J. Great Lakes Res. 31 (Supplement 1):1–5
Internat. Assoc. Great Lakes Res., 2005

FOREWORD

Great Lakes Nearshore Habitat Science

BACKGROUND

Humans have dramatically altered the Great Lakes basin of North America through agricultural practices, urban development, industrial and commercial activities, and introductions of non-native species (Christie *et al.* 1987, Steedman and Regier 1987, Edsall 1996). Stressors associated with these changes have overwhelmed natural ecosystem processes throughout the basin (Regier and Hartman 1973, Steedman and Regier 1987). The nearshore zone, in particular, has been heavily impacted by chemical pollution, organic enrichment, and physical alterations resulting from intense industrialization and urbanization (Krieger *et al.* 1992). This is of great concern because fish diversity in Great Lakes littoral areas is high (Brazner 1997), and nearshore areas are important to the life histories of most native Great Lakes fishes, including many that are primarily pelagic (Goodyear *et al.* 1982; Lane *et al.* 1996a,b). This is also true for the many coastal wetland, benthic, and planktonic organisms that comprise the lower portion of food web and provide other important ecosystem services. This trend toward habitat degradation is expected to continue, necessitating the implementation of enlightened management strategies to ensure the future sustainability of remaining nearshore habitats critical to maintaining native biodiversity.

Until recently, little attention has been given to the study, management, protection, and restoration of Great Lakes nearshore habitats. For example, littoral zone fishes in the Great Lakes have been poorly studied due to the logistical difficulties involved in conducting surveys and a perception of nearshore areas as "wet deserts" that support few species of interest (Brazner and Beals 1997). In comparison with most other freshwater ecosystems (e.g., inland lakes, wetlands, streams, and rivers), our understanding of Great Lakes nearshore and coastal margin habitats is in its infancy. What is meant by critical nearshore habitat is a challenge to define and measure. The spatial and temporal scales at which individual aquatic organisms interact within their environs on a day-to-day basis are typically different than the spatial scales at which environmental (i.e., habitat) change is occurring (Fahrig 1992, Matthews 1998). Moreover, we are only just beginning to understand the importance of how connectivity and multi-scale juxtaposition of different habitat types influence Great Lakes biota at multiple life stages (Steedman and Regier 1987, Kelso and Minns 1996).

Also lacking is an appreciation for the degree that biota inhabiting Great Lakes nearshore, benthic, and coastal habitats are inextricably linked to physical processes of the basin. The pattern and distribution of Great Lakes nearshore habitats are controlled, in part, by the underlying physical characteristics of the basin and interactions between energy, water, and the landscape (e.g., Sly and Busch 1992, Higgins *et al.* 1998, Mackey 2005). Habitats are defined by a range of physical characteristics and energy conditions that can be delineated geographically and meet the needs of a single species, biological community, or ecological function related to life stage (Mackey 2005). To be utilized as habitat, these physical characteristics and energy conditions must exhibit an organizational pattern, persist, and be "repeatable"—elements that are essential to maintain a sustainable and renewable resource (Peters and Cross 1992). Within the Great Lakes basin, individual species, biological communities, and the ecosystem as a whole have adapted to, and utilize the natural range of available habitats, including seasonal patterns and movement of water, energy, and materials through the system (e.g., Busch and Lary 1996, Jones *et al.* 1996). Maintaining the dynamic processes that produce multi-scale resource heterogeneity must be a key objective of managing and protecting Great Lakes nearshore, benthic, and coastal habitats and communities.

The physical processes of the Great Lakes are arguably much more akin to those of oceanic vs. inland lake ecosystems. Thus, lessons learned about relationships between biota and physical habitat features of other freshwater systems (e.g., Tonn and Magnuson 1982, Eadie and Keast 1984, Lyons 1989, Benson and Magnuson 1992) are likely to have little relevance to the Great Lakes nearshore and coastal areas. As a result, large knowledge gaps exist.

