Assessing the Representation of Aquatic Features and Species in Protected Areas in the Great Lakes Watershed

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Abstract

Balanced representation of high quality occurrences of species and ecosystems in a protected area system supports conservation of natural heritage. The protected area system in Ontario was designed by evaluating terrestrial features explicitly and aquatic ones only implicitly. An assessment of the protected area system in Ontario revealed a balanced representation of stream class types in the western part of the Lake Erie watershed. A more balanced representation of stream classes in the eastern part of the watershed can be achieved by adding three classes of surface water fed streams, and high gradient, spring-fed headwater streams. A more balanced representation of aquatic species in the Lake Erie watershed can be achieved by adding small, surface water streams in which target species occur in the west and all types of surface water streams in which target species occur in the east.

Introduction

The Canadian portion of the Great Lakes basin contains some of the largest and most intact landscapes and aquatic communities in North America. Some of the continent's most significant freshwater coasts, rivers, lakes, fens, bogs and wetlands are located here. Our efforts to conserve the best of these aquatic ecosystems are hampered, however, by a lack of knowledge detailing the variety and extent of aquatic habitats in need of conservation and protection on an ecoregion-wide basis.

The goal of the Natural Heritage Areas Program of the Ministry of Natural Resources is to *"establish a system of protected natural heritage areas, representing the full spectrum of the province's natural features and ecosystems"* (OMNR, 1997). Protecting natural heritage is one objective that supports the MNR goal of sustainable natural resource development. In Ontario, there is a tradition of terrestrial classification and a set of guidelines to protect parts of the terrestrial landscape. A formal process to define terrestrial diversity on the basis of 14 site regions and 67 site districts within the regions has been developed to inventory and assess terrestrial resources. The results from this process are used to identify natural features of conservation value and to guide species at risk recovery strategies and plans, to identify areas for protection, to guide planning efforts and direct field surveys. No comparable formal system exists to organize, inventory, represent and assess aquatic diversity. The Ministry of Natural Resources recognized the need for and urged a formally organized system to protect aquatic natural values (OMNR, 1997). Criteria such as representation, condition, diversity, ecological considerations, and special features guide the designation of areas for protection (Crins and Kor, 2000). These criteria are relevant to terrestrial and aquatic habitat and ecosystems; in practice selection of most protected areas in Ontario resulted from application of these criteria from a terrestrial perspective.

Although general guidelines for aquatic resource management exist, protection of aquatic resources to date has been largely incidental to terrestrial protection efforts. Poor correspondence between a terrestrial and fish faunal region classification at the level of tertiary watersheds (Mandrak, 1998) suggests that the protection of aquatic biota and aquatic ecosystems are not well served using terrestrial-derived processes to identify protected areas. Here I assess the effectiveness of protected areas in the Lake Erie watershed in terms of representation of aquatic stream segment classes and target aquatic species.

Study Area

The Lake Erie watershed was used to assess the effectiveness of protected areas to conserve aquatic species and features. The study area includes wetlands and inland lakes within the Lake Erie catchment and contributing streams. The watershed was divided into a western and eastern part based on hydrology, geology and climate. Roughly the Thames and Grand River watersheds divide the Lake Erie watershed into the western and eastern parts.

Data Sources

In the Lake Erie watershed, fish distribution data can characterize tertiary watersheds (8 units, 800 – 4,800 km^2) with respect to species diversity and post-glacial dispersal (Mandrak, 1995). Investigations of smaller spatial units reveal gaps in the biological data coverages. Comprehensive distributional data for other aquatic taxa – mollusks, aquatic insects, plant - do not exist at any scale. For these reasons, I marshaled evidence from biological and physical databases to characterize aquatic features in the Great Lakes watershed and assess the effectiveness of the protected area system to conserve these natural resources.

