Environmental Monitoring and Assessment Techniques for Seven Beneficial Use Impairments in Great Lakes Areas of Concern: Summary Descriptions and Information Resources

Hazel E. Wheeler and Ryan W. Archer

Bird Studies Canada
P.O. Box 160
Port Rowan, ON
N0E 1M0

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Introduction

For several years, plans and strategies have been developed by federal, state/provincial, and local-level entities to delist Beneficial Use Impairments (BUIs) designated within 42 Great Lakes Areas of Concern (AOCs). For the majority of AOCs that have yet to delist, the vehicles for these efforts have primarily been Stage 1 and 2 Remedial Action Plans (RAPs), which have functioned to identify BUIs, existing data, information gaps and assessment requirements for each BUI; outline delisting criteria and targets; and provide remediation and restoration strategies.

Plans to monitor BUI status over time in response to remediation, management and restoration activities have often been incorporated into RAPs. However, these plans are often very general in content and scope, and require further refinement to readily facilitate implementation by local RAP coordinating organizations. When developing or refining monitoring plans, careful consideration must be given to the methods that are used to monitor and assess ecological variables. Several factors must be considered when developing these plans, including measurement parameters, monitoring intensity and scope, cost, equipment and personnel requirements, quality assurance/quality control, training requirements, regional applicability, data sharing capacities, and how these methods contribute to existing restoration goals. In order to maximize the scientific merit and applicability of the results, while working within financial means available, it is important to use applicable, proven methods that have been utilized in other AOCs or other jurisdictions, or have been scientifically tested and validated.

RAP committee personnel from various AOCs have indicated their desire for assistance to build on existing monitoring plan guidelines outlined in their RAPs. Recognizing the importance of effective monitoring in facilitating the BUI delisting process, many RAP representatives are interested in enhancing information exchange among AOCs and other agencies and organizations, particularly with respect to monitoring strategies and methodologies. Further, some have stated the need for improved standardization of monitoring and assessment practices, where possible, in order to enhance data compatibility and exchange. In response to these needs, Bird Studies Canada (BSC) was awarded a grant by the National Fish and Wildlife Foundation to determine monitoring information needs among selected U.S. and binational AOCs, investigate monitoring plans and methodologies in use across Great Lakes AOCs or reported in the scientific literature, and propose monitoring methodologies to those selected AOCs' RAP committees that are tailored to their information needs.

Since 1995, BSC has been informing wetland habitat and wildlife status information needs of AOCs through its Marsh Monitoring Program (MMP). The MMP is a long-term, binational marsh bird and amphibian monitoring program that utilizes a network of several hundred Citizen Scientists from across the

Great Lakes basin to annually collect data on bird and calling amphibian species. These data allow us to monitor long-term population trends and develop habitat association models to better inform conservation strategies for these species and their associated wetland habitats. MMP contributions have also included development and utilization of bird and amphibian community-based indices of biotic integrity (IBIs), as well as utilization of an aquatic macroinvertebrate IBI, to contribute to habitat and wildlife status reporting and conservation planning.

The information provided in this report far exceeds the scope of the MMP by suggesting monitoring techniques that address to the following seven BUIs:

- Degradation of Fish and Wildlife Populations
- Fish Tumors or Other Deformities
- Bird or Animal Deformities or Reproductive Problems
- Degradation of Benthos
- Eutrophication or Undesirable Algae
- Degradation of Aesthetics
- Loss of Fish and Wildlife Habitat

This report is a collection of individual stand-alone chapters, or “modules”, that, for a given BUI, provide one or more suggested monitoring techniques that were deemed to provide relevant information based upon established delisting criteria, or where those don’t exist, generalized monitoring goals as determined by the RAP. A list of suggested methodologies is provided for each BUI with the understanding that certain methodologies may be more applicable to certain AOCs. Monitoring techniques were further selected based on considerations of cross-AOC applicability, tested scientific validity, existing and comprehensive source information, cost, and other factors affecting feasibility of implementation. For each technique we provided a concise summary of its application and what data are collected, information about personnel and equipment requirements and cost (where available), a brief history of use and validation, and source information for the reviewer to retrieve further information and documentation about the technique if desired.

The provision of monitoring methodologies in this report is not meant to be prescriptive, or to over-ride or conflict with existing strategies. These are suggestions based upon BSC staff research and consultation with RAP personnel, and are meant to build upon monitoring strategies that may have been previously developed by individual RAP committees or coordinating federal or state agencies.

