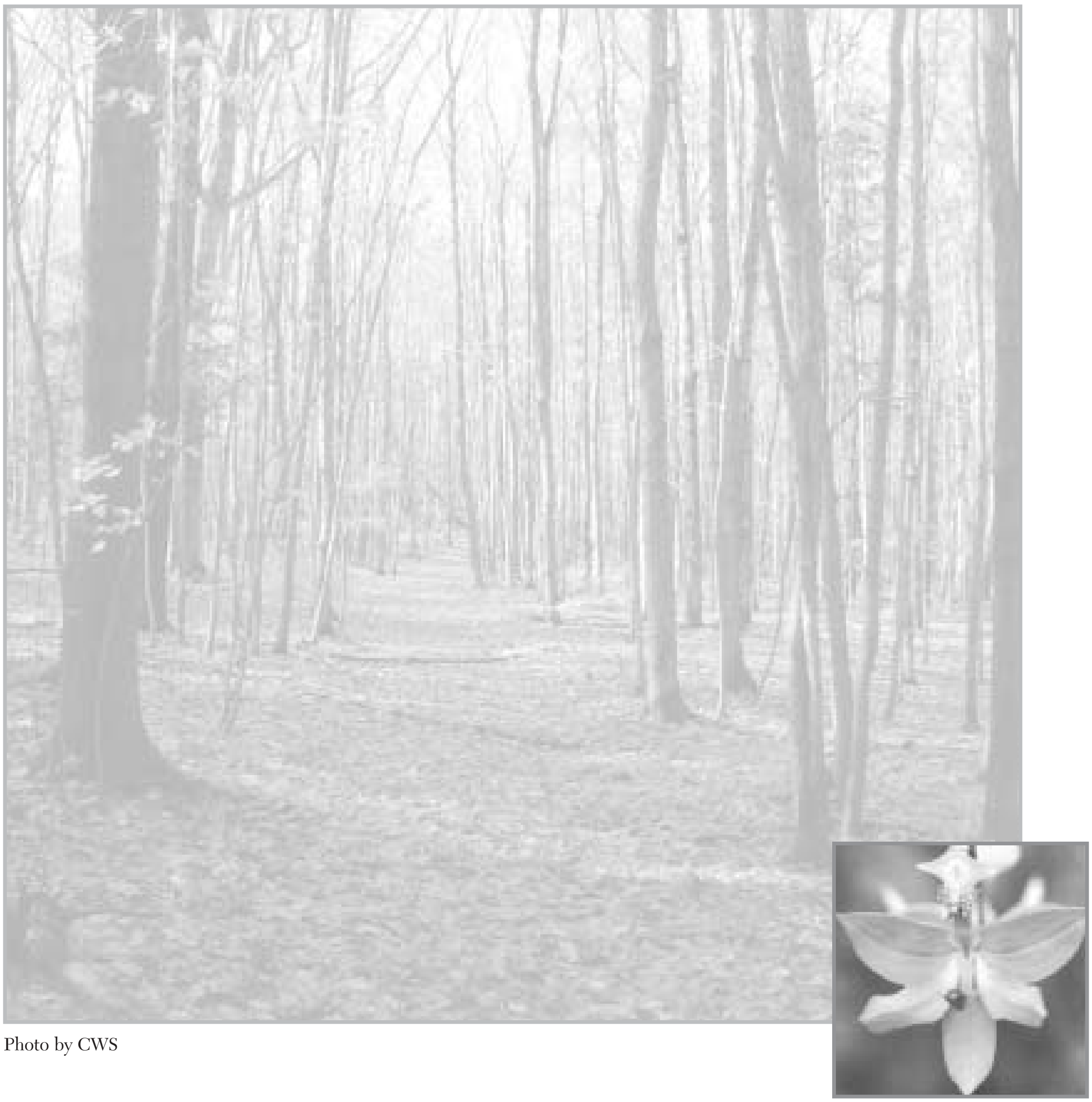
The *Framework* is meant to be built upon and to be adapted according to historical and present local conditions. The *Framework* will hopefully continue to serve as a starting point to develop strategies to conserve habitat, develop natural heritage systems and discuss guidelines regarding other habitat types such as grasslands.

Acknowledgements for the Second Edition

A Framework for *Guiding Habitat Rehabilitation in Great Lakes Areas of Concern* (the *Framework*) has been the product of many individuals since its beginning in 1995 and publication of the first edition in 1998. It was guided and championed by the Ontario Ministry of the Environment, the Canadian Wildlife Service of Environment Canada and the Ontario Ministry of Natural Resources. Al Sandilands and Chris Wren from Ecological Services for Planning Limited helped in the initial development of the first edition and expertise was drawn from organizations and agencies within and outside of Areas of Concern (AOCs) which included conservation authorities, private consultants, Environment Canada, the Department of Fisheries and Oceans, the Ontario Ministry of Natural Resources, and the Ontario Ministry of the Environment. Environment Canada's Great Lakes Cleanup Fund and the Ontario Ministry of the Environment provided funding.

The second edition resulted from a 2002 assessment of the *Framework* that showed a need to update the guidelines and science upon which they were based. Brian McHattie, Brian Henshaw, Lionel Normand, and Keith Sherman made major contributions to the second edition. Valuable review and comments were provided by Nancy Patterson, Mike Cadman, Angus Norman, the South-Central Ontario Conservation Authority Natural Heritage Discussion Group, Natalie Iwanycki, Lisa Turnbull, Don Wismer, Janette Anderson, Sandra George, Rimi Kalinauskas, Carolyn O'Neill, Scott MacKay, John Marsden, Anne Borgman and Sandra Skog.

Table of Contents



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Introduction

A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (*Framework*) was published as a first edition in the mid-1990s for Remedial Action Plan (RAP) teams and Public Advisory Committees (PACs). These groups were working to rehabilitate ecosystems in 17 Canadian Areas of Concern (AOCs) across the Great Lakes basin. As of 2003, there are 15 AOCs subsequent to the delisting of Collingwood Harbour and Severn Sound.

In most of these locations, loss of fish and wildlife habitat and related degradation of populations have been identified as "beneficial-use impairments". The term was coined by the International Joint Commission and is used to categorize problems in AOCs. Before an AOC can be considered restored, targets must be developed to measure progress. Remedial Action Plans guide the remediation of AOCs to the point that their environmental condition (as defined by the restoration of beneficial-use impairments) is comparable to regional conditions outside of AOCs.

Primarily, the *Framework* assists those developing and implementing RAPs to select appropriate fish and wildlife habitat targets as part of delisting criteria and provide guidance to initiatives which will, post-listing, help maintain or enhance habitat conditions to support viable fish and wildlife populations. The *Framework* can be used on a regional basis throughout the Great Lakes basin to help establish targets for habitat that will support minimum viable wildlife populations.

Secondly, the *Framework* provides a method to prioritize locations for wetland, riparian and forest habitat rehabilitation projects across a watershed or other landscape unit. The guidelines presented here are based on an understanding of how much habitat is required to provide for the ecological needs of fish and wildlife species in three types of habitat: wetlands, riparian areas, and forested areas. Note that the terms rehabilitation and restoration are used synonymously throughout this document.

Beyond the AOCs, the *Framework* has demonstrated broad applicability in jurisdictions across Ontario where factors have led to ecological degradation. In a number of locations outside of AOCs, information from the *Framework* helped to guide the development of comprehensive habitat rehabilitation plans, including identifying priority upland and aquatic projects. These plans worked in tandem with protection plans toward achieving a functioning system of protected natural areas (Canadian Wildlife Service, 2002). This approach is designed to build on the natural heritage system of protected areas currently implemented in the province through the municipal land-use planning process.

A natural heritage system identifies the current system of natural areas that is in many cases degraded by past land-use decisions, such as fragmented and small forest patches or drained wetlands. This second edition of the *Framework* provides updated guidance on where and how much habitat to rehabilitate in order to attain a more fully-functioning natural heritage system (i.e., by expanding and linking forest patches, re-flooding wetland soils).

Development background for this guide

In response to a need for restoration targets as expressed through the RAP program, Ecological Services for Planning Limited was hired in early 1995 by Environment Canada (Canadian Wildlife Service), the Ontario Ministry of the Environment and the Ontario Ministry of Natural Resources to undertake a review of literature pertaining to natural heritage strategies. The resulting document, *Using the Natural Heritage Strategy Approach to Develop Habitat Rehabilitation and Restoration Targets and Project Priorities*, recommended upland habitat targets derived from landscape ecology concepts, reviewed environmental mapping approaches, and provided case studies on how the approach could be implemented using two AOCs as examples: Nipigon Bay and Toronto and Region AOCs.

In January 1996, the document was used to develop a Canada-Ontario Remedial Action Plan Steering Committee interim report entitled, *Identifying Habitat Rehabilitation Targets and Priorities in Great Lakes Areas of Concern: Upland Systems* (Environment Canada, the Ontario Ministry of Natural Resources and Ontario Ministry of the Environment and Energy, 1996). The report was later refined to include guidelines for riparian and wetland habitat rehabilitation based on an additional literature search by Ecological Services for Planning Limited. Pilot applications using a variety of approaches were then funded by the Great Lakes 2000 Cleanup Fund (now Great Lakes Sustainability Fund) with local partners in nine AOCs, which served to test and improve early versions of the *Framework*.

Since its publication in 1998, the first edition of the *Framework* has been cited and used widely both within and outside of AOCs. It has gained recognition as a basic overview of current ecosystem principles applied to rehabilitation within the Great Lakes basin. Within AOCs, the *Framework* has been used to establish rehabilitation sites, formulate watershed and natural heritage strategies and, in some cases, help set delisting criteria.

In 2003, Gartner Lee Limited were contracted by Environment Canada (Canadian Wildlife Service) to review recent pertinent literature and to present suggested amendments to guidelines and their rationales, primarily based on new science. Results of the review, which were incorporated in this second edition, ensure that the *Framework* maintains currency and applicability in a swiftly evolving area of scientific investigation and understanding.

Guidelines are not targets

The *Framework* should be viewed as a means to guide, not dictate, local decisions, providing planners and rehabilitation teams with the best available information to enable them to make their own decisions on how much habitat is required to rehabilitate local watersheds and landscapes. The *Framework* does not represent policy or legislation – its guidelines are meant to assist and to be used within existing statutes and policies such as the provincial *Planning Act*. The *Framework* is not watershed or landscape specific. The guidelines provided are not intended as mandatory limits or targets, and it is not intended that every area must meet the guidelines expressed here.

In terms of AOCs, RAPs tend to focus on the remediation of water quality and the habitats of species which play a direct role in aquatic ecosystems. The benchmark for terrestrial habitat, which is the focus of the *Framework*, is largely defined in the RAP process by conditions in the landscape adjacent to AOCs, upstream of AOCs or other site-specific considerations. In setting aquatic and terrestrial delisting criteria, the bounds of RAP objectives have to be primarily considered. The *Framework* can augment and assist in setting delisting criteria, bearing in mind RAP objectives, can help set regional targets and benchmarks for habitat, and can provide a context for the status of habitat in AOCs compared to regional conditions.

An understanding of local conditions is required to set habitat rehabilitation targets that make sense for local cultural and natural conditions. In this way, the *Framework* is broadly applicable to both impoverished and richer landscapes.

The wetland, riparian and forest habitat categories addressed here capture many characteristics of Great Lakes AOCs. Agencies and/or personnel working in AOCs may also develop their own local strategies to deal with additional and equally-important habitat categories such as grassland, alvar, and lake habitats. Indeed, these habitat types may warrant future investigation within the scope of the *Framework*. In some AOCs, including St. Clair River, habitats such as grassland may be essential to restore wildlife habitat.

In most AOCs, and across southern Ontario, changes to ecosystems have not been so great as to preclude rehabilitation of those systems to approach a state of naturalness using pre-settlement conditions for context. Such rehabilitation has occurred in the former AOCs, Collingwood Harbour and Severn Sound, where habitat had not been degraded or lost to a degree where ecosystem functions were irreversibly altered or lost. Local conditions and remaining habitat were considered in rehabilitation efforts that ultimately restored natural systems to a viable state in a post-settlement landscape. However, changes in urban areas of some AOCs may have shifted ecosystems to an entirely new state. Providing wildlife habitat and other ecosystem functions such as maintenance of base flows in streams and local climate moderation can only partially be provided through restoration and creation of habitat emulating pre-settlement conditions. New baselines for habitat and functions may have to be set that consider urban areas and their balance with regional watershed or landscape conditions, and new systems may have to be devised to remediate lost ecosystem functions and mitigate and balance the impacts of large urban centres beyond their own borders.

Overall, a review of the ecological literature makes it clear that the habitat guidelines, such as 30 percent forest cover or 75 percent riparian cover, represent minimum desirable habitat proportions. Landscapes with habitat exceeding these minimum amounts should be conserved and enhanced whenever possible.

How to use this guide

Guidelines provided here are for three habitat categories: wetlands, riparian areas, and forested areas. In reality, of course, these habitats overlap and are separated only to provide clearly understood guiding principles. For instance, the wetland habitat section discusses forested wetland or swamp habitat in reference to the significant hydrological role it plays; the forest habitat section refers to its key biological role in providing bird-nesting habitat. Similarly, riparian wetlands are found along vegetated flood plain zones, which are discussed in the wetland and riparian habitat sections.

Each habitat category contains a background section and a discussion of guidelines and supporting rationale. Some guidelines lend themselves well to quantification and tables illustrating optimum levels and threshold values, while other guidelines are more qualitative. In Appendix 1, an example can be found of a natural heritage strategy that used the guidelines for the former Severn Sound AOC. Appendix 2 is an overview of the Toronto and Region Conservation Authority's Terrestrial Natural Heritage Strategy, which considers the influence of the matrix of surrounding lands when setting rehabilitation or conservation targets.

Appendix 3 describes how *Framework* thresholds and guidelines can be integrated into Official Plans by municipal planners in a top-down fashion. Many agencies have used *Framework* guidelines in creating watershed strategies and natural heritage strategies with the intention that the documents be considered and applied by municipalities.

Setting guidelines for habitat – some considerations

The *Framework* guidelines are intended as minimum ecological requirements. The state of the historic landscape (pre-settlement) should be used as a base reference point for restoration. AOC watersheds, municipalities or other land units that contain higher amounts of habitat than outlined here (e.g., 35 percent forest cover, 15 percent wetlands) should maintain or improve that habitat.

In the case of the Niagara River AOC, wetlands comprised nearly 40 percent of the landscape in pre-settlement times; whereas, in the Humber River watershed in the Toronto and Region AOC, it is unlikely that wetlands ever exceeded five percent of the watershed. The establishment of a historic or fundamental context for ecological function provides one of the reference points required to assist in setting targets.

The second reference point is the existing condition, along with some knowledge of the magnitude of impacts. Comparison of these two conditions provides a realistic context for the establishment of targets and identification of rehabilitation activities. The historic condition provides the direction for restoration while the existing condition indicates how far the system is from being healthy and what needs to be improved. The knowledge of the magnitude of impacts is also necessary because the establishment of targets must include an assessment of what might reasonably be achieved with existing restoration technology and land-use patterns.

Guidelines provided in the *Framework* represent the best understanding from the current state of ecological knowledge. They are intended to provide the guidance needed to set local habitat restoration and protection targets. The state of ecological knowledge is rapidly improving so targets set today may need to be revised as the understanding of complex, dynamic ecosystems evolves.

Primary importance of habitat protection

For RAPs, the focus is on restoring degraded fish and wildlife habitat in an AOC, and this document is designed to assist in that pursuit. *However, it needs to be emphasized that the protection of* ***existing*** *habitat must remain the most important planning activity in any jurisdiction.* RAP teams and PACs must work with local planning authorities to ensure that habitats (or natural areas) are identified and protected within the AOC and the surrounding landscape. The link to the loss of fish and wildlife habitat beneficial-use impairment becomes clear when natural heritage system plans (Riley and Mohr, 1994) identify gaps in the system, or when existing habitat is determined to be impaired. Protection and rehabilitation of impaired or missing habitats is integral to a fully-functioning natural heritage system.

Stressors beyond habitat

There are additional stressors that affect fish and wildlife populations beyond the loss of habitat. Poor water quality due to low oxygen conditions or the presence of toxic substances may explain why fish and wildlife communities are impaired when other aspects of suitable habitat appear to be present. Some researchers believe that declines in amphibian populations in apparently pristine habitats may be due to factors such as viruses, acid rain, concentrations of nitrates, or increased exposure to UVB light. Beyond habitat issues, restoration practitioners should be aware of any additional stressors from the surrounding landscape that may impair fish and wildlife populations.

Beyond watershed boundaries

Management of habitats for fish and wildlife may fail if restricted to a watershed. Restoration planners working on a watershed scale should be prepared to link with planning studies being conducted at other scales, including ecological units such as an ecodistrict or ecoregion. For example, the *Big Picture Project* (Carolinian Canada, 2002) deals with the Carolinian zone. Planning across ecosystems ensures restoration and protection of a full range of ecosystem types and can help mitigate cumulative impacts. To promote linkages of habitat between watersheds and across landscapes, surviving habitat corridors and geographic features should be carefully considered. Valley lands and stream corridors often form the basis for linkages from the Great Lakes inland and large landscape features such as relict glacial landscapes (e.g., moraines, dune systems) and unique topographic features (e.g., the Niagara Escarpment, the Frontenac Arch) provide inter-watershed and greater bioregional linkages. Restoration of, and to, these features may be the best strategy to efficiently ensure species can disperse and forage between the habitat within the watershed and the broader landscape.

Landscape matrix

The guidelines and thresholds in the *Framework* are not landscape or watershed specific. Natural heritage and watershed strategies can further address ecosystem integrity by considering guidelines in the context of land-use in a specific watershed. For example, a given percentage of forest cover in a largely urban watershed may not provide habitat for the same number of forest bird species as it might in a rural landscape. Natural systems are best considered in the context of the remainder of their watershed, which may be composed of varying proportions of rural and urban land-uses. This matrix of land cover types in a landscape can influence the habitat quality, ecological function, and composition of flora and fauna species. As noted previously, Appendix 2 offers an example of a natural heritage strategy that considers a matrix of land-uses, the Toronto and Region Conservation Authority's Terrestrial Natural Heritage Strategy.

Species at Risk

Species context should be considered alongside landscape context. Specific habitat requirements for species should be considered, especially for those regarded by the federal or provincial government to be at some risk of extinction or extirpation. Rehabilitation of habitat should consider habitat attributes critical for such species, and the presence of these species will likely be a factor in prioritizing habitat rehabilitation and protection projects. Under the federal *Species at Risk Act*, critical habitat is described as "…the habitat that is necessary for the recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species." (Canada, 2002).

Table 1. Summary of Wetland, Riparian and Forest Habitat Restoration Guidelines

Parameter	Guideline
Wetland Habitat Guidelines	
Parameter	**Guideline**
Percent wetlands in watersheds and subwatersheds	Greater than 10 percent of each major watershed in wetland habitat; greater than six percent of each subwatershed in wetland habitat; or restore to original percentage of wetlands in the watershed.
Amount of natural vegetation adjacent to the wetland	For key wetland functions and attributes, the identification and maintenance of the Critical Function Zone and its protection, along with an appropriate Protection Zone, is the primary concern. Where this is not derived from site-specific characteristics, the following are minimum guidelines: ■ Bog: the total catchment area ■ Fen: 100 m or as determined by hydrogeological study, whichever is greater ■ Marsh: 100 m ■ Swamp: 100 m
Wetland type	The only two wetland types suitable for widespread rehabilitation are marshes and swamps.
Wetland location	Wetlands can provide benefits anywhere in a watershed, but particular wetland functions can be achieved by rehabilitating wetlands in key locations, such as headwater areas for groundwater discharge and recharge, flood plains for flood attenuation, and coastal wetlands for fish production. Special attention should be paid to historic wetland locations or the site and soil conditions.
Wetland size	Wetlands of a variety of sizes, types, and hydroperiods should be maintained across a landscape. Swamps and marshes of sufficient size to support habitat heterogeneity are particularly important.
Wetland shape	As with upland forests, in order to maximize habitat opportunities for edge-intolerant species, and where the surrounding matrix is not natural habitat, swamps should be regularly shaped with minimum edge and maximum interior habitat.
Riparian Habitat Guidelines	
Parameter	**Guideline**
Percent of stream naturally vegetated	75 percent of stream length should be naturally vegetated.
Amount of natural vegetation adjacent to streams	Streams should have a minimum 30 m wide naturally vegetated adjacent-lands area on both sides, greater depending on site-specific conditions.
Total suspended sediments	Where and when possible suspended sediment concentrations should be below 25 milligrams/litre or be consistent with Canadian Council of Ministers of the Environment (1999) guidelines.
Percent of an urbanizing watershed that is impervious	Less than 10 percent imperviousness in an urbanizing watershed should maintain stream water quality and quantity, and preserve aquatic species density and biodiversity. An upper limit of 30 percent represents a threshold for degraded systems.
Fish communities	Watershed guidelines for fish communities can be established based on knowledge of underlying characteristics of a watershed (e.g., drainage area, surficial geology, flow regime), historic and current fish communities, and factors (and their relative magnitudes) that currently impact the system.
Forest Habitat Guidelines	
Parameter	**Guideline**
Percent forest cover	At least 30 percent of the AOC watershed should be in forest cover.
Size of largest forest patch	A watershed or other land unit should have at least one 200-ha forest patch that is a minimum 500 m in width.
Percent of watershed that is forest cover 100 m and 200 m from forest edge	The proportion of the watershed that is forest cover 100 m or further from the forest edge should be greater than 10 percent. The proportion of the watershed that is forest cover 200 m or further from the forest edge should be greater than five percent.
Forest shape	To be of maximum use to species such as forest-breeding birds that are intolerant of edge habitat, forest patches should be circular or square in shape.
Proximity to other forested patches	To be of maximum use to species such as forest-interior birds, forest patches should be within two km of one another or other supporting habitat features.
Fragmented landscapes and the role of corridors	Connectivity width will vary depending on the objectives of the project and the attributes of the nodes that will be connected. Corridors designed to facilitate species movement should be a minimum of 50 m to 100 m in width. Corridors designed to accommodate breeding habitat for specialist species need to be designed to meet the habitat requirements of those target species.
Forest quality – species composition and age structure	Watershed forest cover should be representative of the full diversity of forest types found at that latitude.