Characterizing Stream Segments

The waterflow was delineated into ecological units based on size, geology, tributary confluence, and connections to distinct system types. Attributes for each unit were estimated based on information from various map layers, e.g., surficial geology, hydrology, and landcover. These units were characterized in terms of individual segment and subwatershed variables (Table 1). Variables relating to segment size, gradient, geological characteristics, and connectivity to different system types were analyzed using Principal Components Analysis (PCA) to characterize the variation in the physical data. Data were transformed using natural logarithm and Arcsine transformation as required to approximate Gaussian distributions. PCA revealed that five axes explained about 70% of the variation in the data and variables related to segment size (area), gradient, geological permeability, and connectivity loaded strongly on those axes. These variables were used to characterize stream segments in detailed analyses below.

Table 1. *Stream and catchment variables estimated using automated GIS processes.*

VARIABLE	SEGMENT	SUBWATERSHED
Size	Length	Area
Gradient	Slope	
Hydrologic regime		Geologic permeability
Connectivity	Connected to wetland or inland lake	
Position	Elevation	Place within flow network

Assessment Framework

Stream Segment Class Representation

Exploratory and more detailed analyses were conducted to assess the effectiveness of protected areas to conserve aquatic species and habitat. In the first instance, segments along two dimensions were characterized – geological permeability (an indicator of groundwater recharge and discharge) and connectivity (an indicator of potential for species to access distinct system types, e.g., streams, inland lakes and wetlands). Segments were placed in two categories for each dimension yielding four segment classes for the feasibility analysis. After this, two dimensions were added – gradient and stream size – based on results from the PCA. For the detailed analyses I divided the four dimensions into two classes each yielding a total of 16 segment types (Table 2).

The frequency and percent occurrence of system types were calculated for the western and eastern parts of the Lake Erie watershed. Next, the frequency and percent occurrences of each type within protected areas were estimated. Using chi-square goodness-of-fit, system types that were under-represented in the western and eastern Lake Erie watersheds were identified. Noting target species occurrences in protected areas and assessing overall aquatic system and target species representation, findings from these analyses were refined.

In this analysis protected areas included National and Provincial Parks, Conservation Reserves, Provincially Significant Wetlands, and Areas of Natural and Scientific Interest. Segments contained entirely or in part within these types of protected areas were identified (Paleczny *et al.*, 2000).

Table 2. Segment classes to characterize aquatic features in the Lake Erie watershed.

SEGMENT CLASS	PERMEABILITY	STRAHLER (SIZE)	CONNECTIVITY	GRADIENT
1	low	small	unconnected	low
2	high	small	unconnected	low
3	low	large	unconnected	low
4	high	large	unconnected	low
5	low	small	connected	low
6	high	small	connected	low
7	low	large	connected	low
8	high	large	connected	low
9	low	small	unconnected	high
10	high	small	unconnected	high
11	low	large	unconnected	high
12	high	large	unconnected	high
13	low	small	connected	high
14	high	low	connected	high
15	low	large	connected	high
16	high	large	connected	high