Methods

The seven BUIs that this report focuses on were those that BSC project staff felt could be feasibly addressed within the scope of this project, in terms of providing information about meaningful and usable monitoring practices. The designated BUIs for each U.S. and binational AOC were identified; all of those that did not possess at least one of the seven selected BUIs were eliminated from consideration, while all other AOCs were contacted to determine their suitability for inclusion in this project.

To inform RAP personnel and other relevant AOC stakeholders about this project, BSC staff produced a one-page fact sheet that described the rationale and goals for this initiative. This fact sheet, which was also designed to solicit interest in becoming involved with the project, was distributed via email to all identified AOC stakeholders. Email communications were followed by phone calls to RAP coordinators or other RAP personnel to provide further information, answer questions about the project, and identify whether the information we offered to provide would be of value to that particular AOC.

The following AOCs expressed an interest in receiving monitoring protocol recommendations and were therefore included in this report:

- Black River AOC, Ohio
- Buffalo River AOC, New York
- Detroit River AOC, Michigan
- Eighteenmile Creek AOC, New York
- Grand Calumet River AOC, Indiana
- Lower Fox River/Green Bay AOC, Wisconsin
- Maumee River AOC, Ohio
- Menominee River AOC, Wisconsin/Michigan
- Muskegon Lake AOC, Michigan
- Niagara River AOC, New York
- Rochester Embayment AOC, New York
- Rouge River AOC, Michigan
- St. Louis River AOC, Minnesota/Wisconsin
- St. Mary's River AOC, Michigan
- Waukegan Harbor AOC, Illinois
- White Lake AOC, Michigan

For each AOC, delisting criteria and targets were identified for each addressed BUI, if they existed, through conversations with RAP representatives, AOC web pages and RAP documentation. These channels were also used to gain further information about current monitoring activities and monitoring information gaps. The resulting information was summarized, and provided guidance toward identifying relevant, useful and applicable monitoring methods for each AOC.

A comprehensive literature review was conducted to identify possible monitoring methods and determine data that were available for the targeted BUIs. When possible, expert consultation was used to augment this review. In gathering this information special consideration was given to the suitability and practicality of monitoring and assessment methods to adequately fulfill the information requirements of the stated delisting goals and criteria across the selected AOCs.

Several factors were accounted for in selecting the suggested methods: Quality of data; ease of implementation; specialized equipment or personnel needed; historical use; and cost. Greater weight was given to methods that have been field-tested or were already in use in some AOCs, but novel methods were also considered when deemed beneficial.

1. Degradation of Fish and Wildlife Populations

We present here a diverse suite of methods for fish and wildlife monitoring, as well as guidelines for setting reasonable targets against which to measure fish community health (Section 1.1, Fish Community Target-setting Framework).

When choosing monitoring methods, consideration must be given to regional relevance. Certain suites of monitoring methodologies, such as the Rapid Bioassessment Protocols (Section 1.4), were designed to have wide-ranging applicability. Others have been developed by state agencies (i.e. Michigan Department of Environmental Quality Procedure #51, Section 1.3) which, though similar to the more broadly applicable protocols, have slight modifications to make them state- or region-specific. If available, state- or region-specific protocols may be considered preferential, but more general protocols should not be discounted as a viable option in their absence.

Wildlife monitoring protocols should be chosen based on what species are present and/or expected in an area. While it may be desirable to monitor animals that are threatened or rare as they are at greater risk of extirpatation, the detectability of these species is extremely low, making them poor candidates for monitoring. Small mammals (i.e., mink and otters) make excellent candidates for wildlife monitoring as historical trapping records can be used to augment more recent population data.

The following section summarizes 13 monitoring/assessment methodologies that we suggest for consideration to evaluate the status of this BUI.

1.1. Fish Community Target-setting Framework

Organization of Origin: Toronto and Region Conservation Authority (TRCA)

Years in Use: Published in 1995

Summary
The goal of the TRCA Framework is to set fish community targets based on expectations of what a habitat should be able to support. These expectations arise from physical characteristics of the watershed, the existing fish community, and factors impacting the system. Though complete restoration of an area may be impossible, historic conditions should be considered as a reference point to maintain perspective when assessing the health of the ecosystem.

The characteristics to be considered when setting fish community targets are:

- size of drainage basin;
- percentage coarse soils by drainage area;

- baseflow ratio; and,
- historic fish community.