Habitat Guidelines

2.1 Wetland Habitat Guidelines

Wetlands – a critical part of the landscape

A high proportion of Ontario's fish and wildlife species inhabit wetlands during part of their life cycle. Many of the species at risk of extinction in southern Ontario are highly dependent on wetlands. Wetlands shave off peak flows and impound water, thereby increasing the travel time of water down a watercourse. This slowing action not only reduces water velocities and peaks immediately downstream, it also results in an asynchronization of peaks (i.e., peak flows from tributaries reach the main watercourse at different times). Wetlands provide a significant economic benefit from a flood-control perspective, and can be more efficient than flood impoundment systems. Wetlands augment low-flow by raising local water tables, which in turn contribute to stream base flows. Wetlands also perform significant roles in water-quality improvement.

The following series of wetland habitat guidelines relate to the amount of wetlands in a watershed, the amount of vegetation adjacent to a wetland, wetland type and location, and shape and size.

Table 2. Summary of Wetland Habitat Guidelines

Parameter	Guideline
Percent wetlands in watershed and subwatersheds	Greater than 10 percent of each major watershed in wetland habitat; greater than six percent of each subwatershed in wetland habitat; or restore to original percentage of wetlands in the watershed.
Amount of natural vegetation adjacent to the wetland	For key wetland functions and attributes, the identification and maintenance of the Critical Function Zone and its protection, along with an appropriate Protection Zone, is the primary concern. Where this is not derived from site-specific characteristics, the following are minimum guidelines: ■ Bog: the total catchment area ■ Fen: 100 m or as determined by hydrogeological study, whichever is greater ■ Marsh: 100 m ■ Swamp: 100 m.
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Wetland location	Wetlands can provide benefits anywhere in a watershed, but particular wetland functions can be achieved by rehabilitating wetlands in key locations such as headwater areas for groundwater discharge and recharge, flood plains for flood attenuation, and coastal wetlands for fish production. Special attention should be paid to historic wetland locations or the site and soil conditions.
Wetland size	Wetlands of a variety of sizes, types, and hydroperiods should be maintained across a landscape. Swamps and marshes of sufficient size to support habitat heterogeneity are particularly important.
Wetland shape	As with upland forests, in order to maximize habitat opportunities for edge-intolerant species, and where the surrounding matrix is not natural habitat, swamps should be regularly shaped with minimum edge and maximum interior habitat.

2.1.1 Percent Wetlands in Watershed and Subwatersheds

> *Guideline*

Greater than 10 percent of each major watershed in wetland habitat; greater than six percent of each subwatershed in wetland habitat; or restore to original percentage of wetlands in the watershed.

> *Rationale*

Critical ratios of wetland area to watershed area will vary according to channel slope, as well as land-use or land cover within a watershed (Detenbeck *et al*., 1999). In addition, the interaction of riparian buffer zones, soil types and other factors (e.g., forest cover) will affect hydrologic effects of wetland loss or gain within a watershed. When considering wetland restoration opportunities or guidelines, it is also important to consider the location and type of wetlands that might be appropriate within a landscape. This assessment can be based on historical and current patterns of wetlands in the landscape (Bedford, 1999; Detenbeck *et al*., 1999).

Historically, wetland coverage within the Great Lakes Basin exceeded 10 percent (Detenbeck *et al*., 1999). In Wisconsin, Hey and Wickencamp (1996) examined nine watersheds and found that increasing the amount of wetland in a watershed resulted in reduced watershed yield of water, reduced flooding, higher base flows, and reduced occurrence of high flows. However, these responses flattened very rapidly above 10 percent of wetland cover. A study in Saginaw Bay estimated that having 15 percent of a watershed in wetlands would reduce phosphorus loadings by 66 percent (Wang and Mitsch, 1995), and other studies have determined that having five percent wetland cover greatly helped water quality.

A study conducted by Carol Johnson at the University of Minnesota (Johnson *et al*., 1990) found that watersheds in the southern United States containing less than 10 percent wetlands were more susceptible to incremental losses of wetlands than watersheds with more wetlands. This condition was found to be particularly true for flood control and suspended solids loadings.

The guideline of six percent wetland cover for subwatersheds helps to ensure that wetlands are distributed around the watershed basin, while retaining a realistic wetland-cover percentage that can result in tangible hydrological and ecological benefits on a subwatershed basis. This guideline will also be influenced by historic wetland extent, topography, and soils in a specific watershed or AOC.

Photo by Graham Bryan

2.1.2 Wetland Type

> *Guideline*

The only two wetland types suitable for widespread rehabilitation are marshes and swamps.

> *Rationale*

There are four general wetland types in Ontario: bogs, fens, marshes, and swamps.

Bogs and Fens

Bogs are highly specialized environments and true bogs are rare in the southern part of the Great Lakes Basin. They receive almost all of their water and nutrients from precipitation. They are acidic and have very low productivity. Plants inhabiting bogs must be adapted to these low nutrient levels. There are few trees in bogs (by most definitions six metres tall) – generally less than 25 percent cover and usually consisting only of Black Spruce. The dominant vegetation is usually ericaceous shrubs and sphagnum mosses. Bogs are also characterized by their relative lack of vascular plant species, although they may be rich in other life forms.

Fens receive most of their water and nutrients from groundwater. Depending on the source of the groundwater, they may be either nutrient-rich or nutrient-poor. Nutrient-rich fens are often dominated by sedges. Calcareous fens can support a wide variety of plant species and may be treed with White Cedar (although with less than 25 percent cover). Nutrient-poor fens may be very similar in their character to bogs, with subtle differences in the sedge and moss species that dominate and the presence in fens of so-called "fen indicators" that are typical of higher-nutrient environments. Because carnivorous plants (e.g., various sundews and Pitcher Plants) frequently occur in fens, they are not useful indicators of true bogs.

Bogs and some fens have a substrate of peat covered with mosses. Due to microdrainage patterns, bogs and fens may co-exist, particularly in large wetlands. Occasionally, the edge of a wetland may be a fen as it is exposed to groundwater; however, the accumulations of peat prevent groundwater from reaching the centre where it may be more bog-like. Over centuries, fens may evolve into bogs and vice versa, as a result of how peat forms and changes water flow patterns.

Fens and especially bogs are rare habitats in southern Ontario, off the Canadian Shield. Together, they constitute only one percent of the wetlands remaining in the south. However, in the north and particularly in the Hudson Bay Lowlands, poor fens cover extensive areas. Bogs and fens are highly susceptible to changes in nutrient and water inputs. Even small variations may alter them into other wetland types or even into upland habitat.

Limited information is available on the science of rehabilitating bogs and fens. The best management strategy for these wetland types is to protect them. It is also essential to protect their water sources and not alter their watersheds.

Swamps

As the most abundant wetland type in southern Ontario, swamps comprise 89 percent of remaining wetland area.

Swamps perform many important biological functions. They may be dominated by a variety of coniferous and deciduous shrub and tree species. Swamps also tend to be hummocky and may support upland plant species in these microhabitats. Swamps support higher diversities of plant and wildlife species than other wetland or forest communities. They also provide critical habitat for many species. For example:

- most deer and moose-wintering areas are in coniferous swamps
- a high proportion of cold-water streams originate in swamps (most Brook Trout streams originate in swamps)
- in southern Ontario, forest-interior or area-sensitive species are often found in swamps, as these frequently comprise the largest remaining forested tracts on the landscape
- many of Ontario's wildlife species primarily occur in swamps, including: Wood Frog, Northern Ringneck Snake, Wood Duck, Common Goldeneye, Hooded Merganser, Olive-sided Flycatcher, Cerulean Warbler, Northern Waterthrush, Louisiana Waterthrush, Snowshoe Hare, Woodland Jumping Mouse, and Common Gray Fox.

Swamps also contribute significantly to the amount of forested habitat in southern Ontario. A high proportion of the remaining forests are swamps, as the lands they occupy often have limited capabilities for supporting agricultural crops or other land-uses if they are cleared.

Depending upon the terrain, swamps may perform important hydrological functions. They are frequently in areas of groundwater discharge, thus protecting headwaters of streams. In these situations, swamps maintain the cold-water nature of watercourses through the interception or reflection of heat energy. They also contribute critical nutrients to these small streams through leaves and other detritus. These provide food for grazing species of aquatic invertebrates, which are a basis of the food chain in small streams. Tree limbs and logs are important in-stream cover for aquatic invertebrates and fish.

Swamps along larger watercourses provide storage for floodwaters, thereby reducing peak flows and downstream flooding. This natural inundation within the forest supplies essential nutrients to plant communities and habitat for certain wildlife species. These types of swamps are also important in improving stream water quality. Plant communities in some swamps are very dynamic, with the understory being dominated with wetland species early in the growing season, and species adapted to drier conditions later in the year. Spring flooding provides ephemeral ponds that are used for breeding by frogs, toads, and salamanders. These same pools are also important breeding areas for invertebrates such as some caddisflies and midges, and these, in turn, are important food for bats and many bird species.

Marshes

Marshes are the other type of wetland in southern Ontario. Although the term wetland usually means a cattail marsh to most people, marshes represent only about 10 percent of the area of wetlands in southern Ontario and 5.4 percent of all of the province's wetlands (Riley, 1989).

Marshes perform many important biological functions. Today, extensive marshes relative to historic conditions are rare in the landscape, so species that require this habitat are also restricted in their distribution. Several fish and wildlife species are totally dependent on marshes, and a high proportion of these are of provincial and federal significance. Some examples of obligate marsh species are: Spotted Gar, Spotted Sucker, Banded Killifish, Bullfrog, Map Turtle, Fox Snake, Pied-billed Grebe, Red-necked Grebe, Least Bittern, Ruddy Duck, King Rail, Virginia Rail, Sora, Common Moorhen, American Coot, Forster's Tern, Black Tern, Marsh Wren, Yellow-headed Blackbird, and Muskrat.

Marshes are used by a high proportion of other fish and wildlife species for some period of their life cycle, frequently for critical functions such as breeding, nursery areas, or for feeding. Jude and Pappas (1992) found that of 113 fish species occurring in the Great Lakes, 41.6 percent were coastal marsh species and 31 percent used coastal marshes for nursery habitat or feeding. In Lake Ontario marshes, 63.9 percent of species present used marshes for spawning and 86 percent of species used marshes as nursery habitat. The importance of marshes to the fish of the Great Lakes and also inland water bodies cannot be overemphasized. Approximately 90 percent of the fish biomass in Lake Erie is forage fish, and most of this is produced in wetlands (Keast *et al*., 1978; Stephenson, 1988; 1990).

One of the most important hydrological functions of wetlands is uptake of nutrients, heavy metals and other contaminants. The efficiency of marshes in improving water quality varies considerably, depending on factors such as the location of the marsh in relation to overland flows, substrate types, dominant plant species, contact time with the water that flows through, and climate. As an example, the marshes at the mouth of Old Woman Creek in Ohio have been estimated to remove 12 to 60 percent of the metals passing through the system and 35 to 80 percent of the biologically active nutrients (Herdendorf, 1992).

Inland marshes are important in flood control. Isolated marshes store water and prevent a certain proportion of precipitation runoff from reaching watercourses. Marshes on watercourses also store water and reduce flow velocity, thereby reducing peak flows.

Marsh vegetation stabilizes shorelines and reduces the risk of erosion. This is a particularly important function in watercourses and on lakes where there is a long fetch. By helping to maintain shorelines, marshes prevent loss of property, reduce sediment delivery to water bodies, and help maintain the character of stream channels.

Types of Wetlands Suitable for Restoration

The two wetland types that are practical for widespread rehabilitation are marshes and swamps. Currently, limited information is available on the science of rehabilitating fens and bogs. The best management strategy for bogs and fens (and for all wetlands) is to protect them by protecting their water sources and not altering their watersheds. In some cases, abandoned pits and quarries that are connected to the water table may offer unique opportunities for fen creation (Hough Woodland Naylor Dance, and Gore and Storrie Ltd., 1995).

Marshes are easier to rehabilitate and a newly-created marsh will be at least partially functional within a few years. It may take longer before a rehabilitated swamp becomes functional, and a few decades before it is fully-functional, as it takes more time for trees and tall shrubs to grow.

Photo by John Mitchell

2.1.3 Amount of Natural Vegetation Adjacent to the Wetland

> *Guideline*

For key wetland functions and attributes, the identification and maintenance of the Critical Function Zone, and the protection of it, along with an appropriate Protection Zone, is the primary concern. Where this is not derived from site-specific characteristics, the following are minimum guidelines:

- *Bog – the total catchment area*
- *Fen – 100 m or as determined by hydrogeological study, whichever is greater*
- *Marsh – 100 m*
- *Swamp – 100 m.*

> *Rationale*

The amount of natural habitat that is located adjacent to wetlands can be particularly important to the maintenance of wetland functions and attributes. These adjacent lands are often referred to as "buffers". However, in many cases they form an intrinsic part of the wetland ecosystem, providing a variety of habitat functions for wetland-associated fauna that extend beyond the wetland limit and therefore could better be described as Critical Function Zones (CFZs).

Critical Function Zones defined

The term Critical Function Zone (CFZ) describes non-wetland areas within which biophysical functions or attributes directly related to the wetland of interest occur. This could, for example, be adjacent upland grassland nesting habitat for waterfowl (that use the wetland to raise their broods). It could also be upland turtle nesting habitat for turtles that otherwise occupy the wetland, foraging areas for Leopard Frogs, dragonflies or nesting habitat for birds that often straddle the wetland-upland ecozone (e.g., Yellow Warbler). A groundwater recharge area that is important for the function of an adjacent wetland could also be considered a CFZ.

Effectively, the CFZ is a functional extension of the wetland into the upland. Once identified, the CFZ (with the wetland itself) needs to be protected from adverse effects that originate from outside the wetland and its CFZ, by a Protection Zone (PZ). This could range in scope from a simple fence (for example to dissuade human access) to a vegetated area for intercepting storm water run-off or providing physical separation from a stressor. Effectively, the Protection Zone is aimed at reducing impacts on wetland functions that originate from the upland side.

The combined CFZ and its Protection Zone may range in total width from a few metres to hundreds of metres.

Other "buffer" functions such as providing a filtering function to reduce nutrients or contaminants, decrease indirect effects such as noise or visual disturbance, or reduce direct human-associated intrusions into the wetland from the outside, are better addressed through a PZ, which is analogous to a barrier or filter strip. The PZ can also be integrated into urban design, offering opportunities for the focussing of pedestrian traffic, recreation, aesthetics, interpretation, and integration of urban infrastructure (e.g., storm water management facilities as barriers).

These two layers on the outside of the wetland – the CFZ (that encapsulates functions that extend out from the wetland) and the PZ that seeks to protect the CFZ from outside influences – together make up the total adjacent-lands area (i.e., the wetland buffer).

Differentiating between CFZs and PZs within the overall adjacent lands, the *Framework* encourages a shift towards the development of Multicriteria Evaluation for buffers (van der Merwe *et al*., 2001). This approach encourages the identification and prioritization of various criteria that are selected on a site specific basis. This could result, for example, in the encouragement of some land-uses or activities within the PZs, but not within the CFZs. The use of these "bands" within the adjacent-lands area could help resolve some difficult land-use questions when urban development is proposed close to wetlands.

The overall adjacent-lands width needs to be responsive to the ecological setting (e.g., the complementary effect of adjacent habitats [Pope *et al*., 2000; Guerry and Hunter, 2002]) and its inter-relationships with potential stressors (Gartner Lee Limited, 1992). Management objectives, individual characteristics of the wetland, ecological interactions with upland areas, the source, magnitude and frequency of potential stressors and engineering options, all contribute to the design of effective adjacent-lands areas.

Table 3. Critical Function Zones

Function or Attribute (when present)	Extent of attribute into uplands (CFZ)	Reference	Notes
Nesting Painted Turtles	1 m to 620 m, mean 90 m	Christens and Bider, 1987.	
Spotted Turtle and Blanding's Turtle	(Distances are mean plus standard deviation.) Spotted Turtle 85 m for nesting, 54 m for dormancy; Blanding's Turtle 380 m for nesting, 18 m for basking and 114 m for dormancy	Joyal *et al*., 2001.	Used radio-tracking in Maine.
Spotted Turtle	Nesting 75 m to 312 m; dormancy up to 412 m	Milam and Melvin, 2001.	Used radio-tracking of 26 animals in Massachusetts.
Freshwater turtles	73 m for 90 percent of nests	Burke and Gibbons. 1995.	Used radio-tracking.
Green Frog foraging forays	Mean 36 m, standard deviation 25 m	Lamoureux *et al*., 2002.	Used radio-tracking in New York. Terrestrial feeding areas may be critical (based on frog mass changes).
Ambystoma salamanders	Means: 125 m for adults, 70 m for juveniles; 164 m (90 percent)	Semlitsch, 1998.	Recommends corridors be integrated into adjacent land determination.
Tiger Salamander (an Ambystoma)	173 m	Trenham, 2001.	Study may have under-estimated adjacent-land requirements.
Nesting waterfowl	0 m to more than 400 m; 90 percent were within 200 m	Henshaw and Leadbeater, 1998.	Based empirical data over two years and 102 nests at coastal marshes. About 20 percent of nests were inside or within 25 m of wetlands. May be applicable where suitable waterfowl nesting habitat is present.

Table 4. Protection Zones

Stressor	Suggested extent of protective zone (PZ)	Reference	Notes
Herbicide drift from agricultural lands	Strip at edge of cultivated fields (data indicate >6 m to 9 m)	Boutin and Jobin, 1998.	Cites other studies suggesting 5 m to 10 m.
Nitrate	16 m to 104 m	Basnyat *et al*., 1999.	Objective was >90 percent nitrate removal.
Non-point source agricultural pollutants	16.3 m grass/woody strip (riparian)	Lee *et al*., 2003.	Removed >97 percent of sediment, narrower (7 m) grass provided some benefits.
Residential stormwater	15 m; 23 m to 30 m on slopes greater than 12 percent	Woodard and Rock, 1995.	Groundcover type also very important.
Urban cats	190 m	Haspel and Calhoon, 1991.	Predation rates on wildlife variable.
Lawn-related (e.g., wood piles, composting)	19 m to 38 m	Matlack, 1993.	Fencing may achieve same results in less width.
Recreation-related (e.g., camping, hacked trees)	67 m to 130 m	Matlack, 1993.	
Human disturbance by watercraft	Flush distances (proximity of disturbance that will cause bird to leave a nest) (mean plus standard deviation) approximately 45 m to 80 m for Great Lakes species (no waterfowl). Recommended distances are greater.	Rodgers and Schwikert, 2001.	Empirical data, based on a Florida study of personal watercraft and outboard-powered boats.
Human disturbance on nesting Great Blue Herons	100 m	Rodgers and Smith, 1995. Erwin, 1989.	Flush distance was 32 m plus 5.5 m standard deviation, plus 40 m to mitigate antagonistic behaviour.

Table 5. Selected Reviews or Guidelines that Consider Adjacent Lands Areas

Citation	Adjacent lands	Notes
Brown, M.T., J. Schaefer and K. Brandt. 1990.	Groundwater mostly 30 m to 168 m (range 6 m to 168 m). Sedimentation PZ 23 m to 114 m. Wildlife CFZ 98 m to 223 m.	Provided PZ minimum and maximums based on landscape associations. Average conditions used, based on literature review.
Castelle, A.J., A.W. Johnson and C. Conolly. 1994.	Minimum of 15 m to 30 m under most circumstances, but site-specific.	Provides review of literature pertaining to sediment removal, nutrient removal, stormwater runoff, moderation of temperature, habitat diversity, wildlife and human impacts (i.e., CFZs and PZs).
Gabor, T.S., A.K. North, L.C.M. Ross, H.R. Murkin, J.S. Anderson, and M.A. Turner, 2001.	No conclusions are offered regarding minimum or maximum adjacent lands areas.	Presents literature regarding PZs for sedimentation and erosion, nutrient management, pathogens and pesticides.
Lowrance, R., S. Dabney and R. Schultz. 2002.	Presents 10 U.S. adjacent-lands practices (USDA-NRCS). Range from 1 m to 30 m.	Generally providing PZ for erosion control, reduced contamination transport or other agricultural benefits. Recommend caution regarding very narrow strips.
Norman, A. J., 1996.	Baseline adjacent lands area of 50 m, then subject to site-specific considerations (e.g., waterfowl production, sensitive hydrology).	PZ and CFZ literature reviewed, mostly pre-1989 literature. Includes citations for wildlife. (e.g., nesting waterfowl).