Conservation Target Species

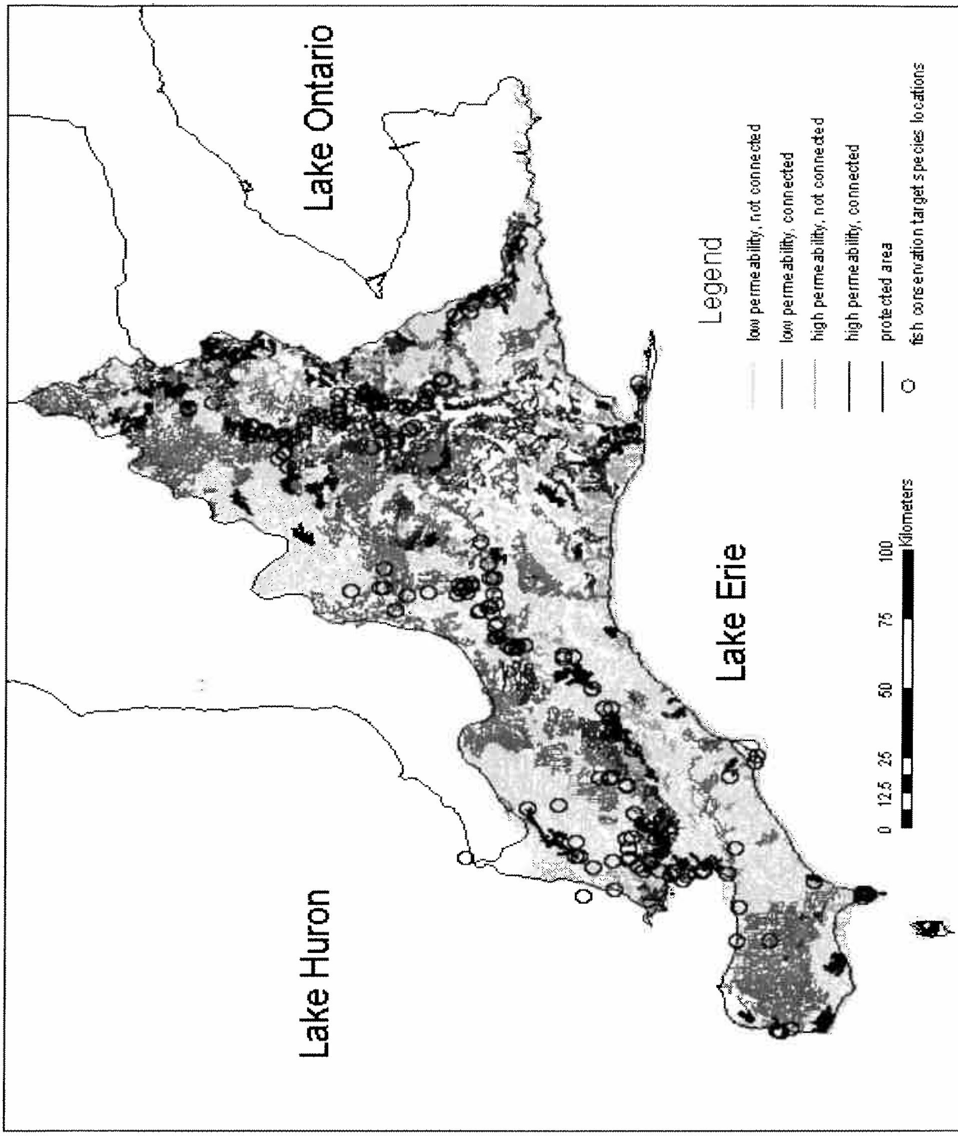
Target species were defined using criteria established through formal review processes of the North American network of conservation data centres and Canadian and Ontario government agencies. Aquatic species ranked G1 to G3 (less than 5 to 100 occurrences) by conservation data centres were included in this study. Also included were species defined according to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and Committee on the Status of Species at Risk in Ontario (COSSARO) designations of 'Endangered', 'Threatened' (COSEWIC and COSSARO), 'Special Concern' (COSEWIC) and 'Vulnerable' (COSSARO). In total 33 aquatic insect species, 7 mollusk species, and 25 fish species were included in these analyses. I refer to these species collectively as conservation target species.

Findings

Exploratory analyses showed that most target fish species occurred in streams flowing across relatively impermeable geological areas (Figure 1). These streams were likely dominated by surface water flows (Portt *et al.*, 1989); some formed networks with wetlands and inland lakes.

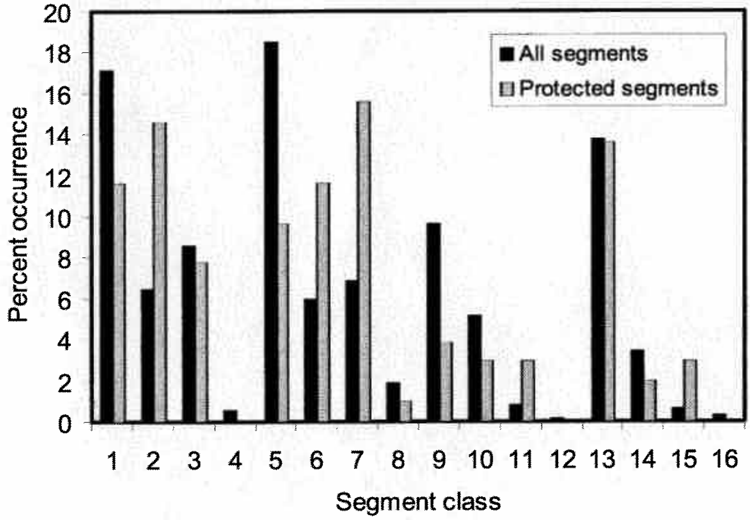
In the western part of the watershed, 6 stream segment classes (types 5, 1, 13, 9, 3, 7) comprise 75% of the occurrences; in the eastern part, 7 classes (types 13, 5, 6, 9 7, 14, 1) comprise 76% of the occurrences (Figures 2 and 3).