These four characteristics can be applied to the basic framework to derive expectations for the makeup of the fish community that should exist, and target species for management efforts can then be chosen appropriately. Though the details of the fish-community framework are geared toward watercourses in southern Ontario, the basic premise behind it is widely applicable.

When combined with a thorough fish sampling method (see Sections 1.2-1.5) the TRCA Framework provides a compete methodology to assess fish community health in the absence of a reference site.

Specialized Personnel Requirements
Sound knowledge of geomorphology, hydrology, and soils of the watershed
Sound knowledge of local historical fish communities

Equipment Requirements
None

Cost
Not Available

History of Use/Validation
Fish community targets have been set using the TRCA Framework for three watersheds within the TRCA jurisdiction, and are being applied as part of their respective watershed management plans. This framework was included in the Canadian Wildlife Service publication *Framework for Guiding Habitat Rehabilitation in the Great Lakes* (see Section 7.1), which was developed in 1995 for Remedial Action Plan and Public Advisory Committees to help guide rehabilitation of Canadian Areas of Concern.

Sources and Additional Reading
Environment Canada. 2004. How Much Habitat is Enough? A Framework of Guiding Habitat Rehabilitation in Great Lakes Areas of Concern. Canadian Wildlife Service. http://www.on.ec.gc.ca/wildlife/docs/pdf/habitatframework-e.pdf. Accessed Sept 23, 2008.

1.2. Great Lakes Coastal Wetlands Monitoring Plan

Organization of Origin: Great Lakes Coastal Wetlands Consortium (GLCWC)

Years in Use: In development since 2002

Summary

The Great Lakes Coastal Wetlands Monitoring Plan (GLCWMP) is a collection of standardized and field-tested monitoring protocols for a suite of biological indicators of Great Lakes coastal wetland health, and associated metrics. These protocols include those for vegetation, macroinvertebrates, fish, amphibians, and birds. A publicly-accessible database has been specially designed to house data collected using these protocols. The consistent, basin-wide use of these protocols will therefore better inform Great Lakes researchers and policy-makers about the status and trends of the lakes at a basin-wide scale.

<u>Macroinvertebrate Community Indicator</u>

Macroinvertebrate sampling should occur in late July through August, when most late instar aquatic macroinvertebrates are present. Samples are taken from the water column using D-frame dip nets in randomly selected locations, with care taken to sample all microhabitats at each location. Only fully inundated vegetation should be sampled to remove variability that can be caused by fluctuating water levels. Macroinvertebrates should be hand-picked from each sample, taking care to select a representative size-range or organisms, and preserved in 70% ethanol for identification. Organisms should be identified to the lowest taxonomic level possible, and voucher specimens sent to experts for confirmation when necessary.

Coastal wetland macroinvertebrate community health is calculated using the Index of Biotic Integrity (IBI) described by Uzarski *et al.* (2004). This IBI is calibrated specifically for bulrush (*Scirpus* spp.) and wet meadow plant zones, though a cattail (*Typha* spp.) IBI has been developed for Lake Ontario by Environment Canada and the Central Lake Ontario Conservation Authority (2004a, 2004b). However, sampling should still occur in other plant areas if possible as those data can contribute to further IBI development.

<u>Fish Community Indicator</u>

Many methods exist for fish sampling (trap nets, seining, electrofishing, etc.), and the specific characteristics of an area, as well as the goals of the sampling, will dictate the most appropriate method. The GLCWMP describes the methodology for sampling using fyke nets or electrofishing, although the IBI metrics presented are only calibrated for fyke netting. If different methods are to be used, then the metrics should be recalibrated for that method.

Fyke netting:

Fyke nets should be placed in dominant vegetation zones in a wetland, with at least three replications per zone, and left overnight. Care should be taken to ensure the tops of the nets are above the water surface to minimize the chance of air-breathing vertebrates becoming caught and drowning. Nets should be set perpendicular to plant zones, with leads in adjacent plants, to catch fish moving along the edge of the zone.

All fish greater than 25 mm in length should be identified, enumerated, and examined for deformities (see Section 1.6). If taxonomic identification is questionable, a voucher specimen should be preserved and brought back to the lab for verification.

Fish community health is calculated using the IBI described by Uzarski *et al.* (2005). This IBI relates specifically to bulrush (*Schoenoplectus* spp.) and cattail (*Typha* spp.) dominated wetlands, but sampling may also occur in other plant zones as other metrics will be developed.