Inventory, classification, assessment, and monitoring efforts are desperately needed to identify and prioritize coastal and nearshore areas with high-quality nearshore habitats that are essential to Great Lakes ecosystems. Without comprehensive knowledge of the types of habitats that exist (the locations, connections, and spatial extents of habitats; the conditions of existing habitats; or the importance of these habitats to biodiversity), it is difficult to effectively devise management and restoration strategies that will lead to recognizable improvements in Great Lakes ecosystems. Identification and subsequent protection of high-quality nearshore habitats will yield far greater conservation and resource benefits compared to the incremental gains to be realized through restoration of these habitats after they have become degraded (Kelso *et al.* 1996). Moreover, the inventory, assessment, and monitoring process can also help to develop recovery criteria for restoration projects, an essential element for tracking progress (or lack thereof) in aquatic ecosystem restoration efforts (Hughes and Larsen 1988, Hughes *et al.* 1990).

There is presently a major emphasis on implementing and realizing restoration in the Great Lakes as evidenced by the large amounts of action-oriented funding that have been made available by grantors in recent years. For example, "Restoring the Great Lakes" has recently become the focus of considerable discussion and debate among environmental groups, resource managers and agencies within the Great Lakes (e.g., U.S. EPA 2004, U.S. Policy Committee 2002). Without understanding the processes and interactions between underlying physical and biological components of the ecosystem, resource managers and policymakers cannot make informed recommendations for appropriate actions to be taken. In some cases, inappropriate or ineffective restoration measures may actually delay positive ecosystem response or exacerbate the problem because science is absent or neglected (Minns *et al.* 1996). Without sound science, the risk of making costly mistakes is high. This risk can be lowered by investing in research and monitoring activities that provide a strong science-based foundation to guide future resource management and restoration decisions.

RATIONALE FOR THIS ISSUE

This special issue is an outgrowth of a workshop held at the Grand Valley State University Lake Michigan Center in Muskegon, Michigan, on 1–2 April 2003, the results of which are reported elsewhere (Goforth and Carman 2003). Support for the workshop was generously provided by a grant from the Great Lakes Fishery Trust with the goal of identifying factors that currently impede efforts to evaluate, manage, protect, and restore nearshore fishery habitats in the Great Lakes. More than 50 Great Lakes fisheries experts from multiple agencies, academic institutions, and non-governmental organizations attended the workshop. Ensuing discussions by participants suggested a need to capture the current state of research focused on nearshore and coastal margin habitats in the Great Lakes basin.

The papers presented in this volume are grouped according to major hydrogeomorphic habitat zone (Table 1). For our purposes, the nearshore aquatic habitat zone is defined as the area between the shoreline and the 10 m depth contour, and generally includes unprotected open- and shallow-water embayments. The coastal margin zone is defined as the area of the land-water interface that is influenced by lake-effect events, and typically includes coastal wetlands and marshes, estuaries (or their freshwater equivalents), river mouths and the lower reaches of tributaries, back bays and coastal ridge and swale dune complexes, and well-protected embayments. The rationale behind this grouping is that the fundamental processes acting on these habitat zones are different, and the response of biological communities to stressors affecting those habitat zones would likely be different as well.

These papers explore new concepts and ideas focused on Great Lakes nearshore, coastal, and benthic habitats. The topics addressed by these papers fall into three broad areas of investigation: 1) habitat characterization—habitat inventory, classification, and mapping; 2) physical-biological linkages - processes, stressors, and disturbance; and 3) biological utilization—spatial and temporal patterns of use and how biological organisms and communities utilize nearshore, coastal, and benthic habitats as a function of life-stage.

Five of the papers contribute to Great Lakes nearshore and coastal habitat characterization from both biological and physical perspectives. Minns and Wichert propose an alternative way to classify Great Lakes fish habitats by defining habitat domains based on dynamic process-oriented mea-

TABLE 1. Grouping of papers according to major hydrogeomorphic habitat zone.