Figure 1. *Four classes of stream segments, the location of protected areas and fish species conservation targets in the Lake Erie watershed.*



Results from the chi-square goodness-of-fit test revealed significant differences for the observed and expected frequency of occurrences of segment types within and outside of protected areas in the western and eastern parts of the Lake Erie watershed. In the western part of the watershed, some segment types were significantly over-represented and none were under-represented suggesting the segment types were adequately represented in this portion of the watershed. In the eastern part of the watershed some segment types were significantly under-represented suggesting that a better balance of aquatic features would be achieved by targeting surface water streams for addition to the protected area system.

***Figure 2.** Percent occurrence of stream segment types within and outside of protected areas in the western part of the Lake Erie watershed.*



Species Representation

Fish

About 70% of the target fish species occurrences in the western part of the watershed were associated with large, low gradient segments with relatively impermeable geology that were either connected or unconnected to wetlands or inland lakes (Figure 3). Target fish species occurred in numerous segment types that were not included in protected areas. Selecting segments of type 5 and 9 with target species will improve the balance in protected areas for fish species in the west part of the watershed. These two segment types are somewhat under-represented (Figure 2) but the degree of under-representation is not statistically significant.

About 65% of the target fish species occurrences in the eastern part of the watershed were associated with large, low gradient segments with relatively impermeable geology that were connected to wetlands or inland lakes (Figure 5). Target fish species occurrences in protected areas were under-represented for segment types 5, 9 and 16. Selecting these segment types with target species for addition to the protected area system would improve the balance in terms of representation of fish species and aquatic features.

Figure 3. *Percent occurrence of stream segment types within and outside of protected areas in the eastern part of the Lake Erie watershed.*