Table 6. Adjacent-Lands Guidelines

For key wetland functions and attributes, the identification and maintenance of the Critical Function Zone (CFZ), and the protection of it, along with an appropriate Protection Zone (PZ), is the primary concern. Where this is not derived from site-specific characteristics, the following are minimum guidelines:

Wetland Type*	Habitat Guidelines
Bog	Catchment
Fen (poor fens and rich fens)	100 m or as determined by hydrogeological study, whichever is greater
Marsh	100 m
Swamp	100 m

* There are varying definitions of wetland types, particularly bogs. This guideline is based on the definition of wetland types provided by OMNR (1994).

Determining a guide for the appropriate delineation of adjacent-lands areas requires knowledge of the attributes of the area of interest, an understanding of the existing or future stressors, the use of up-to-date science to help determine both the likely extent of attributes (including their CFZs), and the type and extent of PZs that may be required. In the following tables (Tables 3, 4 and 5) some examples are provided.

A review of these tables demonstrates that appropriate adjacent-lands areas cannot be determined based on a one-size-fits-all approach. A scientifically supportable CFZ/PZ combination might be 170 metres in one location and 50 metres in another even though both locations may be part of the same wetland system. Determination must be based on functions, attributes, site characteristics, stressors, design, and, not least, management objectives and expectations for the adjacent-lands area.

Based on current knowledge, the literature increasingly indicates that the greatest CFZ requirements tend to be associated with wildlife attributes, especially those around marshes. Much of this new information is coming from studies that are making use of new miniature tracking technologies. It is critical that rehabilitation efforts focus on the CFZ of key existing or anticipated species.

Most wetlands around the Great Lakes Basin are likely to support at least some wildlife attributes that also include the upland areas as seasonal habitat. Therefore, minimum wetland adjacent-lands areas based on water quality parameters alone (i.e., 15 metres to 30 metres on slopes of less than 12 percent with good ground cover) are unlikely to be sufficient. Based on this review, the CFZ for attributes associated with wetlands can only be determined based on site-specific knowledge of those attributes and their sensitivities, and on management objectives.

Based on the current level of scientific support for adjacent-lands areas, reasonable minimum guidelines are provided in Table 6.

2.1.4 Wetland Location

> *Guideline*

Wetlands can provide benefits anywhere in a watershed, but particular wetland functions can be achieved by rehabilitating wetlands in key locations such as headwater areas for groundwater discharge and recharge, flood plains for flood attenuation, and coastal wetlands for fish production. Special attention should be paid to historic wetland locations or the site and soil conditions.

> *Rationale*

Wetlands rehabilitated anywhere within a watershed will provide an array of benefits including regulation of peak water flows and increases in biodiversity, provided that they are sites suitable for creating or restoring wetland habitat.

Increasingly, there is scientific guidance available regarding the "best" location for wetlands within a watershed (e.g., Griener and Hershner, 1998; DeLaney, 1995). This will depend in part on the characteristics of a watershed (Norton and Fisher, 2000). However, there is little doubt that landscape setting is important for wetland function (Mitsch and Gosselink, 2000) or that the correct landscape placement is also important for wetland creation projects (Babb *et al*., 1997).

Wetlands can provide benefits that address specific objectives, problems or research needs when they are strategically-located. Guidance on determining the strategic location of, and approach to, wetland restoration projects is becoming increasingly available. Almendinger (1999) describes a method to prioritize restoration sites for water quality improvement, while Bedford (1999) suggests an approach that relies on the *a priori* establishment of cumulative effects to help determine past and present wetland profiles.

In headwater areas, wetlands can provide critical functions. For swamps, these include protection of the quality of groundwater discharge (and/or recharge), introduction of leaves and woody debris that are essential to the diversity of fish and macroinvertebrates downstream (Gurnell *et al*., 1995 cited in Detenbeck *et al*., 1999), and reducing the warming of streams at the source. In turn, good water-quality conditions in higher portions of watersheds are likely to benefit downstream coastal wetland ecosystems (Crosbie and Chow-Fraser, 1999).

Further downstream, palustrine and riverine wetlands are important in reducing and asynchronizing peak flows, improving water quality, and providing habitat for aquatic invertebrates, fish and other wildlife.

In lakes, marshes are critical habitat for fish, and it has been demonstrated that wetland habitat in lakes supports about 60 percent more fish biomass than unvegetated areas (Petzold, 1996). These wetlands may be critical to the fisheries of an entire lake. For example, changes in the amount and type of wetlands at Long Point have affected the fish assemblages populating all of Lake Erie (T. Whillans, pers. comm.).

Existing land-uses, complementary habitat types (e.g., upland forest for amphibians), hydrology, water depths, substrate types, and fetch should be examined to determine the area suitable for rehabilitation. Ideally, all potential areas should be restored to wetland vegetation.

A second priority is to expand existing marshland. The larger a marsh, the better protection it provides zooplankton and fish from predators, and the higher the species richness in terms of birds. It has been demonstrated that fragmentation of marshes within lakes can result in depletion of zooplankton and the fish species that depend on them. Even in systems where zooplankton is not a concern, small marsh patches may be ecological traps.

They attract fry of many fish species as nursery habitat, but predation rates by common piscivores (fish that eat other fish) such as Rock Bass may be very high. However, small marshes – especially a high concentration of marshes in a landscape – can be beneficial in terms of waterfowl production.

If a new marsh is to be created within a lake, select the site where the largest marsh can be established, for the reasons mentioned above. Although even a tiny patch of wetland will increase biomass of invertebrates and fish, areas of at least 0.4 hectares should be the goal. Wetlands situated within 100 metres of another are more likely to have movement of fish among them, and the two patches are likely to collectively support more species than they would if they were isolated from each other. Nonetheless, opportunities for establishing a new wetland that is isolated from other marshes should definitely not be ignored. New marshes can create new nodes of fish production, can increase fish biomass in the lake, and can be important for other species such as waterfowl, amphibians and reptiles.

The following, in no particular order, are recommended locations for restoring wetlands in AOCs:

- headwater wetlands, particularly swamps, should be restored where they previously existed
- on-line or flood plain marshes and swamps should be rehabilitated or restored on second and third-order streams
- rehabilitation of wetlands in lakes is a very high priority because of their extreme importance to fish as well as other wildlife species
- rehabilitation of wetlands in known historic locations is encouraged, where still feasible
- any wetland, no matter where it is in a watershed or how large it is, will provide some benefits.

Photo by CWS

2.1.5 Wetland Size

> *Guideline*

Wetlands of a variety of sizes, types and hydroperiods should be maintained across a landscape. Swamps and marshes of sufficient size to support habitat heterogeneity are particularly important.

> *Rationale*

Treed swamps are a type of forest and they have the potential to support area-sensitive wildlife species (those that require larger areas of continuous habitat in which to be productive) or edge-intolerant species (those that prefer to use habitat away from the influence of habitat edges, also often referred to as "interior" habitat species). In AOCs, swamp forests may be the only remaining significant contributors to interior-forest habitat, so the discussion on forest size and species that may be expected in forests of different size applies here also. However, swamp forests provide interior habitat for a different suite of specialist area-sensitive forest species compared to large patches of upland forest.

Wetlands of a wide range of sizes can be important for local or regional biodiversity. For example, a small (<0.5 hectare) salamander breeding pond within an upland forest may be a critical habitat feature. These temporary wetlands are also likely to support a unique group of species (Snodgrass *et al*., 2000), hence increasing the diversity of assemblages of species in an area. These animals and invertebrates often respond to the short hydroperiod (length of time the wetland has standing water) and the absence of predatory or competing fish. Snodgrass *et al*. (2000) also found that in the southeast U.S. at least, there was no relationship between wetland size and amphibian diversity.

For marshes, even small units (e.g., 0.01 hectare) may be important for breeding amphibians or as waterfowl habitat, in the latter case especially for springtime pairing and feeding where a series of small wetlands exist in an area. In addition, some species of wildlife have adapted to exploit a complex of wetlands in the landscape and will readily move between them to forage (e.g., Northern Harriers, herons, dabbling ducks). This is the reason that the Ontario Wetland Evaluation System recognizes the concept of wetland complexes (OMNR, 1994).

Independent of whether or not large forest units are important (see discussion under forest cover) large swamps tend to have greater habitat heterogeneity (that is, the habitat is more varied within them), which in turn tends to support more species of wildlife (Golet *et al*., 2001). This effect can also be seen in marshes, and is often termed "interspersion" or the juxtaposition of different marsh communities (e.g., submerged versus emergent vegetation); although the mechanisms for maintaining heterogeneity in marshes are very different from swamps (e.g., bathymetry, water depths and hydroperiod).

High levels of habitat interspersion (i.e., open water/submerged vegetation, emergent vegetation and in some cases shrubs) within a marsh provide higher quality-habitat for a wider variety of species than, for example, a narrow band of cattails around the shoreline. It must be emphasized that marshes are very dynamic systems, so the ratio of open water/submerged vegetation to emergent vegetation (the optimum "hemi-marsh" for some species is around 1:1) and the interspersion pattern, may vary considerably from year to year. However, size remains a key factor: there is less chance that smaller wetlands will have sufficient areas of different marsh habitat types regularly available to be used as productive habitat by wildlife.

There is limited evidence to suggest that not all wildlife species benefit from high interspersion; some may require extensive stands of emergents with few or no openings (i.e., Northern Harrier), while others seem to prefer areas dominated by emergents, but with small, isolated openings (i.e., Least Bittern).

Like other wetland types, larger marshes and wetland complexes also have the ability to attract area-sensitive wildlife species. Area-sensitive birds may include species such as Marsh Wren (10 hectare), Black Tern (30 hectare) and Forster's Tern (larger coastal systems). The Black Tern will nest in smaller wetland units if larger feeding areas are located nearby. There are also a number of other species, such as Least Bittern and King Rail, which occasionally occur in smaller wetlands, but long-term viable populations are associated with extensive wetlands.

Table 7. Wildlife Use of Various Sized Habitats

Area	Forest/Treed Swamp	Marsh
1 ha	■ Edge tolerant mammals (Gray Squirrel) ■ Common edge-tolerant birds (Blue Jay, American Crow) ■ A few birds may be associated with mature trees (Black-capped Chickadee, Eastern Wood-Pewee)	■ Small populations of Muskrat ■ Edge-tolerant birds (Red-winged Blackbird, Canada Goose, Mallard) ■ Persistent and common herpetofauna (such as Green Frog and Midland Painted Turtle)
4 ha	■ A very few common edge-tolerant birds (Downy Woodpecker, Great Crested Flycatcher) ■ Eastern Chipmunk may be present	■ Similar species as above, but may also support Bullfrog
10 ha	■ Still dominated by edge-tolerant species may have very small areas of interior habitat supporting low numbers of modestly area-sensitive species (Hairy Woodpecker, White-breasted Nuthatch)	■ May support Marsh Wren, other waterfowl species
30 ha	■ May be large enough to support some species of salamander ■ Small populations of edge-intolerant species (Winter Wren, Brown Creeper, Black-and-White Warbler)	■ Similar marsh bird species as above, plus possibly Black Tern
50 to 75 ha	■ A variety of area-sensitive species may be present; some will be absent if there is no nearby suitable habitat ■ Still predominantly edge influenced, but will support small populations of most forest bird species ■ Some will be absent if there is no nearby suitable habitat	■ Least Bittern may be present in marshes of this size
100 to 400 ha	■ All forest-dependent bird species ■ Many will still be in low numbers and may be absent if there is no nearby suitable habitat ■ Woodland Jumping Mouse may be present	■ Small numbers of diving ducks possible (e.g., Redhead, Canvasback, Ruddy Duck)
1,000 ha	■ Suitable for almost all forest birds ■ Some forest-dependent mammals present, but most still absent	■ All marsh species, although some may still have small populations
10 000 ha	■ Almost fully functional ecosystem, but may be inadequate for a few mammals such as Gray Wolf and Bobcat (100 000 ha has been suggested as a minimum)	■ Fully-functional ecosystem

2.1.6 Wetland Shape

> *Guideline*

As with upland forests, in order to maximize habitat opportunities for edge-intolerant species, and where the surrounding matrix is not natural habitat, swamps should be regularly shaped with minimum edge and maximum interior habitat.

> *Rationale*

The optimum shape of a wetland also varies by wetland type. Treed swamps are a type of forest, and the discussion on forest shape applies: they can be most useful to edge-intolerant species when they are regularly-shaped (e.g., a circle). The less edge-to-area ratio a swamp has, the better it will support wildlife species that are adapted to interior habitat conditions (see Figure 1).

There has been little investigation on the effects of wetland shape with respect to other wetland types, such as marsh. It is known that biodiversity responds to internal variation in communities (i.e., emergent versus submerged plant communities within a marsh), and this effect is addressed under Wetland Size.

The shape of a marsh may be important if water quality improvements are an objective. Long, narrow marshes and those that maximize water contact with vegetation and residence time within the wetland are likely to be most effective in improving water quality.

Photo by Eric Dresser

2.2 Riparian Habitat Guidelines

Guidelines for riparian habitats (Table 8) relate to the amount of natural vegetation adjacent to a stream, the width of the vegetated buffer, total suspended solids concentrations, percent imperviousness in urbanizing watersheds, and fish communities.

Table 8. Summary of Riparian Habitat Guidelines

Parameter	Guideline
Percent of stream naturally vegetated	Seventy-five percent of stream length should be naturally vegetated.
Amount of natural vegetation adjacent to streams	Streams should have a minimum 30 m wide naturally vegetated adjacent-lands areas on both sides, greater depending on site-specific conditions.
Total suspended sediments	Where and when possible, suspended-sediment concentrations should be below 25 mg/l or be consistent with Canadian Council of Ministers of the Environment (1999) guidelines.
Percent of an urbanizing watershed that is impervious	Less than 10 percent imperviousness in an urbanizing watershed should maintain stream water quality and quantity, and preserve aquatic species density and biodiversity. An upper limit of 30 percent represents a threshold for degraded systems.
Fish communities	Watershed guidelines for fish communities can be established based on knowledge of underlying characteristics of a watershed (e.g., drainage area, surficial geology, flow regime), historic and current fish communities, and factors (and their relative magnitudes) that presently impact the system.

2.2.1 Percent of Stream Naturally Vegetated

> Guideline

Seventy-five percent of stream length should be naturally vegetated.

> Rationale

In a Toronto area study, stream degradation occurred when riparian vegetation amounted to less than 75 percent cover along first to third-order streams (Steedman, 1987). This is consistent with the target of 75 percent that was selected for the Rouge River watershed in the Toronto and Region AOC.

In the Toronto and Region/Humber River field test of this guideline, the Toronto and Region Conservation Authority (TRCA) commented that there are many cold-water streams that have less than 75 percent, or even less than 50 percent vegetated riparian habitats. TRCA felt that the level of achievement gained by stream buffers was more related to stream integrity as measured by fish community targets than by warm or cold-water.

Related comments were provided by Gartner Lee Limited (1997b) in the Severn Sound/Hogg Creek field test. In Hogg Creek, only 43 percent of the first to third-order streams are vegetated; however, several tributaries of the main branch of Hogg Creek exhibit cold-water characteristics, which seem to relate to a high ratio of baseflow (46.9 percent) as a percentage of average annual discharge per square kilometre. Gartner Lee Limited (1997a) also note that the presence of cold-water streams is heavily dependent on the geological characteristics of the area. They suggested that the guideline may be best viewed as the percentage of riparian habitat that is vegetated along first to third-order streams in permeable soils (i.e., smaller headwater streams in clay soils are more likely seasonally dry and therefore the riparian cover holds less significance). This discussion highlights the need to consider a number of factors in stream corridors along with the readily measurable percentage of riparian cover.

The Importance of Stream Orders

Stream order is a measure of the position of a stream or river in the hierarchy of the tributaries which make up the watershed. First-order streams are headwater streams that do not have any tributaries. Second-order streams are those with only first-order streams as tributaries. Third-order streams start below the confluence of second-order tributaries, and so on. In general, the higher the order, the larger the stream or river. In Ontario, most drainage systems rarely have in excess of a fifth-order stream prior to emptying into one of the Great Lakes.

As the order of a stream increases, the flow and width increases. Small headwater streams are generally of orders one through three. These streams are highly dependent upon vegetative cover for stream temperature moderation and the input of organic matter from adjacent vegetation (e.g., falling leaves and insects) for production. Stream gradient is generally greater in lower-order (one through three) streams, which often indicates higher erosion potential if riparian vegetation is removed. As stream order increases there is greater in-stream productivity and there is a transition from a stream dominated by terrestrial vegetation to one dominated by internal production. Higher order streams generally have a lower gradient with correspondingly deeper, slower-moving flows. Deposition of suspended sediments may be significant in some locations.

The characteristics of lower-order streams (one through three) make them much more dependent upon riparian vegetation and buffer strips for protection of natural ecological functions. From a watershed perspective, planting vegetation along streams of orders one through three will produce greater benefits than planting along higher-order rivers. Woody vegetation along a smaller stream has better potential to provide sufficient cover to lower summer maximum stream temperatures than along the banks of a large river, but deep-rooted vegetation is important in maintaining bank stabilization along larger river systems.

A recent study in a heavily-forested environment found an overall decrease in fish abundance as the length of non-forest riparian patch increased and suggested that downstream fish habitat impairment may follow if forested riparian buffers are disrupted over much more than one kilometre to three kilometres in length (Jones *et al*., 1999). Others have suggested that upstream processes (such as those found in largely deforested watersheds) may overwhelm the ability of riparian vegetation to support stable in-stream habitat (Roth *et al*., 1996 as cited in Jones *et al*. 1999). Guidelines for maximum lengths of disrupted riparian buffer and their location within the watershed could be generated on a watershed basis, thus taking account of the conditions encountered.

The percent of natural vegetation along first to third-order streams is readily measured through the use of remotely-sensed data and Geographic Information Systems (GIS). However, it is often difficult to measure grassy vegetation remotely, so percent vegetated often refers to percent woody vegetation. In some cases, grassy vegetation may be preferable to woody vegetation (i.e., adjacent to first-order headwater streams that are small and often arise from cool groundwater). These cool, narrow streams (less than 2.5 metres) often do not require thermal protection or leafy material from a shrub or tree, as grasses will suffice (Blann *et al*., 2002). Therefore, it is important to note that although it is difficult to measure using remote sensing techniques, grassy riparian vegetation may be just as important to the stream system as woody vegetation.

The Rouge River example: Applying the 75 percent rule

The TRCA completed a study of the Rouge River drainage system, called the Forested Watersheds Study, which analyzed watercourses by order and amount of riparian vegetation. This information is used to guide habitat restoration and reforestation efforts (Strus *et al*., 1995). Summarized below are the amounts of stream/river by order with riparian vegetation on either side of the stream.

The habitat targets for the Rouge River watershed include a 30-metre buffer strip along 75 percent of stream length. A threshold of fish community degradation in Toronto area streams was defined when less than 75 percent vegetated cover remained in riparian lands. From the table above, it is apparent that none of the stream groups examined has 75 percent forest cover. To achieve the best benefit for rehabilitation effort, priority will be given to first-order streams.

Non-Forested Streams

Stream Order Forested	Area (ha)	Length (km)	Percent
1st	1,216.0	202.0	18.0
2nd	483.0	80.0	33.0
3rd	211.0	35.0	41.0
Other	691.0	115.0	40.0
Total	**2,601.0**	**432.0**	**40.5**

Source:
Modified from Strus *et al*., 1995

Photo by Eric Dresser

2.2.2 Amount of Natural Vegetation Adjacent to Streams

> *Guideline*

Streams should have a minimum 30-metre wide naturally vegetated adjacent lands area on both sides, greater depending on site-specific conditions.

> *Rationale*

It is difficult to generalize about the effectiveness of natural vegetative adjacent lands (buffers) in riparian situations as so much depends on the nature of the watercourse, soil types, vegetation cover types, slopes, and adjacent-land uses. In addition, the possibility of solutions that incorporate remedial bioengineering techniques to attenuate adjacent-land width requirements is a developing field that will play an increasing role in the future.

A review of adjacent-land requirements for the attenuation of sediments and nutrients was provided in the section of this report that addresses the amount of wetland vegetation adjacent to wetlands. However, riparian zones possess an unusually diverse array of species and environmental processes (Naiman and Decamps, 1997), and in many respects, the science is necessarily more complex than that which applies to wetlands.

A review of riparian adjacent lands (Knutson and Naef, 1997) presented a variety of sources that varied in the typical range of three to 200 metres, but with a preponderance in the 23 to 60-metre range (all these are applied to both sides of the stream). They concluded by recommending that fish-bearing streams have either 46 or 61-metre buffers depending on their classification, extending to 76 metres for shorelines or streams of state-wide significance.