Amphibian Community Indicators:

See Section 1.7 (Marsh Monitoring Program)

Bird Community Indicator:

See Section 1.7 (Marsh Monitoring Program)

Specialized Personnel Requirements

Macroinvertebrate Community Indicator:

Minimal training for field protocol

Experience in macroinvertebrate identification to at least the family taxonomic level

Fish Community Indicator:

Minimal training for field protocol

Experience in fish species identification

Amphibian Community Indicators:

See Section 1.7 (Marsh Monitoring Program)

Bird Community Indicator:

See Section 1.7 (Marsh Monitoring Program)

Equipment Requirements

Macroinvertebrate Community Indicator:

D-frame dip net	Sample bottles
Forceps/eyedroppers	70% alcohol
Sorting pans	Waders/rubber boots or boat

Fish Community Indicator:

Fyke nets	Chest waders
Buckets	Fish processing boards
Filter apparatus	Boat

Amphibian Community Indicators:
See Section 1.7 (Marsh Monitoring Program)

Bird Community Indicator:
See Section 1.7 (Marsh Monitoring Program)

Cost
See Burton et al. (2008) for detailed cost breakdown

History of Use/Validation
The GLCWMP arose from the need for standardized environmental indicators to better identify and track the status and trends of Great Lakes coastal wetlands on a basin-wide scale. Throughout the 1990s and early 2000s, experts from government, non-governmental organizations, academics, as well as other interested groups, worked to identify these indicators to report coastal wetland conditions and trends at the biannual State of the Lakes Ecosystem Conference (SOLEC). The final indicator suite was resolved following SOLEC 2004. Beginning in 2002, coordinated efforts among several expert researchers were initiated across the Great Lakes basin to field-test selected sampling protocols to monitor these indicators. These indicators and sampling protocols were subsequently revised where necessary, and in addition to a basin-wide coastal wetland inventory, standardized wetland classification scheme, proposed sampling design, database design, cost analysis and implementation plan, were reported as part of the GLCWMP.

Sources and Additional Reading
Burton, T.M., Brazner, J.C., Ciborowski, J.J.H., Grabas, G.P., Hummer, J., Schneider, J., and D.G. Uzarski (eds). 2008. Great Lakes Coastal Wetland Monitoring Plan. Great Lakes Coastal Wetland Consortium, Great Lakes Commission. http://www.glc.org/wetlands/documents/finalreport/Great-Lakes-Coastal-Wetlands-Monitoring-Plan_FINAL.pdf. Accessed Oct 7, 2008.

Environment Canada and Central Lake Ontario Conservation Authority. 2004a. Durham Region Coastal Wetland Monitoring Project: Year 2 Technical Report. Downsview, Ontario: ECB-OR.

Environment Canada and Central Lake Ontario Conservation Authority. 2004b. Baseline Conditions of Durham Region Coastal Wetlands: Preliminary Findings 2002- 2003. Downsview, Ontario: ECB-OR.

Uzarski, D.G., T.M. Burton and J.A. Genet. 2004. Validation and performance of an invertebrate index of biotic integrity for Lakes Huron and Michigan fringing wetlands during a period of lake level decline. Aquatic Health and Management, 7:269-288.

Uzarski, D.G., Burton, T.M., Cooper, M.J., Ingram, J.W., and Timmermans, S. 2005. Fish habitat use within and across wetland classes in coastal wetlands of the five Great Lakes: development of a fish-based Index of Biotic Integrity. J. Great Lakes Res. 31(Suppl.1):171-187.

1.3. Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers (Procedure #51)

Organization of Origin: Michigan Department of Environmental Quality

Years in Use: Revised in 2002

Summary

Michigan's Qualitative Biological and Habitat Survey Protocols consist of three separate monitoring and assessment protocols (fish, benthic macroinvertebrates, habitat) for wadeable streams and rivers, along with all necessary data collection forms, QA/QC procedures, and extensive lists of taxonomic references to aid in organism identification.

<u>Fish Sampling Protocol</u>

Fish sampling should be conducted to ensure that all habitats in a given reach are sampled in relative proportion to their representation within that reach. Sampling is performed by electrofishing, so appropriate safety precautions must be taken (rubber waders and gloves, insulated net handles, etc).

Starting downstream, a minimum two-person electrofishing team will move upstream, collecting all stunned fish and placing them in water-filled buckets for identification and enumeration. All fish greater than 20 mm in length are identified to species level, examined for external anomalies, and released unless required as a voucher specimen, in which case it should be preserved and brought back to the lab. Any questionable identifications should be preserved and brought to the lab for verification.