Hydrogeomorphic Zone	Habitat Characterization	Physical-Biological Linkages/Disturbance	Biological Utilization
Nearshore Aquatic	Minns and Wichert Haack *et al.* Waples *et al.* Mackey and Liebenthal	Meadows *et al.*	Roseman *et al.* Goforth and Carman
Coastal Margin	Albert *et al.*	Stanley *et al.* Gathman *et al.*	Uzarski *et al.* Meixler *et al.* Jacobus and Webb

sures where temperature, light, and motion are the primary axes of the new paradigm and individual and population processes like growth, survival, and movement are the preferred fish metrics. This innovative approach focuses on functional relationships and processes rather than on the static physical of biological components of the system. Haack *et al.* explore the potential impact of groundwater on nearshore habitats, a little studied but potentially important component influencing nearshore water quality and habitat distribution. They propose a conceptual model based on existing models of groundwater/seawater interaction along marine coastal margins to describe the interconnection among geologic, hydrologic, chemical, and biological processes for different nearshore habitats in Lake Erie. Waples *et al.* demonstrate the capabilities of new technology to efficiently and economically collect bathymetric and acoustic data along with innovative methods to classify and map substrate characteristics across broad areas of the lakebed. Mackey and Liebenthal provide a conceptual framework and practical approach to classify, map, and assess the distribution and relative stability of lakebed substrates within Great Lakes nearshore zones. Finally, Albert *et al.* present a hydrogeomorphic classification scheme for Great Lakes coastal wetlands and provide a framework for describing coastal wetland types according to physical processes as well as characteristic plant and animal communities. The framework and methods presented by these papers have great potential for framing future studies of nearshore habitat dynamics and associations between resident biota and nearshore and coastal margin habitats.

Three additional papers improve our understanding of the physical-biological linkages between nearshore and coastal margin habitats and the biological communities that use them. Meadows *et al.* demonstrate the need for multidisciplinary approaches when assessing cumulative impacts within coastal margin and nearshore systems. Based on observations of cumulative impacts from a small set of study sites, Meadows *et al.* suggest that continued shoreline alterations may lead to widespread changes in nearshore coastal processes and sediment dynamics affecting nearshore biological communities and potentially facilitating the spread of existing and new non-native, invasive species. Stanley *et al.* provide insight into the responses of coastal wet meadows to anthropogenic stressors. From this study, the authors suggest that agricultural weeds may provide a useful means for monitoring the integrity of Great Lakes coastal wet meadows. Further, their data suggest that native wet meadow species re-vegetate previously disturbed sites once anthropogenic stressors have been lifted, suggesting that these systems will likely be responsive to restoration and management efforts. Gathman *et al.* examine plant species' responses to changing water levels in coastal wetlands of northern Lake Huron. Based on their data, they conclude that variability in lake level is critical to maintaining plant diversity within the wet meadow zones of these wetlands, a finding that has significant implications for issues related to water-resource management and withdrawals in the Great Lakes.

The five remaining papers address issues related to biological utilization of Great Lakes nearshore, coastal, and benthic habitats. Roseman *et al.* explore the relationship between interannual variability in year-class strength of Lake Erie walleye, *Sander vitreus*, and seasonal habitat characteristics in the nearshore zone in western Lake Erie. These analyses illustrate the persistent and repeatable nature of habitats necessary to maintain a sustainable and renewable resource. Goforth and Carman present the findings of a pilot study seeking to explore relationships between Great Lakes nearshore biological communities and adjacent shorelines. The results of this study suggest that Great Lakes nearshore communities are responsive to shoreline characteristics, especially as they relate to changes in substrate composition and stability. This work provides a foundation to build a more robust research effort regarding the relationships and cumulative impacts of shoreline development on nearshore biological communities and ecology. Uzarski *et al*. offer a means for assessing the integrity of Great Lakes coastal wetlands using a fish-based Index of Biotic Integrity (IBI). The IBI is based on basin-wide evidence that fish community composition is driven by local plant zonation and is correlated with physical, chemical, and land use/cover variables within coastal wetlands. Such fish-based IBIs have proven useful for assessing ecological and biological integrity of other freshwater systems, and the IBI presented herein has great potential for supporting assessment, monitoring, and restoration efforts in Great Lakes coastal wetlands. Meixler *et al*. characterize fish assemblages of protected embayments and associated wetlands in Lake Ontario. They demonstrate the importance of wetland habitats of these embayments in supporting fish communities of adjacent littoral habitats by providing nursery habitat for resident fishes. Finally, Jacobus and Webb explore the distribution and behavior of fish within a naturally patchy coastal marsh of northern Lake Huron, thus defining fragmentation limits important for maintaining native fish communities within these ecosystems. Such fragmentation limits may be highly useful in identifying and framing restoration goals for coastal marsh ecosystems of the Great Lakes.