In reviews by Castelle *et al*. (1994) and O'Laughlin and Belt (1995), and based on a variety of site-specific conditions, adjacent-lands widths of three to 200 metres were found to be effective for different functions in riparian zones. The Castelle *et al*. (1994) review looked at the effectiveness of different-sized areas in sediment removal. The relationship between width and sediment removal was non-linear, with disproportionately wider areas required for relatively small improvements in sediment removal. For example in one test case, widths of 30.5 metres removed 90 percent of sediments on a two percent slope, but a width of 61 metres was necessary to remove 95 percent of sediments. In another study, a 24-metre width removed 92 percent of sediment in runoff from a feedlot; two other studies found that widths of 60 metres were effective in removing 80 percent or more of sediments even on steep slopes.

Relatively narrow adjacent-lands areas may be adequate when the area is in good condition (i.e., dense, native vegetation on undisturbed soils), and the adjacent-land use has a low impact potential (i.e., parkland, low density residential, shallow slopes, or non-erosive soils). Larger adjacent lands areas are required for high value resources, where the area is in poor condition, where soils are less permeable or highly erodible, slopes are steep, or where the adjacent-land use is intense (e.g., intensive agriculture). Widths may also be influenced by the sensitivity of the receiving watercourse and its ability to assimilate any stressors.

Established vegetated adjacent-lands areas are fairly efficient at removing excess nutrients from water. In some studies, areas as narrow as 4.6 metres wide have been 90 percent effective in removing nitrogen and phosphorus, but most areas require a minimum of 10 to 15 metres. A 30-metre wide adjacent-lands area along a stream adjacent to logging operations greatly reduced nutrient levels to below drinking-water standards. Wooded riparian adjacent land areas in Maryland removed 80 percent of excess phosphorus and 89 percent of excess nitrogen, mostly within the first 19 metres. A recent study (Lee *et al*., 2003) found that >97 percent of sediment and 80 to 90 percent of key nutrients could be removed with a 16.3-metre mature grass/woody riparian adjacent-lands area. The Draft Chesapeake Bay Program (2001) recommends buffers of 7.6 to 76 metres.

The range of appropriate adjacent-lands area widths based on function is great; for most functions, the published range in the literature varies from a few metres to over 100 metres. In addition, the total width of the riparian zone is indicated as the feature of interest in some literature (e.g., as wildlife corridors or habitat). However, riparian adjacent lands areas are usually described for application to each side of the watercourse and this has created some confusion.

In conclusion, the recommended guideline is a minimum 30-metre wide naturally vegetated adjacent-lands area on each side of the watercourse. This minimum is strongly supported in the literature for riparian systems, but depending on site-specific parameters it may need to be greater to attain the desired level of function. It is also worth noting that there is increasing scientific support for this guideline to be expanded to 50 metres and this is one guideline that may change in the future as more information becomes available.

2.2.3 Total Suspended Sediment Concentrations

> *Guideline*

Where and when possible suspended sediment concentrations should be below 25 milligrams/litre or be consistent with Canadian Council of Ministers of the Environment (1999) guidelines.

> *Rationale*

Suspended sediments may adversely affect aquatic habitat by filling in interstices of coarse substrate, thereby limiting habitat for aquatic invertebrates. As amounts increase and material settles, coarse substrate may be covered with finer sediments, fish eggs may be smothered, and under extreme conditions, fish that feed by sight may have difficulty in finding prey, gills may become clogged, and disease may occur. Suspended sediments may also adversely affect plant communities by reducing light penetration into the water column, reducing the extent of submergent vegetation, and smothering plants. Increased abrasion of stream channels may occur from an oversupply of suspended sediments. For a concise overview of the problem of sediment in water for fish see OMNR (1992); more detailed information is available in the Canadian Environmental Quality Guidelines (CCME, 1999).

Alabaster and Lloyd (1982) presented the quality of fishery that may be expected with different levels of suspended sediments:

- normally less than 25 milligrams/litre: no harmful effects
- normally between 25 and 80 milligrams/litre: good fishery maintainable
- normally between 80 and 400 milligrams/litre: moderate to poor fishery maintainable
- normally greater than 400 milligrams/litre: poor quality fishery maintainable.

In an evaluation of this guideline on the urbanized Don River, the TRCA found that suspended sediment levels varied dramatically with flow conditions where the dry weather flows tended to have much less suspended material than high flows. In response to this, the Don Watershed Report Card (Don Watershed Regeneration

Council and TRCA, 1997) suggested the target for suspended sediment to be achieved by 2030 should be less than 80 milligrams/litre more than 75 percent of the time, incorporating the understanding that management activities will only be effective in reducing suspended sediments for the intermediate and small flow events in an urbanized watershed. Suspended sediments will not consistently be within the 25 to 80 milligrams/litre threshold.

Gartner Lee Limited (1997b) found a similar pattern in Severn Sound's Hogg Creek, a rural agricultural watershed. Peak values of suspended sediments reached 234 and 459 milligrams/litre during short-term runoff events; however, the median amounts of suspended sediments were found to be in the order of 10 milligrams/litre, suggesting that a good fishery is maintainable in the creek. Gartner Lee Limited note that peak concentrations indicated that there are periodic problems associated with runoff that meant that the stream did not remain below the suspended sediment guidelines all of the time. Of importance to the guidelines presented in this *Framework*, Gartner Lee Limited recommended that the high levels of suspended sediments associated with runoff events should be addressed through measures such as developing vegetated adjacent-land strips used to filter runoff from adjacent agricultural land-uses.

In a review of relevant data, Newcombe and MacDonald (1991) found that aquatic biota respond to both the concentration of suspended sediments and the duration of the exposure. They developed a stress index ranking the severity of effects of suspended sediments on fish and aquatic life ranging from lethal (outright mortality), sublethal (reduction in growth rates, moderate habitat degradation, injured tissues), and behavioural effects (reduction in feeding rates, avoidance response, abandonment of cover). They reviewed species-specific effects based on length of exposure, physical effect, and ranking of the effect based on the stress index. From their review of a range of values from different studies they found that the data were too variable to formulate generalizations about the effects of suspended sediments. However, they argued that high concentrations over even a short duration of time (i.e., the spring freshet period discussed earlier in the Toronto and Severn Sound examples) can have extreme effects on biota. This indicates a need to measure and remediate high event-associated concentrations of suspended sediments, not just concentrations calculated by averaging readings taken over a year.

When evaluating the effects of suspended sediments, the concentration, duration, and timing of suspended-sediment values should be taken into account. Large volumes of suspended sediments in urbanized and agricultural watersheds may cause severe but lethal short-term effects on stream biota. Average annual suspended-sediment concentrations in isolation do not tell the complete story. This is why the new CCME (1999) guidelines incorporate various parameters.

Table 9. Total Suspended Sediment Concentrations

A site-specific condition that is based on background levels, not low flow.	
For Clear Flow	**For High Flow**
■ short-term exposure (e.g., over 24 hours) – no anthropogenic-induced increase more than 25 milligrams/litre	■ no increase more than 25 milligrams/litre when background levels are between 25 and 250 milligrams/litre
■ long-term exposure (e.g., over 30 days) – average suspended sediment should not increase by more than 5 milligrams/litre over background	■ no increase over 10 percent of background level when background levels exceed 250 milligrams/litre

2.2.4 Percent of an Urbanizing Watershed that is Impervious

> *Guideline*

Less than 10 percent imperviousness in an urbanizing watershed should maintain stream-water quality and quantity, and preserve aquatic species density and biodiversity. An upper limit of 30 percent represents a threshold for degraded systems.

> *Rationale*

The replacement of natural vegetation with impervious surfaces contributes to disturbed runoff processes within urban watersheds (Booth, 1991; Booth *et al*., 1997; Booth, 2000; Knutson and Naef, 1997). The loss of fish and wildlife habitat, along with channel erosion and downstream flooding, are the primary components of stream-system decline that result from imperviousness within a watershed (Booth 1997; Booth 2000; Knutson and Naef, 1997). The effects of natural vegetation loss to impervious surfaces are often permanent (Booth, 1991), and in this regard implementing mitigation efforts after impervious surfaces are established is largely unsuccessful (Booth, 1997).

The debate on identifying reasonable thresholds for impervious surfaces within a watershed began in 1979. In his pivotal paper, Klein (1979) reported that impairment of stream quality is first noted at 10 to 12 percent impervious cover and becomes severely impaired at 30 percent watershed imperviousness. From a review of the recent literature regarding the effects of urbanization on aquatic systems, the Stormwater Manager's Resource Center proposed that two thresholds exist within urbanized watersheds: at 10 percent imperviousness, certain stream-quality parameters will be affected and at 25 to 30 percent impervious cover, stream quality will consistently shift to a degraded condition (www.stormwatercenter.net).

Booth (1991) found that after 10 percent of a watershed was covered with impervious surfaces, there was a rapid decline in fish habitat and channel stability of riparian zones. In addition, Booth (1991) stated that urban development both magnifies peak discharges and creates new peak runoff events. In a later study, Booth and Jackson (1994) demonstrated that unstable stream banks and channels occurred when watershed imperviousness surpassed 10 percent. Snodgrass (1992) reported that water quality became degraded when hard surfaces from development (e.g., housing, roads) reached 15 to 25 percent of the watershed. State-of-the-art stormwater-management could not prevent stream-quality impairment in the study provided by Snodgrass (1992). Schueler (1994) reports on a number of studies that relate imperviousness to runoff characteristics, the shape of streams, water quality, pollutant loading, stream warming, as well as stream biodiversity. In his review, he suggests that impervious land-use should remain below 10 percent as a guideline to protect stressed streams.

Various indicators of aquatic macroinvertebrate community health are widely used as relationship indicators between watershed imperviousness and aquatic systems. The thresholds presented below are taken from the Stormwater Manager's Resource Center review (www.stormwatercenter.net). As impervious cover increased to eight to nine percent within a watershed, there was a significant decline in wetland aquatic macroinvertebrate health (Hicks and Larson, 1997). When the percentage of total impervious surfaces surpassed five to 10 percent of a watershed landscape, there was a rapid decline in biological stream indicators (May *et al*., 1997). At a study conducted in Washington, D.C., a significant decline in the diversity of aquatic insects was noted at 10 percent impervious cover (MWCOG, 1992). Further, the density and diversity of wetland plants, amphibians, and fish are also impaired as watershed imperviousness exceeds 10 percent (Limburg and Schmidt, 1990; Taylor, 1993; Weaver, 1991).

The most commonly-chosen threshold for impervious surfaces is 10 percent of the land cover within a watershed (Booth, 2000). Although not every watershed will respond uniformly or as anticipated to proposed impervious-surface thresholds, a guideline of 10 percent or less will do much to preserve the health of aquatic systems. Further, a second threshold of 30 percent or less impervious surfaces is suggested for urban watersheds that have, to date, exceeded the proposed 10 percent impervious-surface guideline. In addition, implementing and defending stormwater best-management practices in watersheds that are near or exceeding the 10 percent guideline will aid in maintaining aquatic systems.

In relatively undeveloped rural watersheds, stream baseflow is dictated by underlying soils and geologic conditions that influence the amount of groundwater discharge. Within urbanizing watersheds, however, careful planning must ensue to mitigate the effects of impervious surfaces. Extreme peak flows typical of urban environments can be reduced through minimizing hard surfaces. Booth *et al*. (1997) suggests that by reducing the surface area covered by constructed surfaces (rooftops, pavement, compacted soils), these necessary impervious areas can be generated using new products, such as permeable pavements that allow for infiltration of water.

2.2.5 Establishing Fish Community Targets

> *Guideline*

Watershed guidelines for fish communities can be established based on knowledge of underlying characteristics of a watershed (e.g., drainage area, surficial geology, flow regime), historic and current fish communities, and factors (and their relative magnitudes) that presently impact the system.

> *Rationale*

The TRCA has developed a guide for use in establishing fish community targets and measuring the health of aquatic habitats in Toronto area watersheds. The guide, or *Framework*, can be used to assist in restoring both fish and wildlife habitat and populations. Municipalities and other users of the guide will likely wish to request advice from fishery biologists at the Ontario Ministry of Natural Resources and/or the local Conservation Authority prior to application.

The general *Framework* is derived from TRCA's work in establishing fish management plans for the Rouge River, Don River, and Humber River watersheds in the Toronto and Region AOC. The approach is based on three types of information:

- knowledge of the fundamental or underlying characteristics of the watershed or subwatershed (e.g., drainage area, surficial geology, flow regime) and the makeup of historical fish communities
    - knowledge of what the system is presently supporting (i.e., the existing fish community) and some idea of its condition
    - knowledge of the factors that presently impact the system and their relative magnitudes.

The establishment of a historical context for function provides the fundamental reference point required to assist in setting targets; the second reference point is the existing condition along with some knowledge of the magnitude of impacts. Comparison of these two conditions provides a realistic context for the establishment of targets and identification of rehabilitation activities. The historic condition provides the direction for rehabilitation while the existing condition indicates how far the system is from being healthy and what needs to be improved. The knowledge of the magnitude of impacts is also necessary because the establishment of targets must include an assessment of what might reasonably be achieved with existing technology and land-use patterns.

Based on available literature and work in the Rouge, Don and Humber River watersheds, the *Framework* for setting fish-community targets provides a general guide to assist habitat rehabilitation practitioners in the development of fish-community expectations and targets for watercourses in their area. The *Framework* is based on information available for streams in southern Ontario, and therefore, may not be directly applicable to other areas (see Appendix 4 for a full discussion of its application in Toronto area watersheds).

2.2.6 Additional Riparian Parameters

The *Framework* largely focuses on terrestrial habitat and its relation to the health of streams and waterbodies. The emphasis is on the reduction of terrestrial impacts upon watercourses that can be achieved through protection and restoration of vegetation. There is also a large and growing body of knowledge on in-stream habitat and hydraulic parameters. Factors such as baseflow contributions, a stream's pool-to-riffle ratio, and channel sinuosity should be considered when assessing stream health while conducting a stream rehabilitation program across a watershed.

Photo by CWS

2.3 Forest Habitat Guidelines

The following series of guidelines for forest habitat (Table 9) relate to overall forest cover, size of forest patch, percent of interior forest, shape and proximity of a forest patch to other patches, corridors, and forest quality.

Table 10. Summary of Forest Habitat Guidelines

Parameter	Guideline
Percent forest cover	At least 30 percent of the AOC watershed should be in forest cover.
Size of largest forest patch	A watershed or other land unit should have at least one 200 ha forest patch which is a minimum 500 m in width.
Percent of watershed that is forest cover 100 m and 200 m from forest edge	The proportion of the watershed that is forest cover 100 m or further from the forest edge should be greater than 10 percent. The proportion of the watershed that is forest cover 200 m or further from the forest edge should be greater than five percent.
Forest shape	To be of maximum use to species such as forest breeding birds that are intolerant of edge habitat, forest patches should be circular or square in shape.
Proximity to other forested patches	To be of maximum use to species such as forest-interior birds, forest patches should be within two km of one another or other supporting habitat features.
Fragmented landscapes and the role of corridors	Connectivity width will vary depending on the objectives of the project and the attributes of the nodes that will be connected. Corridors designed to facilitate species movement should be a minimum of 50 m to 100 m in width. Corridors designed to accommodate breeding habitat for specialist species need to be designed to meet the habitat requirements of those target species.
Forest quality — species composition and age structure	Watershed forest cover should be representative of the full diversity of forest types found at that latitude.

2.3.1 Percent Forest Cover

> *Guideline*

At least 30 percent of the Area of Concern watershed should be in forest cover.

> *Rationale*

The amount of forest cover in a landscape determines its ability to support wildlife species. This is particularly noticeable for mammals that require extensive forests. Species such as Gray Wolf, Lynx, Elk, and Wolverine disappeared from southern Ontario shortly after forest clearing was initiated.

Recent literature indicates that a complex relationship exists between the relative importance of overall forest cover versus forest patch size and the ultimate response of individual wildlife species (Lee *et al*., 2002). On balance, the axiom "the bigger, the better" appears to be in the process of replacement by "the greater amount of habitat within the landscape mosaic, the better" (see Austen *et al*., 2001; Golet, 2001; Fahrig, 2002; Lindenmayer *et al*., 2002; Trzcinski *et al*., 1999; Friesen *et al*., 1998; Friesen *et al*., 1999; Rosenburg *et al*., 1999). These studies and reviews have shown or suggested that forest patch size and shape may play a lesser role in maintaining biodiversity than the total amount of forest cover, although the three metrics are to some extent interrelated.

Empirical studies that have examined the independent effects of habitat loss versus habitat fragmentation suggest that habitat loss has a much larger effect than habitat fragmentation on the distribution and abundance of birds (Fahrig, 2002). This is supported by other studies that found forest size and edges effects did not significantly affect either nesting success or the productivity of neotropical songbirds (e.g., Friesen *et al*., 1998). Golet (2001) found that bird relative abundance was not predictable from swamp size and found that the pattern of distribution was consistent with total forest availability. Lee *et al*. (2002) found that the relative importance of patch characteristics, patch size and landscape forest cover varied for different bird species.

A further consideration is that landscape-scale effects (i.e., total forest cover) may be different in largely-forested environments compared to largely fragmented environments. It is possible that in large forested areas (e.g., Quebec's boreal forest) birds respond primarily to local habitat effects (Lichstein *et al*., 2002) whereas in fragmented landscapes, landscape-scale forest cover may be critical (Trzcinski *et al*., 1999). It is also possible that within a landscape matrix that includes a significant urban component, the negative influences originating from the urban matrix will have different implications for these landscape-scale effects. However, analysis is currently lacking on the relative effects on wildlife productivity of forest cover versus forest patch size in these types of systems.

The overall effect of a decrease in forest cover on birds is that certain species disappear and many of the remaining ones become rare, or fail to reproduce, while non-forest and edge species prosper as artificially-inflated populations. Species with specialized-habitat requirements are most likely to be affected adversely. Although little data exist for other wildlife, the reduction of forest habitat likely affects other forest dependent species such as Mole Salamanders, Wood Frogs, and many mammals. In the future, we can expect more empirical data on the effect of forest loss for non-bird species.

In one study area near Ottawa, several species of forest birds disappeared as breeders when forest cover declined to below 30 percent (Freemark, 1988). In Essex County, with only about three percent forest cover, many wildlife species that are common to abundant elsewhere in Ontario are rare (e.g., Black-capped Chickadee and White-breasted Nuthatch [Oldham, 1983]) and 80 percent of the forest-interior species have disappeared. In Ottawa-Carleton, Hairy Woodpeckers may be found in woodlands 10 hectares or even smaller; whereas in the Town of Markham (five percent forest cover) none were found, although some woodlands approached 100 hectares in area.

Table 10 summarizes the number of forest-associated breeding birds in five areas with varying amounts of forest cover. The total number of species present is compared to the number of species that could occur, based on broad geographic ranges. As the top third of the table indicates, 100 percent of the species that should occur are present in Ottawa-Carleton, which is approximately 30 percent forested. In contrast, Essex (at three percent forest cover) has lost almost 40 percent of its forest birds. *The Ontario Breeding Bird Atlas (Atlas)* results (Cadman *et al*., 1987) were used to determine the number of forest-dependent bird species in municipalities with varying amounts of forest cover (an explanation of how to use the *Atlas* for local study areas follows in a subsequent section). A new *Atlas* is being compiled and updates are available on-line: www.birdsontario.org/atlas/atlasmain.html.

Table 11. Number of Forest-Associated Bird Species in Five Areas of Southern Ontario with Differing Percentages of Forest Cover (Adjusted for Potential Breeding Ranges Based on Pre-settlement Habitat)

	Ottawa-Carleton	Haldimand-Norfolk	Waterloo and Wellington	Middlesex	Essex
Percent forest cover	29.4	16.2	14.8/18.2	13.5	3.0
Total number of species within range	94.0	102.0	100.0	102.0	102.0
Number of species occurring	94.0	98.0	88.0	83.0	63.0
Percent of total number of species within range present	100.0	96.1	88.0	81.5	61.7
Number of FIE and FI species within range	60.0	66.0	64.0	61.0	66.0
Number of FIE and FI species present	60.0	2.0	54.0	50.0	36.0
Percent of FIE and FI species within range present	100.0	93.9	84.4	82.0	54.5
Number of FI species within range	18.0	20.0	20.0	20.0	20.0
Total FI species present	18.0	19.0	15.0	16.0	4.0
Percent of FI species within range present	100.0	95.0	75.0	80.0	20.0

FIE Forest-interior/Edge (moderately edge-intolerant) FI Forest-interior (highly edge-intolerant)

Source: Cadman *et al*. (1987); Riley and Mohr (1994)

Other studies have supported a 20 to 30 percent threshold beyond which persistence of bird species was virtually ensured or that habitat configuration had little or no affect on species richness or abundance ((Fahrig, 1997; Andrén, 1994; both cited in Villard *et al*., 1999). Data collected by Tate (1998) also suggests that bird species favouring interior habitat conditions continue to increase in number from 20 percent to at least 35 percent forest cover depending on the scale of the analysis.

Photo by John Mitchell

Effects of Forest Cover Loss and Fragmentation

Forest habitat guidelines are designed to address habitat loss and fragmentation as two of the key factors in the decline of wildlife species. The loss of forest cover not only directly results in habitat loss, but it also contributes to increased water run-off quantity (Bosch and Hewlett, 1982) and associated water-quality concerns. Forest birds are often used as indicators of the quality of the landscape because they are more easily surveyed, and more is known about their habitat requirements and distribution than any other group of wildlife. Much less is known about the sensitivity of invertebrates, amphibians, reptiles, plants, and small mammals to forest fragmentation.