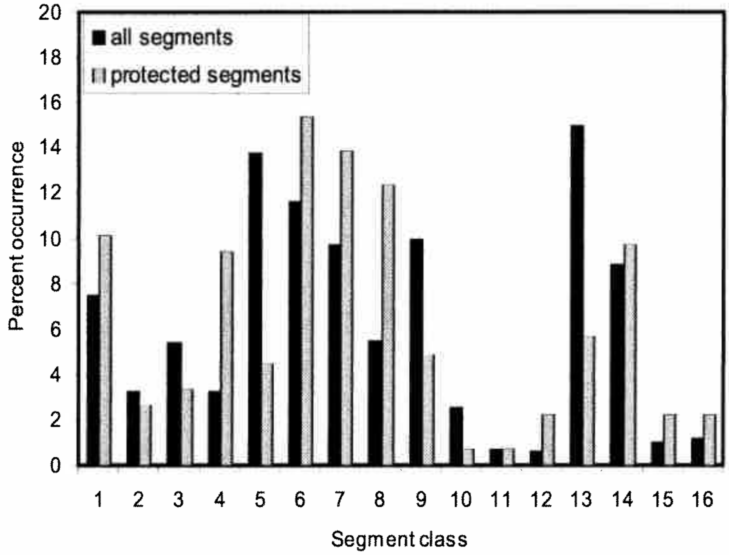


Figure 4. *Target fish species occurrence in the Western Lake Erie watershed.*

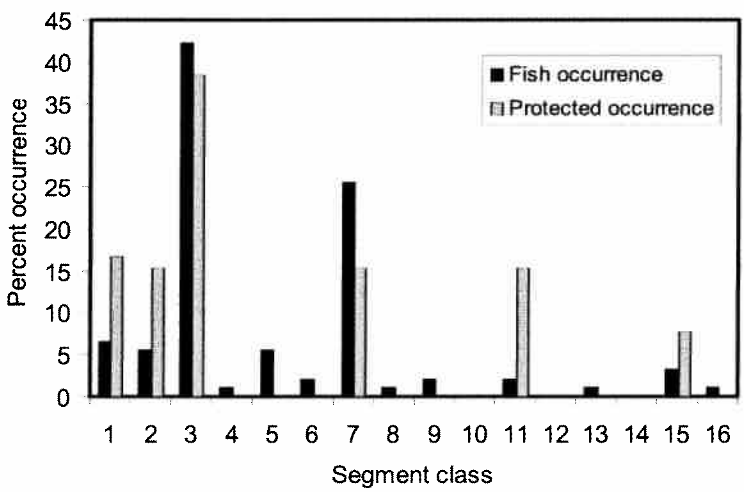
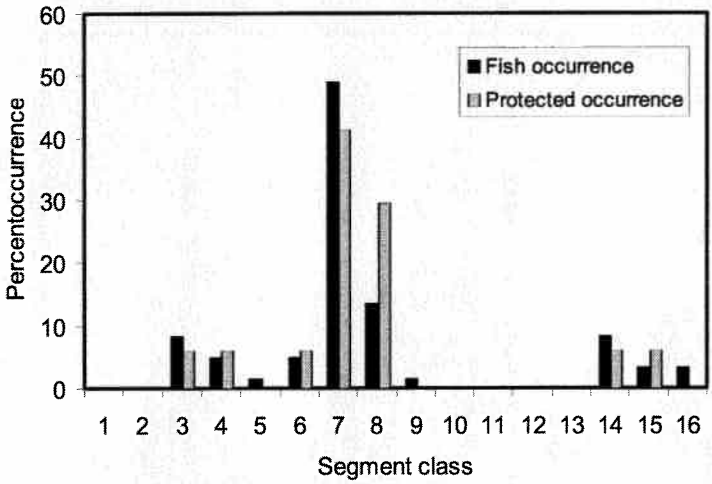


Figure 5. *Target fish species occurrence in the Eastern Lake Erie watershed.*



Mollusks

About 65% of the target mollusk species occurrences in the western part of the watershed were associated with large, low gradient segments with relatively impermeable geology (Figure 6). No target species occurrences in segment types 4, 5, and 7 were included in protected areas (Figure 6). Selecting target mollusk occurrences in segment types 4 and 5 would improve the balance in terms of aquatic features and mollusk species in protected areas; selecting target mollusk occurrences in segment type 7 would improve the balance with respect to mollusk species protection.

About 70% of the target mollusk species occurrences in the eastern part of the watershed were associated with large, low gradient segments with relatively impermeable geology (Figure 7). No target species occurrences in segment types 5, 6, and 14 were included in protected areas (Figure 7). Selecting mollusk target occurrences in segment type 5 would improve the balance in terms of aquatic features and target species in protected areas; selecting target mollusk occurrences in segment types 6 and 14 would improve the balance with respect to mollusk species protection.

Figure 6. *Target mollusk species occurrence in the Western Lake Erie watershed.*