Sampling should occur until at least 100 individual fish are collected, or for no longer than 45 minutes, where the length of the sampled reach is approximately 5-10 times the width of the river, or longer if necessary. If after 45 minutes fewer than 50 fish are collected, or if more than 2% of the fish collected display external anomalies (see Section 1.6), the site will be considered "Poor" and metric calculation is not required.

A list of metrics is provided, where the sum of the metrics is the resultant Fish Score which can be compared to a reference condition. If the percentage of salmonids collected exceeds 1% then the stream is considered coldwater and the metrics do not apply. Thus, quality must be assessed using the macroinvertebrate metrics.

For summaries of other aspects of the Qualitative Biological and Habitat Survey Protocols see Section 4.1 (benthic macroinvertebrate protocols) and Section 7.5 (habitat protocols).

Specialized Personnel Requirements
Experienced electrofisher
Qualified fish taxonomist
CPR certification is an asset

Equipment Requirements

Electrofishing equipment and permits	Polarized sunglasses
Dip nets	Measuring board
Insulated waterproof gloves	Gram scale balance
Chest waders	GPS unit

Cost
Not Available

History of Use/Validation
MDEQ's Procedure #51 is a synthesis of several methods used by the U.S. Environmental Protection Agency (EPA), the Ohio EPA, and the state of Illinois, adapted and tested for use specifically in the state of Michigan. It was developed as a method to more vigorously assess the impacts of non-point source stressors, and can be used as a combined unit for habitat assessment. Its three component parts can also be used independently depending on the monitoring objectives. This monitoring procedure is currently used as part of Michigan's Five Year Basin Cycle Monitoring plan.

Sources and Additional Reading
Michigan Department of Environmental Quality. 2002. Qualitative biological and habitat survey protocols for wadeable streams and rivers (Procedure #51). Surface Water Quality Division; Great Lakes Environmental Assessment Section.

1.4. Rapid Bioassessment Protocols

Organization of Origin: United States Environmental Protection Agency

Years in Use: Since 1989

Summary
The Rapid Bioassessment Protocols (RBPs) consist of four separate biological monitoring and assessment protocols (habitat, periphyton, benthic macroinvertebrates, fish) for wadeable streams and rivers, along with all necessary data collection forms, QA/QC procedures, and extensive lists of taxonomic references to aid in organism identification.

<u>Fish Sampling Protocol</u>

Fish sampling should be conducted to ensure that all habitats in a given reach are sampled in relative proportion to their representation within that reach. Sampling is performed by electrofishing, so appropriate safety precautions must be taken (rubber waders and gloves, insulated net handles, etc).

Sampling should occur between two barriers (i.e. riffles), or in the absence of natural barriers block nets should be erected. Starting downstream, a minimum two-person electrofishing team will move toward the upstream barrier, collecting all stunned fish and placing them in water-filled buckets for identification and enumeration. All fish greater than 20 mm in length are identified to species level, examined for external anomalies, and released unless required as a voucher specimen, in which case it should be preserved in 10% formalin solution. Any questionable identifications should be preserved and brought to the lab for verification.

A habitat assessment for the sampled reach should be completed following fish collection (see Section 7.6)

A number of metrics are presented for use, including reference to where they have been used in the past.

For summaries of other aspects of the RBPs, see Section 4.2 (benthic macroinvertebrate protocols) and Section 5.1 (periphyton protocols).

Specialized Personnel Requirements
Experienced electrofisher
Fisheries professional trained in fish taxonomy.
At least two team members with CPR certification

Equipment Requirements

Electrofishing equipment and permits
Dip nets
Insulated waterproof gloves
Chest waders
Polarized sunglasses
10% buffered formalin
Measuring board
Gram scale balance
GPS unit

Cost

Not Available

History of Use/Validation

The RBPs are a synthesis of several methods used by various state agencies presented as a guide to implementing basic and cost-effective biological monitoring practices, or augmenting existing practices (Barbour *et al.* 1999). Since their inception in 1989, the RBPs have been extensively tested and revised across the US.

Sources and Additional Reading

Barbour, M.T., Gerritsen, J., Snyder, B.D., and J.B. Stribling. 1999. Rapid Bioassessment Protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, Second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. http://www.epa.gov/owow/monitoring/rbp/. Accessed Sept 16, 2008.