One of the key factors that contributes to an understanding of the loss of birds from a fragmented landscape is the concept of metapopulations (semi-isolated populations in a region, linked by dispersion) (Merriam, 1988; Opdam, 1991). Local extirpations of populations occur naturally within forests due to failed reproductive efforts because of factors such as predation, parasitism, adverse weather conditions, natural catastrophes (e.g., fire, floods), and insufficient food. Under normal circumstances, forest patches become recolonized by individuals from adjacent areas (so-called source-sink dynamics [Howe *et al*., 1991]). However, as overall natural area declines, there may be no source of colonists due to other local extinctions as a result of lack of connectivity, and extirpations may become permanent. Recent studies suggest that the same factors may regulate amphibian populations (e.g., Knutson *et al*., 2000).

The metapopulations concept can be used to explain the fact that the breeding bird assemblage in forests changes annually (Villard *et al*., 1992). Common species are always present, but the more specialized species are sporadic in occurrence. It has been demonstrated that the number of breeding pairs in a region remains almost constant, but that the areas used for breeding vary. Thus, a woodland may support a given species as infrequently as once every four or five years, yet this woodland is still critical to the overall maintenance of the regional populations. The disappearance of apparently insignificant woodlands may cause declines in the size of wildlife populations.

Factors such as overall forest cover, forest size, shape and degree of fragmentation all affect the viability of habitat for wildlife species. However, for forest-dependent fauna, the overall forest cover in the environment may be the single most important habitat metric. The negative effects of forest loss may not be countered by careful consideration of the spatial pattern of remaining forest (Trzcinski *et al*., 1999). This may be particularly important to consider in light of the fact that a review of 134 fragmentation studies showed evidence that the ecological mechanisms and effects of habitat fragmentation are poorly understood (McGarigal and Cushman, 2002).

2.3.2 Size of Largest Forest Patch

> *Guideline*

A watershed or other land unit should have at least one 200 hectare forest patch that is a minimum 500 metres in width.

> *Rationale*

In the forest-cover guideline, the relative importance of overall forest cover and the pattern of forest cover were discussed. Despite increasing support in the literature indicating the significant contribution of forest cover, it remains clear that forest patch size can be important to many wildlife species. Some studies have suggested that as the relative importance of patch size, patch characteristics and landscape cover varies for different species and these multiple factors should be considered in conservation planning (Lee *et al*., 2002; Mortberg, 2001; Villard *et al*., 1999; Andren, 1996). By way of examples, some recent studies have identified only large (500 hectare) or continuous forests as sources for Ovenbirds (Burke and Nol, 2000; Mancke and Gavin, 2000); while others have demonstrated productivity in Wood Thrushes that appeared to be independent of forest size (Friesen *et al*., 1999).

Larger patches of forest tend to have a greater diversity of habitat niches and therefore are more likely to support a greater richness and/or diversity of wildlife species. Very large patch sizes are also associated with total forest cover as these phenomena tend to occur simultaneously in real-world landscapes (Villard *et al*., 1999).

Robbins *et al*. (1989) determined habitat area requirements for forest birds in the mid-Atlantic states. Almost all of the bird species documented occurred at least occasionally in forests 100 hectares or smaller; the few species not found in forests this small have been confirmed breeding in southern Ontario forests 100 hectares or smaller. However, 100 hectares is considered an absolute minimum guideline for forest patch size. Many of the most area-sensitive or edge-intolerant species are rare in forests this small; the probability of detecting some of these species in 100-hectare forests is as low as 20 to 30 percent (Robbins *et al*., 1989).

In the Illinois Department of Conservation management guidelines for forest and grassland birds, Herkert *et al*. (1993) suggest that a 400-hectare forest patch was required to support 75 to 80 percent of the highly sensitive regional forest bird species pool. They predicted that a 100-hectare forest patch should contain about 60 percent of the highly-sensitive species. Forest bird species preferring interior habitat conditions, as discussed here, incorporate all of the highly-sensitive species identified by Herkert *et al*. (1993).

In the summer of 1997, Tate (1998) evaluated the forest patch size guideline outlined in this guide by surveying four large forest patches ranging in size from 140 to 201 hectares in the Severn Sound AOC. Tate found over 70 percent of the regional pool of forest bird species in the four forest tracts collectively, and 79 to 87 percent of the expected forest-interior species in individual tracts between 100 and 200 hectares in size. From this work, it was determined that a single tract of 100 hectares was too small to support the regional forest bird community. Instead, a forest patch of 200 hectares was recommended, which will be more likely to provide suitable habitat for species that prefer interior habitat conditions, and over 80 percent of all expected species may occur. Several large tracts of forest are recommended as they will support 90 to 100 percent of all expected species (see Appendix 5 for details).

Table 7 summarized some of the relationships between wildlife and size of forest, marsh and grassland habitat, and the following table summarizes data from Tate (1998) and others.

Table 12. Anticipated Response by Forest Birds to Size of Largest Forest Patch

Size of Largest Forest Patch	Response by Forest Associated
200 ha	Will support 80 percent of edge-intolerant species including most area-sensitive species.
100 ha	Will support approximately 60 percent of edge-intolerant species including most area-sensitive species.
50 - 75 ha	Will support some edge-intolerant species, but several will be absent and edge-tolerant species will dominate.
20 - 50 ha	May support a few area-sensitive species but few that are intolerant of edge habitat.
<20 ha	Dominated by edge-tolerant species only.

2.3.3 Percent of Watershed that is Forest Cover 100 metres and 200 metres from Edge

> Guideline

The proportion of the watershed that is forest cover 100 metres or further from the forest edge should be greater than 10 percent. The proportion of the watershed that is forest cover 200 metres or further from the forest edge should be greater than five percent.

> Rationale

In a southern Ontario study, Sandilands and Hounsell (1994) determined that certain bird species avoided forest edges in small forests when they were breeding. In larger forests, one guild (or group) of species typically nested 100 metres or further from the edge, while a second guild nested 200 metres or further from the edge. More recent work has at least partly confirmed these findings. For example, Austen *et al*. (2001) found that edge intolerant ("forest-interior") species increased and edge-tolerant species decreased with both increasing woodlot size and core area, and Burke and Nol (2000) concluded that Ovenbirds required 90 hectares of interior forest to be successful. Other studies have also found that predator intrusions have the potential to induce patch size effects (Cantrell, 2001); that avian predators can be more abundant in forest edges (Chalfoun *et al*., 2002), and that depth or distance to edge affects forest-breeding birds (Mancke and Gavin, 2000).

As forest area alone cannot account for edge effects within a forest patch (as this is dependent on variables such as shape), guideline thresholds that address distance from an edge or "depth" need to be developed. This concept of forest-interior habitat therefore takes into account the effects of both patch size and patch shape.

Tate (1998) suggests that the amount of interior forest habitat is more critical to improving conditions for edge-intolerant bird species when planning across larger land units (i.e., 1,600 square kilometres) versus smaller subwatersheds (i.e., 100 square kilometres). See Appendix 5 for details.

Table 7 summarizes how forest-associated bird species are affected by differing percentages of intolerant forest cover. In this table, species designated as forest-interior/edge-species are those that tend to nest inside forests, and a high proportion of them nest 100 metres or further from the forest edge. Forest-interior species are those that are most sensitive to habitat edges and are usually found nesting 200 metres or further from the edge. Note that when forest cover declines to around 15 percent (in combination with fragmentation into smaller forest patches), 20 to 25 percent of edge-intolerant species disappear. An exception is Haldimand-Norfolk, which continues to support a high percentage of forest-breeding birds. This is partly because it contains several large (1,000 hectare) forests in relatively close proximity, and several areas within the county contain over 30 percent forest cover.

Deep forest habitat is also a contributor to landscape richness. This is a concept that considers the spatial distribution, quality, and diversity of habitats. A rich landscape has representation of all natural habitats that occurred historically, which are well connected to adjacent habitat types. Not only should a wide range of habitats be represented in a landscape or study area, a range of successional stages of each habitat should be present. Each habitat and each age class of habitat has the potential to support different plant and wildlife species. Rich landscapes enhance biodiversity, and ameliorate the effects of natural catastrophes such as diseases or insect infestations.

Photo by CWS

Using the Forest Cover and Interior Forest Cover Guidelines: Effects of Scale

In order to test the efficacy of the forest habitat guidelines (i.e., 30 percent forest cover, five percent 200-metre interior forest cover), the Canadian Wildlife Service (Tate 1998) used Geographic Information System (GIS) to overlay forest bird species occurrence from the *Atlas* and forest cover from the Ontario Hydro satellite image database of forest cover for southern Ontario. The presence of forest bird species in relation to percent forest cover, and percent forest-interior cover was analyzed at four different scales: 10 000 hectares (100 square kilometres, or a single *Atlas* square); 40 000 hectares (400 square kilometres, or four *Atlas* squares); 90 000 hectares (900 square kilometres, or nine *Atlas* squares); and 160 000 hectares (1,600 square kilometres, or 16 *Atlas* squares).

The applicability of each guideline and the response by forest birds varied considerably with the scale at which statistical analysis was conducted. This work identifies the importance of setting different targets for critical amounts of forest habitat rehabilitation at different scales from subwatersheds up to regional landscapes. Please refer to Appendix 5 for tables demonstrating how the number of forest-interior birds changes with varying amounts of forest cover at different scales.

2.3.4 Additional Forest Parameters

The guidelines outlined above (percent forest cover, size of forest patch, and percent of forest-interior habitat), are readily measured through the use of remotely sensed data and Geographic Information Systems (GIS). Additional guidelines that can be important but more difficult to measure follow.

Forest Shape

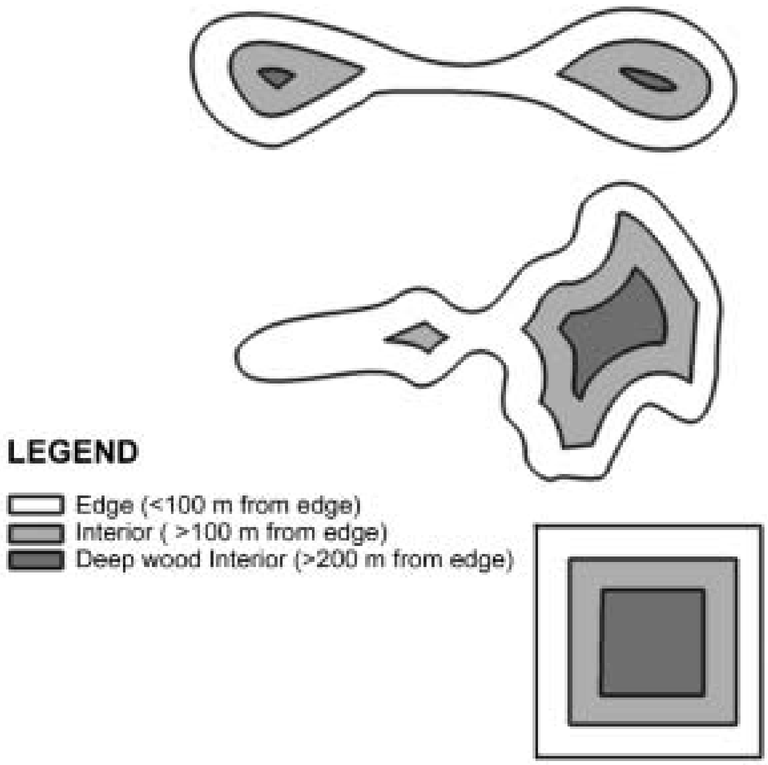
> Guideline

To be of maximum use to species such as fores- breeding birds that are intolerant of edge habitat, forest patches should be circular or square in shape.

> Rationale

Figure 1 demonstrates how habitat shape influences the amount of interior habitat. Square or circular habitats provide the greatest amounts of interior habitat compared to the area of habitat that is influenced by edge. Similarly-sized linear or irregularly-shaped habitats may contain little or no interior.

Figure 1. Forest Shape Determines Amount of Forest-interior (Ecological Services for Planning Limited, 1995)



There is conflicting evidence in the literature regarding the response of birds to edge habitats. Some studies have found evidence that linear habitats may have higher densities or that edge-use avoidance is linked to overall density of the species within the patch (Bollinger and Switzer, 2002). However, the literature appears relatively consistent, for example, on the increased negative effects of Cowbird nest parasitism and avian predators on edge-nesting birds (Chalfoun *et al*., 2002). Although the same authors caution strongly against generalization about nest predators and edges, they found that there were no differences in small and medium-sized mammalian predators between edge and interior.

Areas with high edge-to-interior ratios tend to favour edge specialists and generalist species as opposed to those species that are usually considered to be interior specialists or are at least edge-intolerant. Various edge effects (e.g., predation, disturbance, changes in food supply) may be important in some circumstances for some species. These effects likely extend from birds to other groups such as plants (Bowles, 1999) and bryophytes (Hylander *et al*., 2002).

Some of the confusion regarding the role of patch shape may be due to the use of presence-absence data (which are relatively easy to collect) compared to the detailed investigations needed to determine productivity of various wildlife species in linear versus circular habitat patches. Nevertheless, it is clear that in terms of restoration opportunities, the "infilling" of irregular forest patches can offer considerable benefits in terms of increasing interior habitat conditions (and decreasing the influence of edge) for a relatively small investment.

Proximity to Other Forested Patches

> *Guideline*

To be of maximum use to species such as forest-interior birds, forest patches should be within two kilometres of one another or other supporting habitat features.

> *Rationale*

Habitats in close proximity to other natural areas support more species than isolated habitats of the same size. Recolonization of habitat patches by Scarlet Tanagers (a forest-interior species) was found to decrease as the isolation of patches increased (Hames *et al*., 2001). Interpatch distance was suggested as a critical factor for a study that investigated patch colonization by the Common Buckeye butterfly (for a non-forest habitat) (Haddad, 2000). It is likely that recent improvement in radio-tracking technology will produce some interesting and relevant research on this topic in the future; in one study, male Hooded Warblers were recorded travelling up to 0.5 kilometre over open fields, primarily to solicit extra-pair matings (mating with individuals other than breeding partner) (Norris and Stutchbury, 2001).

Abundant forest cover within two kilometres of a particular forest patch was found to be a significant predictor for the presence of bird species that prefer interior forest habitat in Norfolk County (Austen and Bradstreet, 1996).

Some species with large home ranges may use several patches instead of one large area. Close proximity of habitats also facilitates wildlife movements among them. When rehabilitating habitats, improving the shape of existing habitats and focussing on areas that are near other natural areas will be most effective.

Fragmented Landscapes and the Role of Corridors

> *Guideline*

Connectivity width will vary depending on the objectives of the project and the attributes of the nodes that will be connected. Corridors designed to facilitate species movement should be a minimum of 50 metres to 100 metres in width. Corridors designed to accommodate breeding habitat for specialist species need to be designed to meet the habitat requirements of those target species.

> *Rationale*

Riley and Mohr (1994) presented the arguments for and against the role of corridors as movement corridors and cited Noss and Harris (1986) who proposed a conservation strategy that considers the pattern of existing high-quality nodes relative to actual and potential corridors.

Arguments regarding the utility of corridors continue in the literature (e.g., Hannon and Schmiegelow, 2002; Whitfield, 2001). It is clear that the development of a corridor strategy needs to consider landscape features and attributes (such as natural cover and the composition of surrounding matrix: i.e., to what are we connecting?), matching habitat for target species, corridor opportunities and constraints, as well as a balanced view of potential ecological effects both positive and negative.

The determination of optimum corridor widths for wildlife movement is difficult. This topic is further complicated by the difference between the intrinsic habitat values that may be found within linear habitat patches (e.g., breeding habitat for area-sensitive breeding birds), and the narrower function of movement by plants (through pollination and seed dispersal) or animals along a pathway that facilitates movement from one node to another. An area of only one metre in width will be used as a travel corridor by some wildlife species, while other species that must breed within corridors (e.g., some salamanders, small mammals, or insects) may require much wider features that will support productive breeding habitat. The long-term stability of the corridor within the surrounding existing or future landscape matrix might also be factored into the determination of an appropriate width.

To complicate matters, some species, such as Red Fox and Coyote, often move through open habitat. Others, such as White-tailed Deer, are indifferent to corridors; they tend to go directly from one place to the next and will either travel through open habitat or along a corridor if it happens to be leading in the direction that they want to go. Some species are obligate users of corridors, either being totally dependent upon them to get from one natural patch to another or highly-preferring to use them to get across the landscape.

Corridors 50 metres in width can facilitate movement for common generalist species while stream corridor widths of 75 metres to 175 metres have been suggested for breeding bird species (Spackman *et al*., 1995). These latter researchers also found that 10 to 30 metres was sufficient to include habitat for 90 percent of streamside plant species. Many studies have demonstrated that the wider a corridor is, the more effective it is (Dawson, 1994).

Like wetland adjacent-land areas, corridor widths must be determined based on a functional assessment of what the corridor is expected to achieve. Considering only movement, a minimum guideline of 50 metres to 100 metres is supportable. The provision of breeding habitat for target species would require knowledge of patch size requirement and an analysis of the potential for edge effects. In rural landscapes, it has been suggested that corridors should be as wide as 500 metres for specialist species, although this approach begins to overlap corridor function with other functions such as habitat patch size and shape. Intuitively, in urban environments it might be supposed that wider corridors would be required to provide the same level of function in the face of urban effects, assuming that target attributes might persist at all in an urban matrix.

Corridors for wildlife must provide suitable habitat for the species that are expected to move along them. Vegetation composition in the corridor should be similar to that in the nodes that it is connecting (or reflect soil/historic conditions). The corridor should be continuous between nodes and a minimum width along its entire length, although stepping stones of habitat do have connectivity value, if no other approach is feasible. (See also the discussion on riparian habitat guidelines.)

Forest Quality: Species Composition and Age Structure

> Guideline

Watershed forest cover should be representative of the full diversity of forest types found at that latitude.

> Rationale

Using remote sensing and GIS, quantitative measures such as percent forest cover can be readily measured. However, measuring qualitative information such as species composition and age structure of a forest is more difficult, requiring a higher degree of effort through ground-truthing. Although forest cover may be plentiful in a particular watershed, it may consist of early to mid-successional plant communities, mostly conifer plantations, or a variety of non-native species. Now increasingly available (e.g., through Conservation Authorities), Ecological Land Classification is a useful source of information in many locations.

Austen and Bradstreet (1996) found differences in forest composition, as defined by proportion of deciduous-to-coniferous and swamp to upland forest, were important for individual bird species. For example, Veery and American Redstart were found in areas with more deciduous cover, while Blackburnian Warbler, Pine Warbler, and Ovenbird were found more often in woodlands with more coniferous forest.

Working in the Severn Sound AOC, Tate (1998) suggested that in areas where coniferous and deciduous forest are both naturally occurring, at least one forest patch of 200 hectares is recommended for each forest type to support all or most edge-intolerant bird species.

Site conditions, such as soil and topography, should play important roles in determining which habitat types to restore in a particular area. In order to guide forest and wetland restoration in the Niagara River AOC, Environment Canada (Snell *et al*., 1998) used soil drainage categories to determine the original proportion of upland to lowland forest present. Due to drastic losses of upland forest, they recommended that restoration focus on drier vegetation communities. Deciding which forest types are priorities for restoration requires a sense of the pre-settlement landscape as guidance in the same manner in which a cumulative impact analysis was recommended for wetlands prior to decisions being made on wetland restoration projects (Bedford, 1999).

Photo by CWS

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List of Abbreviations and Acronyms

AOC: Area of Concern

CFZ: Critical Function Zone

CCME: Canadian Council of Ministers of the Environment

FI: Forest-interior

FIE: Forest-interior/Edge

Framework: A *Framework* for Guiding Rehabilitationin Great Lakes Areas of Concern

GIS: Geographic Information System

mg/L: milligrams per Litre

PZ: Protection Zone

PAC: Public Advisory Committee

RAP: Remedial Action Plan

TRCA: Toronto and Region Conservation Authority

UVB: Ultra-Violet radiation of relatively short wavelengths

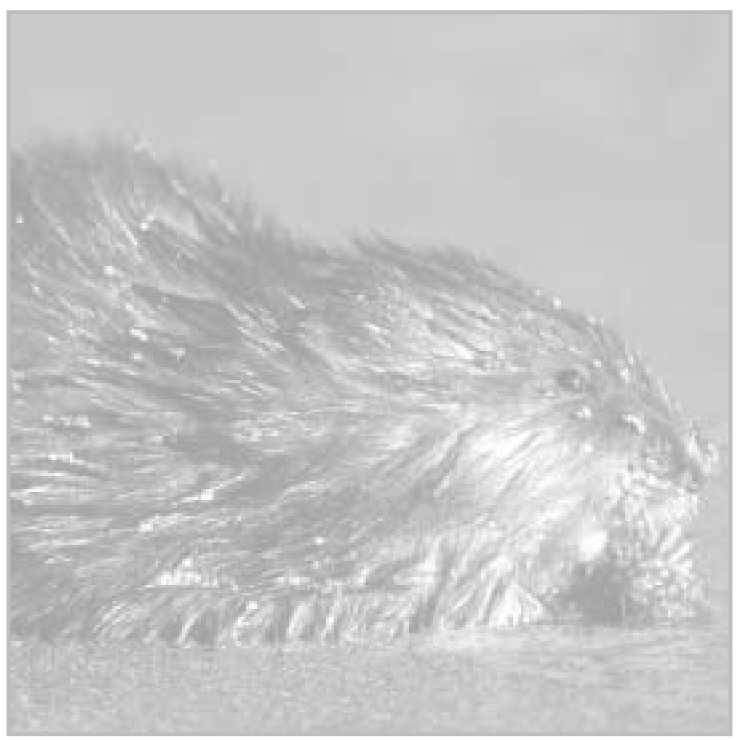

Photo by Eric Dresser

Appendix 1

The Severn Sound AOC: Habitat Identification and Rehabilitation, Delisting and Use of the Habitat *Framework*

The *Severn Sound Remedial Action Plan Stage Two Report* (SSRAP Stage 2) was developed and submitted in 1993. Stage Two reports are intended to set goals and identify remedial and preventative actions to restore beneficial uses. (Stage One reports describe environmental conditions and basic problems and issues.)