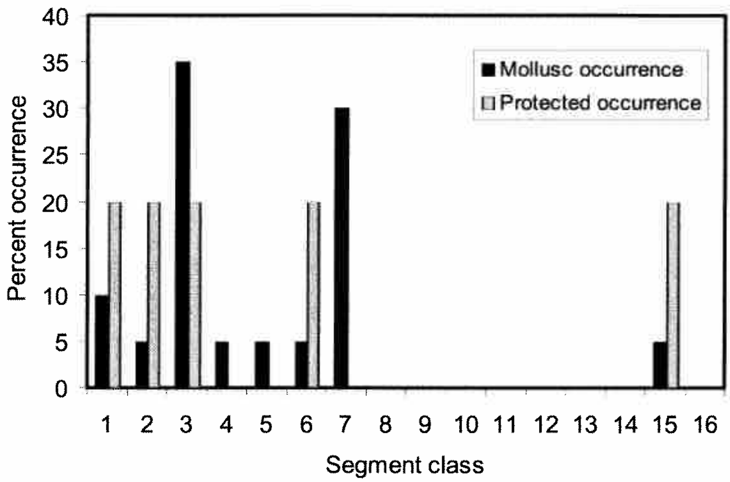
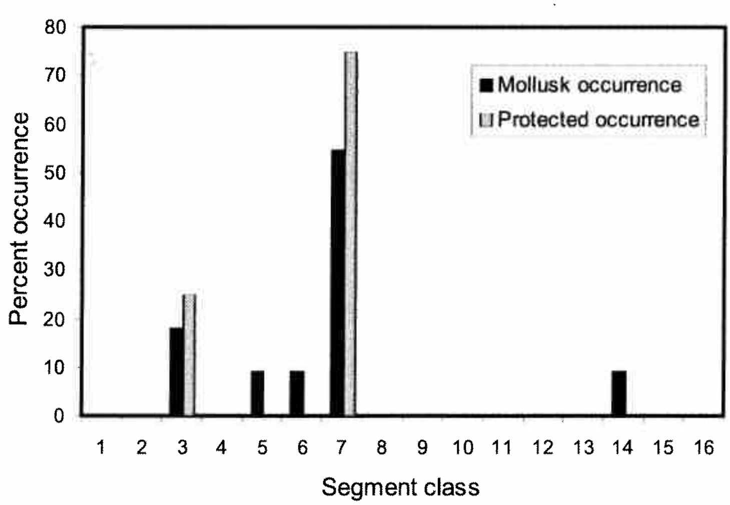


Figure 7. *Target mollusk species occurrence in the Eastern Lake Erie watershed.*



Aquatic Insects

About 60% of the target aquatic insect species occurrences in the western part of the watershed were associated with large, low gradient segments with relatively impermeable geology (Figure 8). Known occurrences of target insect species in the western part of the watershed do not appear under-represented.

About 75% of the target insect species occurrences in the eastern part of the watershed were associated with large, low gradient segments with relatively permeable geology

(Figure 9). Only four target insect species occurrences were observed and of these, only one was in a protected area. Selecting target insect occurrences in segment types 4 and 8 would improve the balance in terms of protecting aquatic features and target species; selecting occurrences in segment type 15 would improve the balance with respect to aquatic insect species.

Figure 8. *Target insect species occurrence in the Western Lake Erie watershed.*

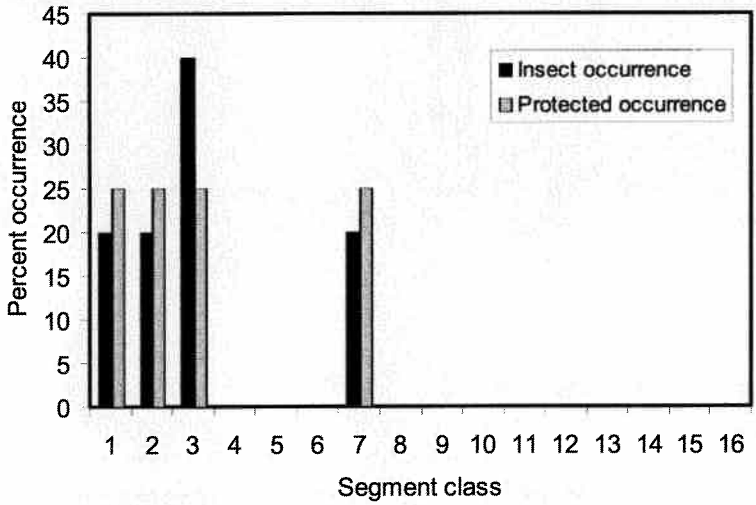
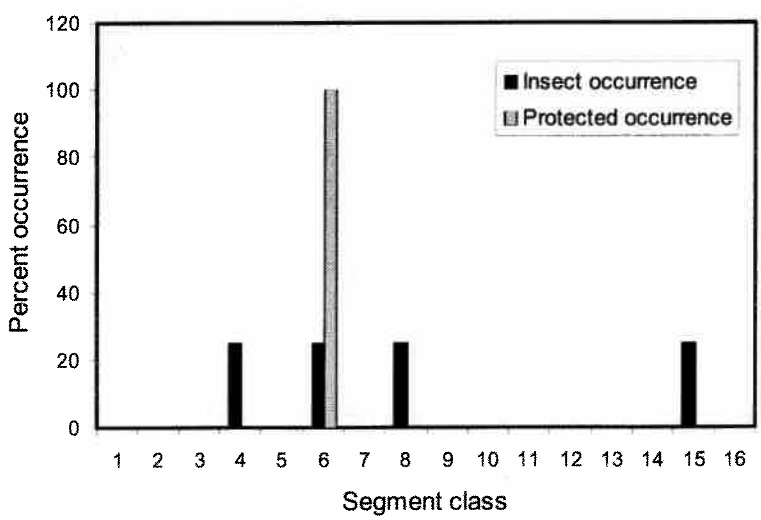