1.5. Large River Bioassessment Protocols

Organization of Origin: United States Environmental Protection Agency

Years in Use: Development began in 1998

Summary

The Large River Bioassessment Protocols (LRBPs) consist of four separate monitoring and assessment protocols (habitat, periphyton, benthic macroinvertebrates, fish) along with reviews and comparisons of a number of methods for each indicator, descriptions of the quality of data gathered at each step, and suggestions for taxonomic references to aid in organism identification.

Fish Sampling Protocol

Electrofishing is suggested as the most efficient method to sample all fish guilds present in a reach, though other methods (seine nets, fyke nets, etc.) can be used if more focused sampling is desired. We will use electrofishing in our protocol example:

A reach should be established apart from any disruptive influences (bridges, inlets, etc.) extending at least 500 m upstream. After flagging the downstream extent on both banks, electrofishing will proceed along the bank from the upstream extent, moving the same velocity as, or a slightly faster than, the river current. Stunned fish should be collected and kept in a large, aerated live well for identification and subsequent release.

All fish greater than 20 mm in length are identified to species level, examined for external anomalies, and released unless required as a voucher specimen, in which case it should be preserved in 10% formalin solution. Any questionable identifications should be preserved and brought to the lab for verification.

A number of metrics are presented for use, including reference to the agency of origin.

For summaries of other aspects of the LRBPs, see Section 4.3 (benthic macroinvertebrate protocols), Section 5.2 (periphyton protocols), and Section 7.7 (habitat protocols).

Specialized Personnel Requirements

Experienced electrofisher
Fisheries professional trained in fish taxonomy.
At least two team members with CPR certification
All team field team members trained in boating and electrofishing safety

Equipment Requirements

Electrofishing equipment and permits
Boat, motor, and trailer
Dip nets
Insulated waterproof gloves
Insulated footwear
Polarized sunglasses
Laser range-finder
Topographic maps
Live wells with functioning aerators and water circulation
10% buffered formalin
Measuring board
Gram scale balance
GPS unit
Safety equipments (PFDs, etc)
First aid kit

Cost

Not Available

History of Use/Validation

The protocol for non-wadeable streams and rivers was developed to address biomonitoring and assessment needs of those waterways that fall outside the scope of wadeable rivers and streams, for which many protocols have been developed. Though some components are still in development (i.e., habitat assessment), the protocols are generally a synthesis of methods developed by different state agencies. Because large rivers have high variability in physical and chemical parameters, emphasis is placed on choosing the appropriate method for the river in question.

Sources and Additional Reading

Angradi, T.R. (editor). 2006. Environmental Monitoring and Assessment Program: Great River Ecosystems, Field Operations Manual. EPA/620/R-06/002. U.S. Environmental Protection Agency, Washington, D.C. http://www.epa.gov/emap/greatriver/EMAPGREFOM.pdf. Accessed Sept 19, 2008.

Flotemersch, J.E., Stribling, J.B., and M.J. Paul. 2006. Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers. EPA 600-R-06-127. US Environmental Protection Agency, Cincinnati, Ohio. http://www.epa.gov/eerd/rivers/non-wadeable_full_doc.pdf. Accessed Sept 19, 2008.

1.6. DELTs Anomaly Index

Organization of Origin: Ohio Environmental Protection Agency

Years in Use: Since 1979

Summary

The DELTs (deformities, fin erosions, lesions, tumors) Anomaly Index uses external fish malformations as an indicator of environmental health. It is applied to all fish species, of any size, within a given sample zone. A DELTs Index value above 0.5% (greater than 0.5% of fish exhibit DELTs) indicates an impaired system, and the impairment can be categorized as “moderate”, “strong”, or “high” depending on the percentage.

Fish sampling is best done by electrofishing to ensure fair representation of all species present. All fish in a given reach should be collected, any DELTs recorded, and the fish released in a timely manner. The DELTs Anomaly Index is not age- or species-specific, so this information need not be recorded.

Some background research should be conducted prior to application of the DELTs Anomaly Index, as some fish species are more susceptible to virally- or genetically-induced tumors, making them inappropriate for use in assessment practices (Baumann 1992).