Wherever possible in the RAP process, delisting objectives were developed that were specific, reproducible and defensible measures to respond to each of the use impairments in the Severn Sound AOC. The SSRAP Stage 2 identified that littoral, tributary and watershed habitats were important to the ecosystem health of Severn Sound and that these habitats were degraded in several areas (SSRAP Stage 3). The objectives set out in the SSRAP Stage 2 reflected the best indicators available at the time of writing. The delisting objectives for the use impairment, *degradation of fish and wildlife habitat*, for the Severn Sound RAP were as follows:

- To implement the Severn Sound Fish Habitat Management Plan and other policies to enhance and prevent the loss of fish and wildlife habitat.
- To encourage the restoration of fish habitat in target areas by proponents of new shoreline development.
- To develop plans for rehabilitation or development of new coastal wetland areas as opportunities arise.
- As part of the Matchedash Bay project (North American Waterfowl Management Plan 1991), to:
  i) secure and manage 1,715 hectares of wildlife habitat
  ii) restore and develop 1,427 hectares of habitat for waterfowl and other wetland -dependent wildlife
  iii) maintain and enhance 442 hectares of habitat for staging waterfowl.
- To rehabilitate tributaries and riparian areas for fish and wildlife habitats.
- To maintain existing colonial waterbird nesting sites within and near Severn Sound.
- To maintain and increase Osprey nesting sites within Severn Sound.

(Source: SSRAP Stage 2)

In some cases, knowing that methods were under development, the indicators used to assess the objectives were left "to be determined". Since implementation of remedial actions did not occur all at once or by a certain date, the rigorous measurement of change in ecosystem health is difficult. This has been especially true in the case of habitat restoration since the planting of trees and shrubs and the rehabilitation of riparian habitat still continues. The full benefit of each individual project will be realized as rehabilitated areas mature.

Substantial implementation of remedial actions, such as habitat restoration, took place between the late 1980s and 2002. At the end of that period, the third stage of the RAP process commenced. This stage involved documenting completed actions and the status of each use impairment. During the period between the release of the SSRAP Stage 2 and the SSRAP Stage 3, additional indicators had been developed to assess use impairments as well as improved methods to measure ecosystem responses. In terms of habitat, some indicators were based on *Framework* guidelines.

The principles followed in assessing the status of the delisting objectives included:

- selecting a variety of indicators wherever possible that best reflected the status of the delisting objective
- selecting a measurable end point or threshold for each indicator
- having indicators that should show measurable changes in time and in space.

Indicators used to evaluate delisting objectives in Severn Sound

The first edition of the *Framework* was evaluated to be applied on a subwatershed basis in the AOC and considered as indicators for the assessment of RAP delisting objectives (Gartner Lee Limited, 1997a; Gartner Lee Limited, 1997b; Tate, 1998, Sherman and McPhail, in prep.).

The following guidelines were selected for use as indicators in Severn Sound.

Upland Habitat

a. percent forest cover >30 percent of watershed

b. interior forest with 100 metre buffer >10 percent

c. interior forest with 200 metre buffer >five percent

d. size of largest forest patch: at least one patch with a minimum of 200 hectares, minimum of 500 metres across

e. shape and proximity considerations for forest patches and corridors

f. forest cover should represent full diversity of species composition and age structure found in ecoregion

Riparian Habitat

a. percent of stream naturally vegetated: at least 75 percent of first to third-order streams

b. amount of natural vegetation adjacent to streams at least 75 percent of a 30-metre buffer of natural vegetation on both sides of the streams

c. suspended solids concentrations <25 milligrams/litre for the majority of the year

d. percent urbanized: <15 percent imperviousness in an urbanized watershed

e. fish communities based on fish-community survey and temperature

Wetland Habitat

a. percent wetlands in watershed and subwatersheds: >10 percent of each major watershed, >six percent of each subwatershed or restore to original percent wetlands

b. amount of natural vegetation adjacent to each wetland: >240 metres width of adjacent natural vegetation (using adjacent forest cover in Severn Sound)

c. wetland type: marshes and swamps suitable for rehabilitation

d. wetland size and shape: swamps as large and regular as possible to maximize interior forest, marshes of various sizes and shape to maximize interspersion

In addition to the literature review carried out to support the *Framework*, a review of local conditions and other studies was used to evaluate and augment the guidelines as indicators for use in Severn Sound. Interior forest habitat guidelines were evaluated in the Severn Sound area using interior forest bird species as indicators (Tate, 1998), which allowed the health of the Severn Sound interior bird populations to be directly assessed as well as the habitat metrics (forest cover, 100 metre and 200 metre interior forest, patch size).

Identifying habitat in the Severn Sound AOC

Severn Sound forest habitat, riparian habitat and wetland habitat was examined using the *Framework*. The watershed was divided into 16 subwatersheds, which range from 24 to 121 square kilometres. A Geographic Information System (GIS) analysis was conducted on each subwatershed to determine the status of habitat targets and to refine the habitat strategy for the Severn Sound AOC (see Appendix 1 – Figure 1; McPhail, 1999). Changes in forest cover and riparian cover were also examined between 1982 (the year documented in the Ontario Base Map, or OBM, for the area) and 1998, using a forest layer developed from 1998 Ontario Ministry of Natural Resources infrared air photos (see Appendix 1 – Figure 2; Hudolin, 1999). Using the same interpretive techniques and Geographic Information System (GIS) methods, it was also possible to use other available air photo coverage to document longer-term and more detailed time steps in the changes in forest cover for selected subwatersheds.

The value of comparing the *Framework* guidelines among two or more dates is illustrated by Appendix 1 – Figure 1A, where interior forest patch size increases with time over three air photo coverages (1953, 1982 and 1998). Appendix 1 – Figure 2 shows the differences in forest cover between 1982 and 1998 for the entire subwatershed and illustrates the importance of sustaining a net increase in forest cover over time.

Appendix 1 – Table 1 shows that the size of the largest forest patch in Hogg Creek has increased due to strategic planting. This was not the case in all subwatersheds where some form of securement of large forest patches is needed despite a general net gain in percent forest cover.

The assessment of riparian habitat is illustrated in Appendix 1 – Figure 1B. A restoration project was carried out in 1991; the figure shows increases in habitat between 1981 and 1998 in terms of percentage of vegetated stream length and percentage of stream with a 30-metre buffer. The hydrogeology within subwatersheds in Severn Sound (Singer *et al*., 1999) suggests that headwater areas of some streams may not contribute as much to the groundwater recharge/discharge as some of the mid-sections of subwatersheds where groundwater recharge was known to occur. Many of the headwater areas of Hogg Creek are intermittent or warm-water marshes while areas downstream (even fourth or fifth-order streams) have observed groundwater input and maintain continuous cool water flows, suggesting that efforts to restore headwaters may not be as beneficial as efforts on downstream reaches. Despite these local differences, the indicator for Severn Sound streams was that 75 percent of the length of first to third-order streams be vegetated.

In addition to the 75 percent guideline, the threshold value of 50 percent from the narrative portion of the *Framework* was used to evaluate riparian habitat in each subwatershed. The stream segments intersecting wetlands but without forest cover at the bank were also considered as vegetated in the estimate of length of stream with "natural vegetation" for Severn Sound subwatersheds.

As stated in the *Framework*, a number of factors need to be considered in relation to streams and stream corridors in addition to percent riparian cover. For example, the suspended solids guideline for riparian habitat was interpreted for Severn Sound streams to apply to the baseflow period of the year, which usually extends over at least 90 percent of the year. During spring freshet and increased runoff events (usually <10 percent of the year), the suspended solids and the total phosphorus concentrations were found to be significantly related to flow.

The importance of being aware of local conditions in combination with *Framework* guidelines was illustrated along some stream reaches where forest cover was not established along stream banks due to natural meander belts and marsh vegetation. These reaches, however, support cool and cold-water habitat conditions that would be expected on a forested reach. The use of relatively inexpensive temperature loggers to characterize the stream temperature regime was used in Severn Sound tributaries to further characterize stream habitat conditions.

The wetlands evaluated for adjacent natural vegetation consisted of Provincially Significant Wetlands in the Severn Sound watershed (with upland "islands" removed) combined with the smaller unclassified wetlands from the OBM wetland layer. Appendix 1 – Figure 1C shows the status of wetland habitat in 1982 and 1998 with the changes resulting from restoration as well as from natural succession. The percent wetland area guideline of 10 percent of watershed was not met with the exception of Sturgeon River and Wye River watersheds. The percent wetland area guideline of six percent for subwatersheds was generally met, with the exception of Coldwater River (SSRAP Stage 3). Note that no change with time comparison was made for wetlands because no historical layer for wetlands was available other than the Classified – OBM wetland layer.

Other guides and references were used in addition to the *Framework* and field data. Habitat issues such as nearshore fish habitat and waterbird habitat were addressed through other methods developed for the Great Lakes AOCs. A Defensible Methods approach was developed (Minns *et al*., 1999) that combines a physical habitat inventory with a model to classify most of the littoral zone fish habitat suitability for different groupings and life stages of fish in Severn Sound (see also Randall *et al*.,1993; 1998). Surveys of waterbirds and important bird species in Severn Sound also revealed valuable habitat areas within the AOC (Weseloh *et al*., 1997; Wilson and Cheskey, 2001a; 2001b; 2001c).

Site specific initiatives within the Severn Sound area also provide an indication of the restoration status of habitat within the AOC. The Eastern Habitat Joint Venture, part of the North American Waterfowl Management Plan, is conducting a large scale habitat protection and improvement project in Matchedash Bay (Tymoshuk and Martin-Downs, 1990, North American Waterfowl Management Plan, 1991). The Severn Sound RAP Tributary Rehabilitation Project and the Penetanguishene Shoreline and Wetland Restoration Projects are examples of restoration projects that were evaluated on a site specific basis as well as on a subwatershed basis.

Appendix 1 – Figure 1. Habitat Cover Over Time

Examples of measurable changes in upland forest, riparian and wetland habitat conditions for the Hogg Creek watershed.

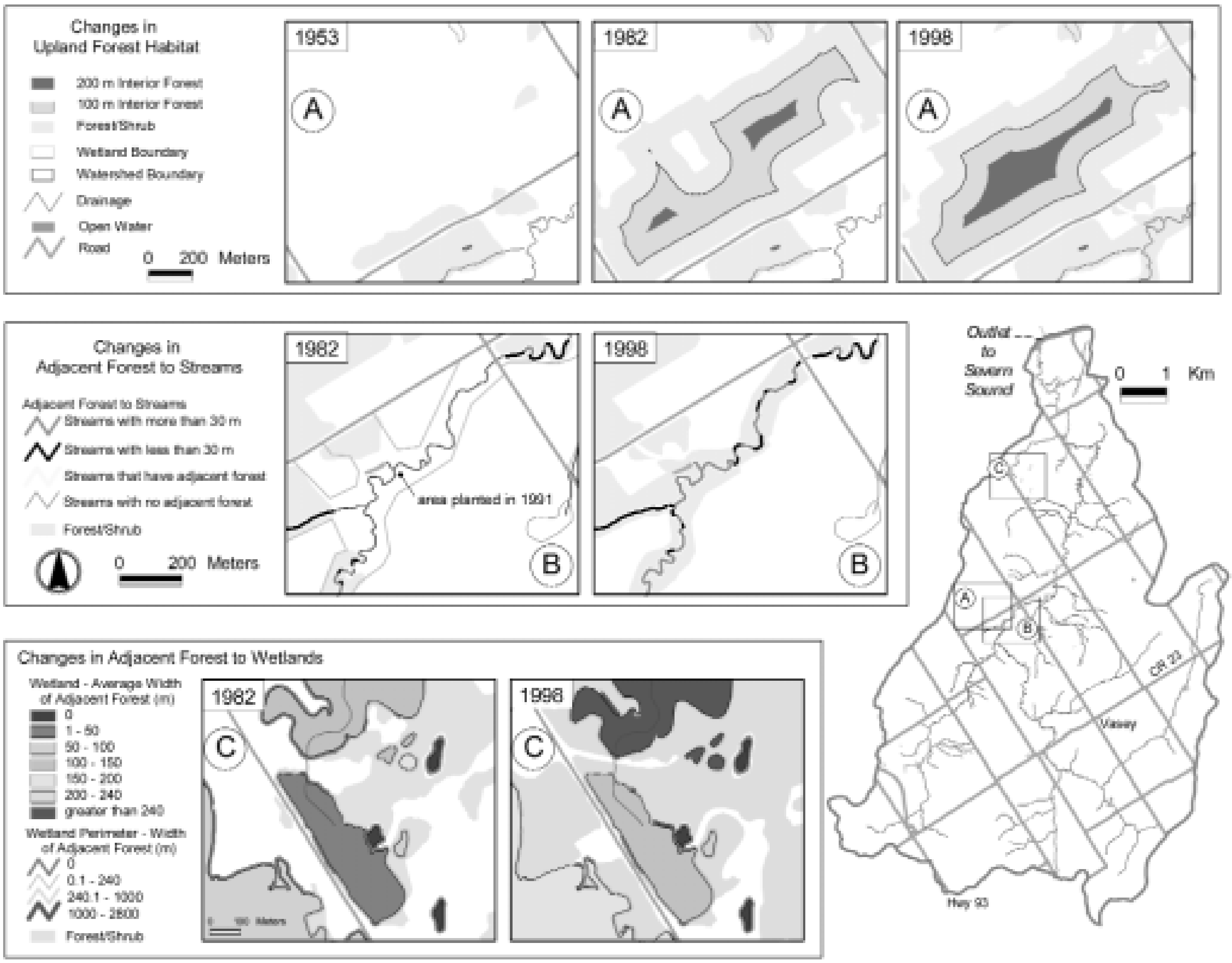

Illustration by Severn Sound Environmental Association

Appendix 1 – Figure 2. Hogg Creek – 1982/98 Difference in Forest Cover

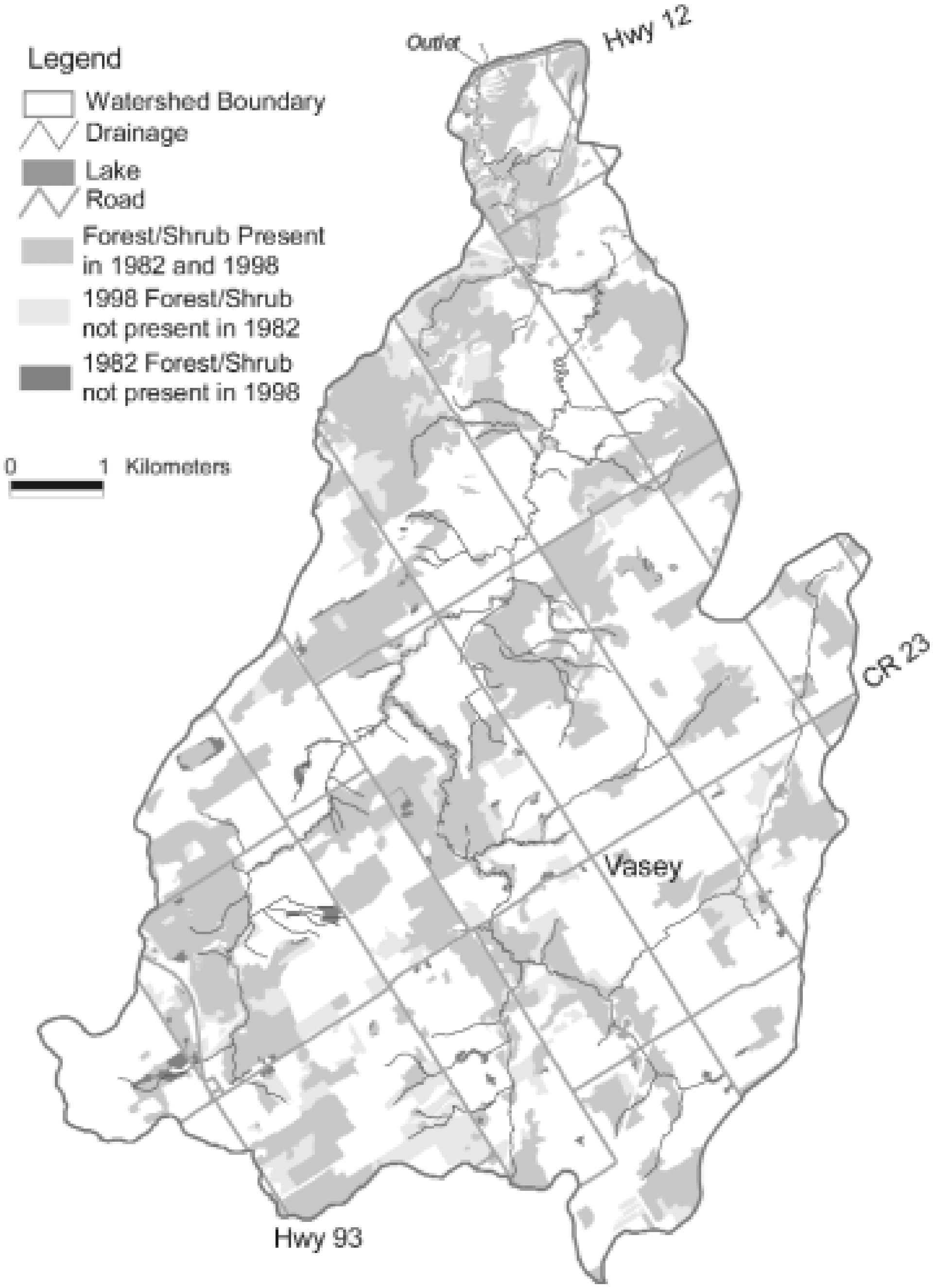

Illustration by Severn Sound Environmental Association

Habitat status in Severn Sound at RAP Stage 3

Upland Habitat

Although there were significant reductions in the size of the largest forest patches, there has been little net change in forest cover across Severn Sound. The 1998 analysis shows that upland habitat targets are generally being met for the Severn Sound watershed with the exception of interior forest targets in Hogg Creek, and some subwatersheds on the Wye River and the North River. These areas will be the subject of further targeting for remediation where feasible.

It would appear from planned or proposed development in some subwatersheds that the reduction in percent forest cover will continue. It should also be recognized that the net increase results from forest planting and natural succession exceed forest removal. In order to sustain forest cover, planting programs should be sustained. Mechanisms to secure large interior forest patches should also be pursued.

Riparian Habitat

Riparian vegetation along first to third-order streams in Severn Sound has increased between 1982 and 1998, with the exception of Silver Creek (North River) and McDonald Creek (Wye River). This increase is evidence of improved awareness of the value of vegetation in stabilizing stream banks and is directly attributable to the Severn Sound RAP Tributary Rehabilitation Project. The longer-term changes in riparian buffers for Hogg Creek show a gradual increase from 1953 to 1998.

The projected future riparian cover will result from changes to livestock-watering practices at traditional farms and expected growth of areas planted during recent Severn Sound RAP Tributary Rehabilitation Project efforts. Since 1991, a total of 133 projects were completed through the project. Some 127 kilometres of stream banks have been fenced and/or remediated, restricting the access of more than 2,700 livestock units. The riparian projects have resulted in more than 470 hectares of fragile valley lands being retired from agriculture. Also, some 154,000 trees and shrubs have been planted.

Appendix 1 – Table 1. Severn Sound RAP – Habitat Restoration Strategy – Hogg Creek Subwatershed. Summary of Forest, Riparian and Wetland Habitat Targets for First to Third-order Streams

Guidelines	Target	1982	1998	Difference
Forest Habitat Guidelines				
% Forest cover	>30	32%	38%	6%
Size of largest patch (Ha)	> 100 Ha	163 Ha	199 Ha	36 Ha
% Forest > 100 m from edge	>10%	6%	11%	5%
% Forest > 200 m from edge	>5%	1%	3%	2%
Riparian Habitat Targets				
% first to third-order streams with natural veg.	>75%	47%	57%	10%
% first to third-order streams with > 30m natural veg.	>75%	29%	40%	11%
% first to third-order steams with natural veg. plus wetlands	>75%	57%	64%	7%
% first to third-order streams with > 30m natural veg. plus wetlands	>75%	36%	44%	8%
Wetland Habitat Targets				
% Wetlands in watershed	>10% (sub>6%)	7%	7%	0%
Amount of vegetation mean width (m)	>240 m	71 m	122 m	51 m

The promotion of the riparian program has been systematic and has resulted in generally increased awareness of the need for restricting cattle access to streams. However, landowners took advantage of the program on a case-by-case basis, which resulted in a gradual and sometimes uneven distribution of projects along the streams. Despite the voluntary nature of the participation, extensive habitat corridors have been realized on several streams in the Severn Sound area. The projects have not been restricted to first to third-order streams.