Taken individually, these papers make significant contributions to nearshore science, and hence efforts to restore and protect Great Lakes habitats. Taken together, it is clear that management of these resources must be comprehensive and integrative. For example, the implications of lake level change and anthropogenic stress for coastal wetland integrity described by Gathman *et al.* and Stanley *et al.* are relevant not only to individual plant species and plant communities, but also to individual fish species and fish communities as described by Jacobus and Webb, Meixler *et al.*, and Uzarski *et al.* Clearly, additional work needs to be done to fill the information gaps that remain in Great Lakes nearshore habitat science. However, we are hopeful that this special issue and its constituent papers will serve to help fill those gaps by informing and inspiring future research on nearshore and coastal margin habitats within the Laurentian Great Lakes.

Scudder D. Mackey
Habitat Solutions
37045 N. Ganster Road
Beach Park, Illinois 60087

Reuben R. Goforth
13 Natural Resources Building
Department of Fisheries and Wildlife
Michigan State University
East Lansing, Michigan 48824

REFERENCES

Benson, B.J., and Magnuson, J.J. 1992. Spatial heterogeneity of littoral fish assemblages in lakes: relation to species diversity and habitat structure. *Can. J. Fish. Aquat. Sci.* 49:1493–1500.

Brazner, J.C. 1997. Regional, habitat, and human development influences of coastal wetland and beach fish assemblages in Green Bay, Lake Michigan. *J. Great Lakes Res.* 23:36–51.

_____, and Beals, E.W. 1997. Patterns in fish assemblages from coastal wetland and beach habitats in Green Bay, Lake Michigan: a multivariate analysis of abiotic and biotic forcing factors. *Can. J. Fish. Aquat. Sci.* 54:1743–1761.

Busch, W.D.N., and Lary, S.J. 1996. Assessment of habitat impairments impacting the aquatic resources of Lake Ontario. *Can. J. Fish. Aquat. Sci.* 53 (Suppl. 1):113–120.

Christie, W.J., Collins, J.J., Eck, G.W., Goddard, C.I., Hoenig, J.M., Holey, M., Jacobson, L.D., MacCallum, W., Nepszy, S.J., O'Gorman, R., and Selgeby, J. 1987. Meeting future information needs for Great Lakes fisheries management. *Can. J. Fish. Aquat. Sci.* 44 (Suppl. 2):439–447.

Eadie, J.M., and Keast, A. 1984. Resource heterogeneity and fish species diversity in lakes. *Can. J. Zool.* 62:1689–1695.

Edsall, T.A. 1996. Great Lakes and Midwest region. In *Status and trends of regional resources.* M.J. Mac, G.S. Farris, P.A. Opler, P.D. Doran, and C.E. Puckett, editors. National Biological Service, Washington, DC.

Fahrig, L. 1992. Relative importance of spatial and temporal scales in a patchy environment. *Theoretical Population Biology* 41:300–314.

Goforth, R.R., and Carman, S.M. 2003. *Research, Assessment, and Data Needs to Promote Protection of Great Lakes Nearshore Fisheries Habitat.* GLFT

Workshop Proceedings, Grand Valley State University Lake Michigan Center, Muskegon, MI. Michigan. April 1–2, 2003. Michigan State University Extension MNFI Report No. 2003-11.

Goodyear, C.D., Edsall, T.A., Ormsby-Dempsey, D.M., Moss, G.D., and Polanski, P.E. 1982. *Atlas of spawning and nursery areas of Great Lakes fishes*. USFWS, Report FWS/OBS-82/52, Volumes 1–14, Washington, DC.

Higgins, J., Lammert., M., Bryer, M., DePhilip, M., and Grossman, D. 1998. *Freshwater conservation in the Great Lakes basin: development and application of an aquatic community classification framework.* Chicago, Illinois: The Nature Conservancy, Great Lakes Program.