Figure 9. *Target insect species occurrence in the Eastern Lake Erie watershed.*



Only for aquatic insects in the eastern part of the Lake Erie watershed was a high proportion of target species occurrences associated with stream types with permeable geology. Fish and mollusk targets were generally associated with stream segments with impermeable geology in both parts of the Lake Erie watershed.

Synthesis

Over the past 10 years or so there has been a shift in emphasis for conservation efforts toward large spatial and organizational scales (Schwartz, 1999). Examples of such large efforts include ecoregional plans of The Nature Conservancy (U.S.) and the Nature Conservancy of Canada, the *Big Picture 2003* (McMurtry *et al.*, 2003) and *Ontario Living Legacy Land Use Strategy* (OMNR, 1999). These initiatives encompass 100,000 km^2 and include the participation of multiple levels of government agencies, non-governmental organizations and academics. Results from these efforts tend to identify large areas for conservation and protection thus supporting ecological theory suggesting a preference for conservation at large scales. Recent ecoregional planning efforts, e.g., the *Great Lakes Ecoregional Plan* (DePhilip, 2001) and the *Canadian Rocky Mountain Ecoregional Assessment* (Rumsey, 2003) utilize notions of representation, efficiency, diversity, and complementarity to identify areas for conservation. Balancing biological – species, communities – and system-level information informs the final selection of sites for conservation (Groves *et al.*, 2000).

Setting conservation goals is a challenge for conservation planners (Margules and Pressey, 2000) and often issues of 'how much to conserve and where?' are necessarily subjective. Goodness-of-fit analysis can provide some guidelines for identifying under-represented habitat types and when combined with distributional information for target species, balanced conservation site portfolios can be identified.

Findings from this study showed contrasting assessment of effectiveness of the protected area system for conserving aquatic features and species. In terms of coarse filter analysis stream segment types appear well-represented in protected areas in the western part of the Lake Erie watershed. Target species representation in the western part of the watershed will be improved by adding small (low and high gradient), surface water streams (relatively impermeable geology) connected to lakes or wetlands in which target species occur.

In the eastern part of the watershed, stream segment type representation can be improved by adding three types of surface water streams and high gradient, ground water fed (relatively permeable geology) stream types to the protected area system. Target species representation in the eastern part of the watershed can be improved by adding small, surface water streams in which target species occur.

This study demonstrates that statistical decision-rules and expert judgement employed in combination can refine the existing protected area system and add rigor to the process for creating a portfolio of sites for conservation. By using the coarse filter, goodness-of-fit approach, or the fine-filter approach in isolation, gaps in the representation of natural features and target species would result. Focussing on coarse-filter information yielded under representation of fish, mollusks and insects in several types of surface water-fed streams in both the eastern and western parts of the Lake Erie watershed. Focussing only on target species analyses yielded under-representation of several kinds of small, surface water fed streams in the eastern part of the watershed. Integrating biological and physical data to refine and identify areas for conservation will improve the effectiveness of the protected area system to conserve aquatic features and species in the Great Lakes watershed.