Wetland Habitat

There was a general increase in mean width of vegetation adjacent to wetlands between 1982 and 1998. Significant decreases were noted in the Bass Lake and Silver Creek subwatersheds due to increasing urbanization and in the Purbrook Creek subwatershed due to an increase of pasture area. Coastal wetland habitat has been rehabilitated in Penetang Bay, Midland Bay and Hogg's Bay. The trend in loss of coastal wetland habitat described by Cairns (SSRAP Stage 2) was greatly reduced through the 1990s. However, increasing pressure to develop shoreline areas, especially during current low water levels (1999 to 2001), have led to destruction of some areas of Provincially Significant Wetlands.

On private lands, rehabilitation projects have resulted in 10 hectares of created wetlands, 36 hectares of enhanced wetlands, and more than 170 hectares of wetlands protected by planning designation or conservation agreement. Classified wetlands and associated complexed wetlands are being systematically reviewed and reclassified, resulting in updated wetland boundaries for better planning protection and enhancements.

How were Framework guidelines used to contribute to delisting the Severn Sound AOC and sustaining the local ecosystem?

Once the status of Severn Sound habitat had been determined, the *Framework* guidelines provided valuable benchmarks to aid the direction of further restoration efforts and protection of habitat areas. The forest-cover mapping and habitat assessment allowed systematic targeting of properties that would provide the greatest benefit to planting programs. The use of this information continues to help focus efforts in ongoing landowner contacts.

Municipalities were provided with habitat assessments for use in Natural Heritage Strategies, Official Plan designations and zoning bylaws, as well as planning decisions on individual land-use proposals.

As a result of the RAP analysis based on the first edition of the *Framework*, the extent of habitat on a subwatershed basis could be summarized in a defensible fashion and presented for expert review. The status of restoration and the rationale for delisting of the Severn Sound RAP for the habitat-use impairment was in part determined based on the analysis. The SSRAP Stage 3 concluded that restoration had been achieved conditional to ongoing assessment and implementation of habitat restoration. This is not surprising considering that the sustainability of habitat in Severn Sound requires ongoing assessment and management.

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Photo by Eric Dresser

Appendix 2

Toronto and Region Conservation Authority (TRCA) Terrestrial Natural Heritage Strategy

The Toronto and Region Conservation Authority (TRCA) has an approach to terrestrial natural heritage that considers all the natural cover in a region (all forest, wetland and native meadow) as one "organism" functioning in the landscape rather than as a collection of individual sites, some of which may be considered "significant". The approach uses the following criteria:

- quantity (the percent natural cover in a region)
- quality (the average habitat patch size, shape and matrix influence)
- distribution (the distribution of that quantity and quality of natural cover).

Calibration

The approach to evaluating the condition of natural systems works in a kind of nested fashion among all scales, for two reasons:

- the basic unit used for assessing quality (size, shape and matrix influence) is the individual habitat patch
- every patch in the TRCA's area of jurisdiction is scored individually but within one range calibrated to the entire jurisdiction's collection of patches.

This allows one to calculate an average-quality value for a natural system at any scale within the broad region (such as the TRCA jurisdiction or Toronto and Region AOC) down to an individual watershed, municipality, subwatershed and individual site. Using the patch as a basic unit within the entire regional patch data set enables one to show how strategies and actions can work together with relevance to smaller or larger scales.

Furthermore, the quality measures can be used to determine a quantifiable target for a desired average quality at any scale or, as in the case of AOCs, a delisting target. Thus, improving natural system quality (average patch size, shape and matrix influence) in the Centreville Creek subwatershed would have a positive influence on the Toronto and Region AOC, for example, and can be portrayed as a quantified contribution toward a targeted quality for delisting the AOC.

This methodology was developed at a time when the RAP guidelines were emerging. The guidelines provided support and inspiration in pursuing this landscape-scale, target-setting exercise. One main point of expansion, however, is the matrix-influence criterion mentioned above, which is discussed further below.

The TRCA is in the process of writing a Terrestrial Natural Heritage Strategy to work with its partners and stakeholders, and assist in associated projects. The Toronto and Region AOC covers most of the TRCA jurisdiction and the collaborative exercise of setting delisting targets is an important objective of the Strategy.

Matrix influence

The most important characteristic of a habitat patch for biodiversity is its size (Kilgour, 2003), which relates to the amount of space required for species to find resources and remain in viable populations. The second factor is matrix influence. (Shape, to a lesser degree, is also a factor in determining the quality of a habitat patch.)

Matrix influence is a measure of the positive or negative influence which a patch receives from its surroundings. Land-uses, especially urbanization, adjacent to a patch can exert pressure or impacts with a profound effect on its biodiversity (Lindenmayer and Franklin, 2002). Conversely, a patch can have a synergistic and beneficial relationship with other natural cover in its surrounding area and, to a lesser degree, with agricultural lands. In other words, a patch's score for matrix influence reflects the degree to which the surrounding land cover and land-uses threaten or contribute to its biological integrity and diversity.

The TRCA measures the character of the matrix within a two-kilometre radius out from the outside edge of each habitat patch. The two-kilometre radius of influence will extend beyond the limit of a study area (a watershed or an AOC, for example) if the patch is near the limit of that study area. The radius length was chosen because:

- it is considered to be a reasonable foraging circuit for predatory species associated with edge effects, such as raccoons, foxes, feral cats and cowbirds (negative influence)
- it is the distance within which most genetic exchange and species dispersal can be expected from most flora and fauna species (positive influence)
- it is a distance that could be considered reasonable by people to regularly visit a natural area for recreational purposes, by walking, cycling or driving (negative influence).

Scoring patch matrix influence

In scoring for matrix influence, the land-cover types are calculated as a percentage of the total area within the two-kilometre radius from the edge of each habitat patch. For the purposes of this calculation, there are three categories of land cover (natural, agricultural and urban); each receives a base value of negative one, zero or one on the gradient of influence.

Natural cover surrounding a patch is considered to have a positive influence and receive a value of one. Included in this category are patches of the major habitat types such as forest, wetland and meadow, as well as open water in the form of lakes, rivers and ponds.

Agricultural lands can have negative impacts such as pesticide runoff, but they also allow for the movement of many species between patches and across the landscape, in particular for amphibian movements between forests and wetlands. As a result, they score zero points as the mid-point on a continuum.

This connectivity function is not provided for many species by urban land-uses. In fact, due to pollution, refuse, recreational pressures, the presence of dogs and cats, invasive species and other negative influences, urban areas in general can be considered harmful to natural habitats. Therefore, they receive a base point of negative one.

The percent of each of the land-cover types is measured for within the two-kilometre matrix, and each is multiplied by the base point value. The three resulting values add up to the matrix influence score for the patch, as in the following example:

Land Cover Type	Percent of Matrix	Cover Type Value	Total
Natural	40	+1	40
Agricultural	30	0	0
Urban	30	-1	-30
		Patch Score	10

From a biodiversity-conservation perspective, the perfect patch surroundings would be totally natural (e.g., wetland within an extensive forest patch, measuring at least two kilometres out from the wetland edge) and would receive a matrix score of 100, while the lowest possible score is negative 100 for a natural habitat patch immersed within an expanse of urban (residential or industrial) land.

Natural systems matrix influence

The patch scores give a localized measure based on single patches that, when averaged for a study area, can give a sense of the overall matrix influence on a natural system as a whole and, when graphed, can show the amount of hectares that fall within a range of matrix influence values for the natural system.

It must be remembered that the value is not only a measure of the urban and agricultural influence on the natural system, but that it also encompasses the internal positive value of the natural cover in toward itself. This natural matrix influence speaks to the concept of patches benefiting from each other and to natural system connectivity at the landscape scale. The combination of all natural, agricultural and urban land-uses in this measure also speaks to land-use planning as a determinant of biodiversity in the landscape.

Matrix values in context

An important consideration is that the TRCA approach is based on three equal attributes. These quality measures (size, shape and matrix) are useful strictly in consideration of the quantity and distribution of natural cover in the landscape. For example, a natural system that in total covers 20 percent of a primarily agricultural watershed could conceivably obtain a good average matrix influence value, especially if its patches are clumped in one area of the watershed. However, that natural cover would not be of sufficient quantity and appropriate distribution necessary to attain the desired biodiversity and ecosystem function in that watershed.

For more information on the TRCA's Terrestrial Natural Heritage Strategy and its matrix influence measure, please contact the TRCA at (416) 661-6600.

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Appendix 3

Applying the Framework to Land-use Planning

The *Framework* was originally designed to provide guidance on how to restore (or delist) AOCs throughout the Great Lakes basin. A 2002 review of *Framework* implementation revealed that the approach has been applied in nine AOCs and several others have considered the guidelines in developing delisting criteria. In practice, Geographic Information System (GIS) mapping of current habitat conditions is undertaken to compare against preferred *Framework* target conditions, and the resulting maps are used to pinpoint "best bet" restoration opportunities (see the Severn Sound AOC approach in Appendix 1).

Interest has been expressed in using the *Framework* guidelines for habitat protection and for restoration through the municipal land-use planning process. The purpose of this appendix is to provide discussion on how the *Framework* can advance habitat protection in land-use planning within, and possibly beyond, AOCs.

The ecological concepts important in conserving the fragmented natural landscapes of southern Ontario can be expressed around the themes of landscape retention, landscape restoration and ecosystem replacement (Riley and Mohr, 1994). Beginning in the 1970s, Ontario municipalities have attempted to protect natural areas by designating environmentally significant areas (ESAs) in Official Plans. In addition, many such plans include specific policies protecting Provincially Significant Wetlands, flood plains and Niagara Escarpment lands. Work introduced by the Ontario Ministry of Natural Resources in the mid-1990s (Riley and Mohr, 1994) advanced natural heritage system planning through identifying a system of core areas with linking corridors and identifying the need for restoration.

This evolution in natural areas protection occurred through recognition that protecting ESAs is problematic as they are often isolated "islands of green" that are too small to support viable wildlife populations. Frequently, these areas were designated as significant because they contained rare species; however, focussing primarily on rare species resulted in population declines of more common species being overlooked until they too were designated rare. The rare-species approach also failed to account for the interdependence of all native species as integral components of a healthy ecosystem.

In many parts of Ontario, habitat loss has been significant. The identification and designation of natural heritage systems in Official Plans still only seeks to protect what exists without consideration for what could or should exist. The focus of this appendix is linking habitat protection with restoration towards protecting long-term, sustainable natural heritage systems that function with ecological integrity.

How can the Framework be incorporated into land-use planning?

Proposed applications are discussed below, drawing upon land-use planning practice examples where applicable. Ways that the *Framework* can be incorporated into land-use planning applications in Ontario include:

- combining protection and restoration philosophy for Official Plans
- developing specific Official Plan policy language
- developing an approach for enhancing natural heritage systems
- scientific grounding for specific policies on protecting significant woodlands and wetlands, and other landscape features.

Combining protection and restoration philosophy for Official Plans

Many Official Plans contain introductory paragraphs that set the tone for the actual policies in a particular section. For example, the Region of Hamilton-Wentworth's 1995 Official Plan (Regional Municipality of Hamilton-Wentworth, 1998) contains a preamble to the section called Natural Setting that reflects the vision developed by their Task Force on Sustainable Development:

> *There exists in Hamilton-Wentworth a system of natural areas of varying significance as well as locations where degraded natural habitat has the potential to be ecologically enhanced or restored…*

Such a preamble, influenced by the *Framework* guidelines, could speak to the current state of the Natural Heritage Strategy, introduce the *Framework* guidelines, and then express a policy interest in not losing any additional habitat while undertaking ecological restoration towards locally-established habitat targets. Habitat protection policies could follow, along with policies stating restoration goals. A table outlining current habitat conditions, local habitat targets, and anticipated end points for habitat restoration could be included.

Policy-making is an art as much as a science and creativity demonstrated by municipal planners often leads to innovative policy initiatives. While the wording would be more local and precise in actual application, the following paragraph illustrates this concept:

> *The current municipal Natural Heritage Strategy incorporates the best of the remaining habitat in the municipality, including core areas and linking corridors. The* Framework for Guiding Habitat Rehabilitation *outlines desired quantities of habitat suitable to maintain ecological integrity. Based on community input, the Municipal Biodiversity Strategy has been developed, which outlines current habitat conditions in the Natural Heritage Strategy, compares those levels against ecologically-desired habitat levels outlined in the* Framework *and, using guidelines contained in the* Framework*, establishes local specific targets for habitat protection and restoration. The policies contained in this section express community interest in protecting and restoring the municipality's biodiversity, using targets derived from the* Framework*. Map 1 (Appendix A) outlines the most desirable locations for restoration of the municipality's natural heritage system."*

Developing specific Official Plan policy language

Opportunities may arise for extracting guidelines from the *Framework* and building them into Official Plan policies. For instance, the City of Windsor sought to develop a greenway along the St. Clair River and developed policy to minimize impervious-surface treatments for the Central Riverfront Park Lands – no more than 15 percent coverage of the total, reflecting *Framework* guidelines of the time (City of Windsor, undated).

Developing an approach for enhancing natural heritage systems

In Ontario, the Planning Act, the Provincial Policy Statements (PPS), and accompanying implementation guidelines provide the primary requirements for development of municipal Official Plans. It is important to note that they are also considered as minimum policies and municipalities are invited to go beyond the PPS in development of their Official Plans (see cautionary note below).

Policy 2.3 of the PPS contains natural heritage policies related to significant woodlands, wildlife habitat, wetlands, valleylands, Areas of Natural and Scientific Interest, fish habitat, and significant portions of the habitat of endangered and threatened species. The Ontario Ministry of Natural Resources Natural Heritage Reference Manual introduces the Natural Heritage Strategy approach that supports section 2.3.3 of the PPS, which states that “the diversity of natural features in an area and the natural connections between them should be maintained, and improved where possible”.

Most municipalities have designed, or are in the process of designing, a Natural Heritage Strategy based on existing habitat that is in most cases below optimum *Framework* guidelines (i.e., less than 30 percent forest cover, small amounts of interior forest, small forest patch sizes, less than 10 percent wetlands, low levels of riparian vegetation). As AOCs have done, municipalities can be encouraged to compare existing levels of habitat with a future desired strategy that meets locally-derived habitat targets drawn from the *Framework* guidelines. One example of building the *Framework* guidelines into policy would be insertion of a Natural Heritage Strategy restoration policy in the Official Plan, with reference to a future-oriented map depicting potential restoration sites.

Scientific grounding for specific policies on protecting significant woodlands and wetlands, and other landscape features

The *Framework* has been used as a key guidance document in criteria development for protection of significant woodlands in the Regional Municipality of Halton (Gartner Lee Limited, 2002). Criteria chosen from the *Framework* include woodland patch size, distance from perimeter, and landscape connectivity.

The *Framework* has also been used to guide habitat protection planning in the community of Willoughby within Langley Township, British Columbia (Astley, 2003). Willoughby is an area faced with increasing housing development. The *Framework* guidelines were used to ensure that wildlife values were incorporated into neighbourhood plans. Due to the fragmented nature of local habitat, the authors used the guidelines to suggest retaining the largest remaining habitat patches and the small number of wetlands present.

Possible Limitations

A recent comparison of the PPS Natural Heritage Guidelines, the *Oak Ridges Moraine Protection Act* regulations, and the *Framework* guidelines found that, in general, the *Framework* guidelines were more protective than the others (Rowe 2002). However, both provincial policies are enshrined in legislation and form a *de facto* mandatory planning approach for municipalities. To date, the *Framework* guidelines do not carry legislative or substantive authority, although they have been used in this way as the examples above indicate.

Although municipalities are invited to treat the PPS as minimum planning guidelines when establishing policy, planners must consider the potential of an Ontario Municipal Board challenge to policies that stray beyond provincial norms. This concern may serve to limit the use of the *Framework* guidelines in Official Plans.

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Photo by Graham Bryan

Appendix 4

Toronto and Region Conservation Authority (TRCA) Fish Community Target-Setting Framework

Management direction for watercourses or subwatersheds often has been based on the existing condition of a fish community. In some situations where the aquatic system has not been severely impacted, the existing fish community is likely a reflection of the historic community and establishing a management direction based on this information would be appropriate. However, in many situations the existing fish community has been impacted by historic or present land-use practices and may not reflect what was historically present, nor the potential fish community that could be present based on the existing physical conditions.

For example, in the Rouge River watershed most of the fish communities are dominated by warm-water species with some cool-water species also present. However, the fundamental characteristics of the watershed such as surficial geology and baseflow indicate that migratory salmonids should be supported although none are present. Through transfers of adult trout into habitats deemed appropriate for spawning, successful reproduction was achieved. In this example the major factors impacting the potential of the fish community were the inability of salmonids to get to appropriate habitat due to migration barriers and, secondarily, water temperature.

This reach is now being managed for cold-water species with planting of riparian vegetation to shade the stream as one of the rehabilitation recommendations. Had the assessment of this watershed not included an analysis of fundamental characteristics, the fish community might have been managed strictly for a warm-water community and it might never have achieved its historic potential.

This general *Framework* is derived from the TRCA fish-management planning approach for the Rouge, Don and Humber River watersheds. Rather than basing planning on existing, often degraded, fish communities, the TRCA establishes targets based on setting an expectation for a fish community. The approach is based on three types of information:

- knowledge of the fundamental or underlying characteristics of the watershed or subwatershed (drainage area, surficial geology, flow regime) and what fish communities have historically been present
- knowledge of what the system is presently supporting (existing fish community) and some idea of its condition
- knowledge of the factors presently impacting the system and their relative magnitudes.

It is important that management targets for fish communities be based in part on an assessment of historic conditions by examining historic fish communities and fundamental characteristics of the watershed such as surficial geology. These factors provide an indication of what a healthy system would support. Without this reference, management decisions would be made relative to an existing condition that may already be impacted. The closer the present condition is to the historic condition, the less impacted and the healthier the system; alternately, a system that deviates significantly from the historic condition is less healthy. Where a system is slowly being degraded, the reference point to determine what might be supported would change over time and perception of health would change. The historic reference point is critical in order to maintain continuity in perceptions of the health of ecosystems.

In some severely-impacted systems, returning to a historic condition may seem unachievable, while in other less degraded systems the historic condition might reasonably be achieved. For example, Taylor/Massey Creek is a highly degraded tributary in the Don River watershed that would have historically supported trout and salmon. Approximately 25 percent of this subwatershed consists of coarse soils, conducive to infiltration. The middle and lower reaches of this tributary would have supported Brook Trout and Atlantic Salmon but presently support only four fish species: Creek Chub, White Sucker, Blacknose Dace, and Fathead Minnow. These conditions are due to extensive urbanization and the absence of stormwater controls (due to the age of the housing development).

The target set for these reaches is to improve conditions so that species such as Johnny Darter and Mottled Sculpin would be supported. In the headwaters where no fish are present, the short-term target is to have a pollution-tolerant fish community present. In the long term, as rehabilitation occurs, the fish community targets could be shifted to more sensitive species. In this situation, the historic condition provided a context and the direction for management while the existing conditions were used to temper expectation of what might reasonably be achieved.

Based on available literature and work in the Rouge, Don and Humber River watersheds, a *Framework* for setting fish community targets has been prepared (see Appendix 4 – Table 1). The *Framework* provides a general guide to assist managers in the development of fish-community targets. It is based on information available for streams in southern Ontario and therefore may not be applicable to other areas due to lack of information. Drainage area is used as a measure of the size and habitat diversity of a watercourse. Based on river theory, the habitat complexity of a watercourse increases with size, resulting in an increase in the number of fish species that can be supported.

Steedman (1988) quantified the relationship between the number of native species present and drainage area for streams in southern Ontario. Steedman also identified species-richness expectations for trophic composition. The expected number of native species in Appendix 4 – Table 1, the categories for the size of drainage basins, and the expected trophic composition were derived from Steedman's work.

The percentage of coarse soils by drainage area is a surrogate for the flow regime in a watercourse. Soils are one of the major determinants of runoff potential, infiltration and groundwater discharge. The coarser the soils, the lower the runoff potential and the greater the potential for infiltration and groundwater discharge to local watercourses. Watercourses with a drainage basin consisting of a high percentage of coarse soils will tend to have a high baseflow and exhibit less fluctuation in flow from storm events. Portt and King (1989) indicated in their literature review that physiographic features and associated geology have distinctive characteristics that influence stream characteristics and the presence or absence of trout species. Nelson *et al*. (1992) found that the presence or absence of trout species related to an area's geologic history.

Surficial geology and soils are important measures of the fundamental characteristics of a drainage basin. Although these features can be covered by pavement or other development, they are not readily eliminated. Knowledge of the geology and soils provides a look past the existing conditions to identify how a basin would have functioned. However, soils and geology are themselves surrogates for the actual flow regime in a watercourse and in some situations may be misleading.