Hughes, R.M., and Larsen, D.P. 1988. Ecoregions: an approach to surface water protection. *J. Wat. Poll. Cont. Fed.* 60:486–493.

_____, Whittier, T.R., and Rohm, C.M. 1990. A regional framework for establishing recovery criteria*. Environmental Management* 14(5):673–683.

Jones, M.L., Randall, RG., Hayes, D., Dunlop, W., Imhof, J., Lacroix, G., and Ward, N.J.R. 1996. Assessing the ecological effects of habitat change: moving beyond productive capacity. *Can. J. Fish. Aquat. Sci.* 53 (Suppl. 1):446–457.

Kelso, J.R.M., and Minns, C.K. 1996. Is fish species richness at sites in the Canadian Great Lakes the result of local or regional factors? *Can. J. Fish. Aquat. Sci.* 53 (Suppl. 1):175–193.

_____, Steedman, R.J., and Stoddart, S. 1996. Historical causes of change in Great Lakes fish stocks and the implications for ecosystem rehabititation. *Can. J. Fish. Aquat. Sci.* 53 (Suppl. 1):10–19.

Krieger, K.A., Klarer, D.M., Heath, R.T., and Herdendorf, C.E. 1992. A call for research on Great Lakes coastal wetlands. *J. Great Lakes Res.* 18:525–528.

Lane, J.A., Portt, C.B., and Minns, C.K. 1996a. *Nursery habitat characteristics of Great Lakes fishes.* Canadian Manuscript Report of Fisheries and Aquatic Sciences 2338.

_____, Portt, C.B., and Minns, C.K. 1996b. *Habitat characteristics of adult fishes of the Great Lakes.* Canadian Manuscript Report of Fisheries and Aquatic Sciences.

Lyons, J. 1989. Changes in the abundance of small littoral zone fishes in Lake Mendota, Wisconsin. *Can. J. Zool.* 67:2910–2916.

Mackey, S.D. 2005. *Physical Integrity of the Great Lakes: Opportunities for Ecosystem Restoration.* Report to the Great Lakes Water Quality Board, International Joint Commission, Windsor, ON.

Matthews, W.J. 1998. *Patterns in freshwater fish ecology.* New York: Thompson.

Minns, C.K., Kelso, J.R.M., and Randall, R.G. 1996. Detecting the response of fish to habitat alterations in freshwater ecosystems. *Can. J. Fish. Aquat. Sci.* 53 (Suppl. 1):403–414.

Peters, D.S., and Cross, F.A. 1992. What is coastal fish habitat? In *Stemming the tide of coastal fish habitat loss,* Pages 17–22, Richard H. Stroud, ed. Proc. of a Symposium on Conservation of Coastal Fish Habitat, Baltimore, MD. Published by the National Coalition for Marine Conservation, Inc., Savannah, GA.

Regier, H.A., and Hartman, W.L. 1973. Lake Erie's fish community: 150 years of cultural stresses. *Science* 180:1248–1255.

Sly, P.G., and Busch, W.D.N. 1992. Introduction to the process, procedure, and concepts used in the development of an aquatic habitat classification system for lakes. In *The Development of an Aquatic Habitat Classification System for Lakes*, pp. 1–13, W.D.N. Busch and P.G. Sly (eds.) Boca Raton, Florida: CRC Press.

Steedman, R.J., and Regier, H.A. 1987. Ecosystem science for the Great Lakes: perspectives on degradative and rehabilitative transformations. *Can. J. Fish. Aquat. Sci.* 44 (Suppl. 2):95–103.

Tonn, W.N., and Magnuson, J.J. 1982. Patterns in the species composition and richness of fish assemblages in northern Wisconsin lakes. *Ecology* 63:1149–1166.

U.S. EPA. 2004. Great Lakes Regional Collaboration. Interagency Task Force Executive Order. U.S. EPA. [online] http://www.epa.gov/glnpo/collaboration/index.html

U.S. Policy Committee. 2002. *Great Lakes Strategy 2002: A Plan for the New Millennium.* Chicago, IL. [online] http://www.epa.gov/glnpo/gls/gls2002.pdf