Factors in addition to representation will help refine the selection of sites for conservation and improve the effectiveness of the protected area system with respect to aquatic conservation. These factors include diversity as indicated by the presence and size of inland lakes and wetlands within sub-catchments. Another factor relates to aquatic habitat condition indicated by landcover and road density within the catchment and proximity to urban locales. These indicators relate to the intensity and type of human-caused disturbance that reduce the ecological function of an area. Stream segments can be ranked according to the indicators listed above and these rankings used to further prioritize representative aquatic areas for addition to protected area systems.

Finally, goals related to minimum size, connectivity or other design criteria are not addressed here explicitly. Criteria such as predicted probabilities of occurrence, and natural rarity and vulnerability to threat relate to biodiversity pattern. The equilibrium theory of island biogeography, meta-population dynamics, consideration of ecological succession, the focal species concept, source-sink population structures, and landscape context of reserves relate to aspects of ecological and evolutionary processes. Together these considerations provide additional guidelines for conservation goals (Margules and Pressey, 2000).

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References

Crins, W.J. and P.S.G. Kor. 2000. *Natural Heritage GAP Analysis Methodologies used by the Ontario Ministry of Natural Resources.* OMNR, Lands and Natural Heritage Branch, Natural Heritage Section: Peterborough, ON.

DePhilip, M. 2001. *Aquatic Planning in the U.S. Portion of the Great Lakes Watershed.* The Nature Conservancy, Great Lakes Program: Chicago, Illinois.

Groves, C., L. Valutis, D. Vosick, B. Neely, K. Wheaton, J. Touval and B. Runnels. 2000. *Designing a Geography of Hope: A Practitioner's Handbook for Ecoregional Conservation Planning.* The Nature Conservancy.

Mandrak, N.E. 1995. Biogeographic patterns of fish species richness in Ontario lakes in relation to historical and environmental factors. *Canadian Journal of Fisheries and Aquatic Sciences,* 52: 1462-1474.

Mandrak, N.E. 1998. *An Assessment of the Suitability of Using a Terrestrial Ecoregion Classification to Protect Aquatic Biodiversity in Ontario.* Department of Biology, Trent University: Peterborough, ON.

Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. *Nature,* 405: 243-253.

McMurtry, M., J. Riley, P. Sorrill and T. Sorrill. 2003. *Big Picture, 2002: Identifying Key Natural Areas and Linkages in Southern Ontario.* Ontario Ministry of Natural Resources (OMNR) and the Nature Conservancy of Canada: Toronto.

Ontario Ministry of Natural Resources (OMNR). 1997. *Nature's Best, Ontario's Parks and Protected Areas: A Framework and Action Plan.* Ontario Ministry of Natural Resources: Peterborough, ON.

Ontario Ministry of Natural Resources (OMNR). 1999. *Ontario's Living Legacy.* Ontario Ministry of Natural Resources: Peterborough, ON.

Paleczny, D.R., P.A. Gray, T.J. Beechey, R.J. Davidson and J.V. Jalava. 2000. Ontario's protected areas: an examination of protection standards with a provisional application of IUCN's protected area management categories. Pp. 850-862. In: S. Bondrup-Nielsen, N.W.P. Munro, G. Nelson, J.H.M. Willison, T.B. Herman, and P. Eagles. *Managing Protected Areas in a Changing World: proceedings of the fourth international conference on science management of protected areas.* Science and Management of Protected Areas Association: Wolfville, Nova Scotia.

Portt, C.B., S.W. King and H.B.N. Hynes. 1989. *A Review and Evaluation of Stream Habitat Classification Systems With Recommendations for the Development of a System for use in Southern Ontario.* C. Portt and Associates: Guelph, ON.

Rumsey, C., M. Wood, B. Butterfield, P. Comer, D. Hillary, M. Bryer, C. Carroll, G. Kittel, K.J. Torgerson, C. Jean, R. Mullen, P. Iachetti and J. Lewis. 2003. *Canadian Rocky Mountain Ecoregional Assessment, Volume One: Report.* The Nature Conservancy and the Nature Conservancy of Canada. No place.

Scwharz, M.W. 1999. Choosing the appropriate scale of reserves for conservation. *Annual Review of Ecology and Systematics,* 30: 83-108.