For example, Robinson Creek is a small cold-water tributary of the Rouge River watershed. Robinson Creek originates from the clay soils of the Peel Plain and should exhibit characteristics of a warm-water stream. However, where the creek valley cuts into the surrounding till to join with the main Rouge, it intersects a zone of upwardly moving groundwater. The amount of groundwater encountered is sufficient to moderate temperatures and stabilize stream flows to the extent that the creek is able to support a small run of migratory salmonids. Therefore, soils and geology should not be used in isolation, but rather in conjunction with other stream measures such as baseflow and historic fish communities.

The baseflow ratio is an index derived from the Habitat Suitability Indices (HSI) developed in the United States (Raleigh, 1982; Raleigh *et al*., 1986). The index is the result of average baseflow divided by the average annual daily flow. The index provides a measure of the quantity of baseflow relative to the annual flow and an indication of the stability of the flow regime. A watercourse with a high baseflow ratio will show little fluctuation in flow from storm events. Baseflow will occupy a large amount of the channel and the water temperatures will tend to be low. Watercourses with these characteristics would support cold-water fish communities.

A watercourse with a low baseflow ratio will tend to fluctuate with storm events. Baseflow will occupy only a small amount of the channel and water temperatures will tend to be high. Watercourses with these characteristics would support a warm-water fish community. In the middle are watercourses with a moderate baseflow ratio, where local conditions may determine whether they can support cold or warm-water fish communities.

Some caution should be used in applying the baseflow ratio on its own since flow can in fact be altered by land-use practices. Furthermore, differences can also arise between watercourses depending on where in the drainage area the groundwater input occurs. For instance, in a creek where the majority of the groundwater input occurs far up in the headwaters, the lower reaches may still have a high baseflow ratio and thus not exhibit a large fluctuation in flow. However, water temperatures may be high because of the distance the groundwater traveled in the creek and the resulting heating that would have occurred.

One example is West Duffins Creek where the baseflow ratio for the lower part of the creek is 23 percent. This would put the creek on the high end of cool water habitat but marginal for trout and salmon. However, the lower part of the creek intercepts groundwater discharge. Enough groundwater enters the watercourse at this point to cool the water and provide summer refugia for Rainbow Trout that spawn in these reaches. The baseflow ratio is a useful tool that should be used in conjunction with the soils and geology.

When fish indicator species are used in conjunction with physical parameters of drainage area, baseflow ratio and soils/geology, insight can be provided as to the historic function of a river system. Using the suite of parameters outlined above, the riverine habitat in a watershed can be categorized into reaches of similar characteristics with an associated fish community. These parameters provide an expectation as to the type of fish community that should be present, the number of native species that should be present, and the trophic composition as per the following table.

Appendix 4 – Table 1. Framework for Setting Fish Community Targets

Size of Drainage Basin	Small <10 km²			Medium 10 to 200 km²			Large>200 km²		
Percentage coarse soils by drainage area	High >25%	Moderate 10 to 25%	Low 0 to 10%	High >25%	Moderate 10 to 25%	Low 0 to 10%	High >25%	Moderate 10 to 25%	Low 0 to 10%
Baseflow ratio	>20%	10 to 20%	0 to 10%	>20%	10 to 20%	0 to 10%	>20%	10 to 20%	0 to 10%
Historic fish community	Trout, salmon, present	Trout, salmon may have been present	No trout or salmon, or migration only	Trout, salmon, present	Trout, salmon may have been present	No trout or salmon, or migration only	Trout, salmon, present	Trout, salmon may have been present	No trout or salmon, or migration only
Expectation									
Habitat category	Cold-water	Cool-water	Warm-water	Cold-water	Cool-water	Warm-water	Cold-water	Cool-water	Warm-water
Total number of native species	<8	<8	<8	8 to 18	8 to 18	8 to 18	>18	>18	>18
Number of Darter/ Sculpin species	3*	3*	3*	3 to 7	3 to 7	3 to 7	>7	>7	>7
Number of Sunfish/ Trout species	2*	2*	2*	3 to 5	3 to 5	3 to 5	>5	>5	>5
Number of Sucker/ Catfish species	2*	2*	2*	2 to 4	2 to 4	2 to 4	>4	>4	>4

* Number of species present should be up to this value

Applying the Framework

In developing the Humber River fish plan, seven habitat categories were defined using the *Framework* approach (see Appendix 4 – Table 2). Each category defines an expectation of function that relates to the physical characteristics of the stream and the fish community that would be present. These categories provide the baseline against which to compare the existing fish community in order to identify impacts that have occurred or are occurring, to identify rehabilitation requirements and establish fish community targets.

In order to provide a better picture of the present health of the fish communities in the individual habitat categories, the Index of Biotic Integrity (IBI) was used. The IBI is a broad measure of health that was adapted for southern Ontario by Steedman (1988). The IBI integrates 10 measures of the fish community at a site and provides a score that can be compared between sites or to a generic scale of integrity. The fish community at a site is scored based on the sum of five sub-indices that measure species richness, local indicator species, and other sub-indices, ranging from a low of 10 to a maximum score of 50.

For the Humber, the IBI ranges from nine to 45, with ranges of nine to 20 being poor; 21 to 27 being fair; 28 to 37 being good; and 38 to 45 being very good. (For the Humber River watershed, Steedman's IBI had to be adapted for the data that was available and one sub-index was removed.) The data for the Humber watershed indicates that 57 percent of the stations sampled scored poor or fair, while the remainder (43 percent) were good or very good. Only one station scored in the very good range. Although the Humber watershed is considered to be in better condition than other watersheds in the Toronto and Region AOC, it remains highly impacted.

Appendix 4 – Table 2. Characteristics of Habitat Categories used in the Humber River Fisheries Management Plan

Habitat Category	Description
Small riverine cold-water	Drainage areas <10 km^2; mainly first and second-order tributaries; most streams are permanent, some are intermittent in their upper reaches; originate primarily on the Niagara Escarpment and Oak Ridges Moraine; most slopes >one percent; coarse soils in drainage area; stable flows and continually low water temperatures due to groundwater inputs
Small riverine warm water	Drainage areas <10 km^2; mainly first and second-order tributaries; high proportion are intermittent; originate primarily on the Peel Plain; most slopes are 0.3 to 10 percent; clay soils with little groundwater discharge; fluctuating water temperatures and flows
Intermediate riverine cold-water	Drainage areas range from 10 to 300 km^2; mainly third and fourth-order streams; drain the Oak Ridges Moraine and Niagara Escarpment; slopes of 0 to 0.3 percent; permanent flow; variety of soil types; relatively stable flows and water temperatures due to inputs from upstream cold-water tributaries
Intermediate riverine warm water	Drainage areas between 10 to 300 km^2; mainly third and fourth-order watercourses; drain the Peel Plain; slopes of 0 to 0.3 percent; some streams dry up or become standing pools in summer; fluctuating flow regime and water temperatures due to low baseflow
Large riverine	Drainage area >300 km^2; fifth and sixth-order watercourses; permanent flow; fluctuating flow regime and water temperatures
Estuarine	Extends from the mouth upstream a distance of 3 km; very low slope (0.03 percent); slow-moving, turbid water, influenced by water level in Lake Ontario
Lacustrine	Low slope, low-gradient areas that may be eutrophic, and in some of the kettle lakes, anoxic near the bottom; on-line or off-line; pond; kettle lake; impoundment; or reservoir

Toward Delisting

The system of habitat categories and the approach presented provides a framework for managers to establish an expected fish community against which to assess the present conditions, establish fish community targets and identify the general health of the system. However, the use of species richness and the presence or absence of a few specific indicator species is not enough of a measure of health to use as the basis for delisting watercourses from the AOC. A broader measure of health such as the Index of Biotic Integrity (IBI), when used in conjunction with the habitat categories outlined above and the riparian guidelines, may provide an appropriate tool for delisting.

The habitat categories provide an expectation for function of the watercourse and composition of the fish community while the IBI provides a measure of health. Targets for delisting could be set based on achieving a certain degree of function, a specific level of IBI and meeting the riparian targets. For example, a watercourse that meets its expected function and general fish community composition would also have to achieve a specific level of IBI and riparian habitat condition before it would be considered delisted.

For the Humber watershed, it may be appropriate to establish targets of: fish communities appropriate for the habitat categories; 75 percent of all stations scoring IBI of good to very good, no stations scoring poor; 75 percent of stream length (first to third-order) with woody riparian vegetation, and; 30 metre riparian buffer along 75 percent of stream lengths (first to third-order). These targets are tangible and can be related to people through the species that are being managed. These types of targets are also adaptable to more impacted systems where a high level of function cannot be achieved.

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Appendix 4 – Table 3. Fish Species Historically and Presently Found in the Habitat Categories in the Humber River Watershed

Habitat Category *	Species Found in One Category	Species Found in Two Categories	Species Found in Three Categories	Species Found in Four Categories	Species Found in All Categories
All habitat categories					American Brook Lamprey, White Sucker, Northern HoggSucker, Redside Dace, Brassy Minnow, Common Shiner, Blackchin Shiner, Blacknose Shiner, Bluntnose Minnow, Fathead Minnow, Blacknose Dace, Creek Chub, Brown Bullhead, Brook Stickleback, Rock Bass, Pumpkinseed, Smallmouth Bass, Largemouth Bass, Yellow Perch, Rainbow Darter, Iowa Darter, Fantail Darter, Johnny Darter
Small riverine cold-water		Northern Brook Lamprey, Rainbow Trout, Brook Trout, Goldfish, Pearl Dace	Atlantic Salmon, Central Mudminnow	Brown Trout, Northern Redbelly Dace, Banded Killifish, Mottled Sculpin	
Small riverine warm-water	Three Spine Stickleback	Northern Pike	Central Mudminnow, Golden Shiner, Emerald Shiner, Sand Shiner	Northern Redbelly Dace, River Chub, Rosyface Shiner, Longnose Dace, Banded Killifish, Yellow Bullhead, Mottled Sculpin	
Intermediate riverine cold-water	Bluegill	Rainbow Trout, Brook Trout, Pearl Dace, Mimic Shiner	Atlantic Salmon, Central Mudminnow, Golden Shiner, Spottail Shiner, Hornyhead Chub, Stonecat	Brown Trout, Northern Redbelly Dace, River Chub, Rosyface Shiner, Longnose Dace, Yellow Bullhead, Mottled Sculpin	
Intermediate riverine warm-water	Bluegill	Northern Brook Lamprey, CommonCarp, Goldfish, Mimic Shiner	Emerald Shiner, Spottail Shiner, Sand Shiner, Hornyhead Chub, Stonecat	Brown Trout, Northern Redbelly Dace, River Chub, Rosyface Shiner, Longnose Dace, Banded Killifish, Yellow Bullhead, Mottled Sculpin	
Large riverine	Fallfish, Blackside Darter	Northern Pike, Common Carp	Atlantic Salmon, Golden Shiner, Emerald Shiner, Spottail Shiner, Sand Shiner, Hornyhead Chub, Stonecat	Brown Trout, River Chub, Rosyface Shiner, Longnose Dace, Banded Killifish, Yellow Bullhead	

* Table does not include estuarine and lacustrine habitats.

Appendix 5

Assessment of Forest Bird Community Integrity: A Draft Methodology and Field Test in the Severn Sound AOC (Report Highlights)

During the summer of 1997, the Canadian Wildlife Service conducted breeding bird surveys in the Severn Sound AOC (Tate, 1998). The purpose of the study was to:

- assess habitat guidelines (percent forest cover and largest forest block) contained in the *Framework* in terms of forest bird species composition, and make recommendations on their utility
- determine the response of the forest bird community to reforestation efforts
- develop criteria for delisting the forest bird community of an AOC
- assess the current status (integrity) of the forest bird community in Severn Sound, and its potential for delisting
- suggest methodology for forest bird community assessment in other areas.

Highlights of this work, combined with Geographic Information System (GIS) and statistical analysis on Ontario Breeding Bird *Atlas (Atlas)* data are provided here. The information serves to validate and expand upon the forest habitat guidelines.

Assessing Forest Habitat Guidelines

Forest Cover Guidelines

> *Methods*

Forest bird data from the Atlas database were combined with the Ontario Hydro satellite-image database of forest cover for southern Ontario to test the forest cover guidelines. Relationships between species and forest cover were determined using regression analyses at three different scales (10 000 hectares; 40 000 hectares; 90 000 to 160 000 hectares). Iterative regression analyses were used to determine thresholds of forest cover, beyond which any increase in species richness (slope) was not significant.

> *Results*

On a scale of a single *Atlas* square, or 10 000 hectares, analyses indicate a strong increase in the number of forest bird species as forest cover within a square increases. Forest-interior bird species exhibit the steepest slope and the best fit for the model.

Forest-interior bird species continue to increase in number to at least 35 percent forest cover. The proportion of forest cover greater than 100 metres from forest edge was also found to have a slight but significant effect when combined with forest cover. Deep forest-interior (greater than 200 metres) was not found to make a significant contribution to interior species richness. Therefore, total forest cover appears to be the most important feature influencing forest-interior species richness and the most critical of the habitat guidelines at the scale of single squares.

On a scale of four adjacent *Atlas* squares, or 40 000 hectares, the number of forest-interior species encountered continues to increase with increasing forest cover to approximately 24 percent forest cover.

At this scale, total forest cover is the primary factor determining the number of interior species expected to occur, and the proportion of 200-metre interior forest is also a significant contributing factor.

Interpretation of the scales of nine adjacent squares, or 90 000 hectares, and 16 adjacent squares, or 160 000 hectares were combined as they demonstrated similar patterns. The observed pattern of increasing numbers of forest-interior bird species with increased forest cover continues to hold at these scales. An increase in number of interior species continues up to 20 percent forest cover. Although total forest cover and 100-metre forest-interior were important independently, neither made a significant contribution to predicting species richness when included in multiple regression models with 200-metre deep interior forest. The important factor in predicting interior species richness at these scales is the amount of 200-metre interior forest in a block.

The following series of tables summarizes the response of two groups of birds, all forest birds and forest-interior birds, to changes in forest cover at four scales. Note which scale best applies to the planning unit being assessed (i.e., a small subwatershed or a larger watershed).

Regional numbers of expected forest birds are 120 species in south-western Ontario, 127 species in south-central Ontario, and 117 species in south-eastern Ontario. A mean value of 121 species was used for the analysis of proportion of expected forest bird species. Numbers of forest-interior birds expected by region, according to *Atlas* breeding ranges, are 31 species in south-western Ontario, 37 species in south-central Ontario, and 36 species in south-eastern Ontario. A mean value of 34 species was used for the analysis of proportion of expected forest-interior bird species.

Regional Patterns

Performing similar analyses on a regional basis for south-western, south-central and south-eastern Ontario suggested some regional differences. Central and eastern regions had much higher average forest cover. The western region showed the steepest increase in numbers of all forest birds and interior species with amount of forest cover. This relationship suggests that even some of the most heavily-forested squares in the south-west (Carolinian zone) may not be supporting as many forest species as they could if more forest habitat were available. These patterns suggest that additional forest cover is most urgently required in the Carolinian zone, and reforestation efforts in that region would likely yield the greatest benefit in terms of increasing forest bird diversity. Both central and eastern regions displayed an increasing number of interior species to 34 percent cover, nearly identical to the overall Ontario estimate of a 35 percent threshold (at a scale of a single square).

The difference in landscape patterns is interesting by comparison with other work. Freemark and Collins (1992) in a study of forest birds in four landscapes of varying forest cover in Ontario, Missouri and Illinois found that the greatest increase in species with forest area (steepest slope) occurred in the landscape of greatest total forest cover. This study, on the other hand, has determined that the total number of species occurring in an area shows the greatest increase with forest cover in the landscape with the least total forest. This result highlights the value of considering diversity on a broad regional scale, rather than on an individual patch basis.

Patch Size Guidelines

> Methods

Four large forest tracts were censused for breeding evidence of all forest bird species and breeding-bird community composition (relative abundance). Sites included two natural primarily deciduous tracts, one pine plantation and one pine plantation/natural deciduous forest mixed tract. Due to logistical constraints, the plantation site was not an isolated forest block, but was continuous with additional plantation and forested swamp for a total of over 400 hectares.

> Results

The two natural forest sites had higher forest bird species richness. The number of forest-interior species was slightly higher in the red pine plantation than in other sites. Note that there are more forest-interior species associated with coniferous (19 species) than deciduous (15 species) forest habitat in the Severn Sound region.

None of the forest tracts supported all forest-interior birds possible in the region. These findings suggest that to support the full complement of forest birds, one forest tract of 100 hectares is not sufficient. The study suggests that a tract of 200 hectares provides habitat for over 80 percent of expected forest-interior birds in a natural deciduous habitat. Several large tracts of forest are recommended to support 90 to 100 percent of expected species. In areas where coniferous and deciduous forest are both naturally occurring, forest tracts of 200 hectares are recommended for each forest type to support all or most native interior species.

The Effects of Reforestation (Plantations)

> Methods

Five survey sites were set up at conifer plantations in the Severn Sound AOC. Plantations ranged in age from one year to 66 years of age. Selected sites were adjacent to remnant natural deciduous forest, typically Sugar Maple. At each site, three survey stations were aligned perpendicular to existing adjacent forest edge: one in natural forest-interior; one at the forest/plantation edge; and, one in the plantation (or recently planted) interior. Point-count surveys were completed at each of the three stations per site.

> Results

The strongest relationship occurs in the plantation interior stations where the number of edge species decreased from five in the one year site to zero in the 66 year-old plantation. Conversely, forest-interior species increased from zero to three at the same stations.

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Appendix 5 – Table 1. Predicted Response of All Forest Bird Species to Percent Forest Cover

Percent Forest Cover	Percent of Expected Forest Bird Species Occurring at Selected Scales			
	1,600 km^2	900 km^2	400 km^2	100 km^2
<5	82	<72	<65	<53
5-10	82-86	72-77	65-70	53-57
10-20	86-89	77-81	70-75	57-61
20-30	89-91	81-84	75-78	61-63
30-40	91-93	84-86	78-80	63-65
>40	>93	>86	>80	>65

Appendix 5 – Table 2. Predicted Response of Forest-interior (FI) Bird Species to Percent Forest Cover

Percent Forest Cover	Percent of Expected Forest-interior Species Occurring at Selected Scales			
	1,600 km^2	900 km^2	400 km^2	100 km^2
<5	60	<44	<40	<26
5-10	60-72	44-57	40-50	26-34
10-20	72-85	57-70	50-61	34-41
20-30	85-92	64-77	61-67	41-45
30-40	92-97	77-82	67-71	45-49
>40	>97	>82	>71	>49

Photo by John Mitchell

Appendix 5 – Table 3. Predicted Response of All Forest Bird Species to Percent 100 m Forest-interior (greater than 100 metres from edge)

Percent Interior	Percent of Expected Forest Bird Species Occurring at Selected Scales			
	1,600 km^2	900 km^2	400 km^2	100 km^2
<1.0	up to 85	up to 75	up to 69	up to 56
1.0-2.0	85-87	75-78	69-72	56-59
2.0-5.0	87-89	78-82	72-75	59-61
5.0-7.5	89-90	82-84	75-77	61-62
7.5-10.0	90-91	84-85	77-78	62-63
>10.0	>91	>85	>78	>63

Appendix 5 – Table 4. Predicted Response of Forest-interior (FI) Bird Species to Percent 100 metre Forest-interior (greater than 100 metres from edge)

Percent Interior	Percent of Expected Forest-interior Bird Species Occurring at Selected Scales			
	1,600 km^2	900 km^2	400 km^2	100 km^2
<1.0	up to 67	up to 53	up to 48	up to 32
1.0-2.0	67-75	53-61	48-54	32-36
2.0-5.0	75-85	61-71	54-62	36-42
5.0-7.5	85-89	71-76	62-65	42-45
7.5-10.0	89-93	76-79	65-68	45-46
>10.0	>93	>79	>68	>46

Table 5. Predicted Response of All Forest Bird Species to Percent Deep Forest-interior (DFI) (greater than 200 metres from edge)

Percent DFI	Percent of Expected Forest Bird Species Occurring at Selected Scales			
	1,600 km^2	900 km^2	400 km^2	100 km^2
<0.5	up to 87	up to 79	up to 73	up to 59
0.5-1.0	87-88	79-81	73-75	59-61
1.0-2.0	88-90	81-83	75-76	61-62
2.0-3.0	90-91	83-84	76-77	62-63
3.0-4.0	91-92	84-85	77-78	63-64
>5.0	>92	>86	>79	>64

Table 6. Predicted Response of Forest-interior (FI) Bird Species to Percent Deep Forest-interior (DFI) (greater than 200 metres from edge)

Percent DFI	Percent of Expected Forest-interior Bird Species Occurring at Selected Scales			
	1,600 km^2	900 km^2	400 km^2	100 km^2
<0.5	up to 75	up to 64	up to 56	up to 38
0.5-1.0	75-80	64-69	56-60	38-41
1.0-2.0	80-86	69-74	60-64	41-44
2.0-3.0	86-89	74-77	64-66	44-46
3.0-4.0	89-92	77-79	66-68	46-47
>5.0	>94	>80	>69	>48

Photo by CWS

Photo by Eric Dresser


Conservation Area
Swamp
WATERLOO REG MUN
BRANT CO
Tree
Nursery

Canada