Specialized Personnel Requirements

Experienced electrofisher
Some training in recognizing DELTs required

Equipment Requirements

Electrofishing equipment and permits
Insulated waterproof gloves
Dip nets
Chest waders
Polarized sunglasses
Digital camera

Cost
Not Available

History of Use/Validation
The Ohio EPA has used the DELTs Anomaly Index since 1979 as a tool for water quality assessment in rivers and streams. This approach takes a broad look at environmental health, rather than focusing solely on the effects of chemical contaminants on fish.

Sources and Additional Reading

Baumann, P, C. 1992. The use of tumors in wild populations of fish to assess ecosystem health. J. Aquat. Ecosyst. Health, 1: 135-146.

Baumann, P, Cairns, V., Kurey, B., Lambert, L., Smith, I., and R. Thoma. 2000. Fish tumors or other deformities. Lake Erie LaMP Technical Report No. 6. http://www.epa.gov/glnpo/lakeerie/buia/lamp6.pdf. Accessed Oct 1, 2008.

Ohio EPA. 1989. Biological criteria for the protection of aquatic life: Volume 3. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning and Assessment, Division of Surface Water. Columbus, OH. http://www.epa.state.oh.us/dsw/documents/BioCrit88_Vol3Sec3.pdf. Accessed Oct 9, 2008.

1.7. Marsh Monitoring Program

Organization of Origin: Bird Studies Canada

Years in Use: Since 1994

Summary
The Marsh Monitoring Program (MMP) is a binational monitoring program that coordinates volunteers throughout the Great Lakes basin to track long-term changes in occurrence and abundance of wetland-dependent birds and calling amphibians within Great Lakes basin coastal and inland marsh habitats at various spatial scales. It also uses measures of species composition and diversity to assess the health of marsh habitats in relation to reference conditions or other monitored marsh sites within the basin. It has been used in this manner to inform AOC habitat and wildlife recovery since 1995. The MMP protocols were adopted to measure bird and amphibian community indicators as part of the Great Lakes Coastal Wetland Monitoring Plan (Section 1.2). It is comprised of a bird, amphibian, and habitat survey. The surveyor has the choice of conducting the bird and/or the amphibian survey, but the habitat survey must be completed by all surveyors once annually. Data are submitted annually to Bird Studies Canada using provided forms. Each survey type is described below.

Bird surveys

The MMP marsh bird survey consists of two visits during early morning or evening hours, between early May and early July. All species heard or seen within designated marsh survey areas are recorded on standardized forms. A 5-minute call-playback is used to elicit call responses from secretive species. For this purpose, a provided Broadcast CD featuring the calls of six secretive species is used. The 5-minute broadcast period is preceded and followed by two 5-minute passive listening periods. Along with species presence, observers record the number of individuals of each species as a measure of abundance.

A marsh bird Index of Biotic Integrity (IBI) was developed for the Great Lakes Coastal Wetland Monitoring Plan (see Section 1.2), but it applies to, and therefore should only be used for, wetlands within Ecoregion 8 around the Great Lakes basin (southern lakes Huron and Michigan, all of lakes Ontario, Erie, St. Clair and their connecting channels). Also, the IBI is most accurate if used in marshes with emergent plant zones greater than 10 hectares in size.

Amphibian surveys

The MMP amphibian survey is a passive, auditory-based survey that consists of three night-time visits between late March and mid-June. Observers record the presence of species within defined marsh survey areas by listening for calls and recording the appropriate species on standardized survey forms. Species abundance is indirectly measured through use of a three-level calling intensity scale, ranging from estimates of one individual to a full chorus for a given detected species.

An amphibian Index of Biotic Integrity (IBI) was developed for the Great Lakes Coastal Wetland Monitoring Plan (see Section 1.2), but it applies to, and therefore should only be used for, wetlands within Ecoregion 8 around the Great Lakes basin (southern lakes Huron and Michigan, all of lakes Ontario, Erie, St. Clair and their connecting channels).

Habitat Surveys

Surveys occur once annually at each station, during daylight hours, between approximately late May and mid-June. Estimated percent cover of herbaceous emergent plants; open water (and floating plants); trees; shrubs; and exposed mud, rock or sand is provided. Further, the dominant plant types are estimated, as well as the marsh size, permanency, and adjacent land use(s).

Specialized Personnel Requirements

Call identification training required for amphibian surveys
Ability to recognize marsh birds by sight and sound for bird surveys

Equipment Requirements

Binoculars	Metal poles
Marsh Bird Broadcast CD (provided)	Reflective tape
Broadcast unit (e.g., portable CD player and external amplified speakers)	Thermometer
	Flagging tape
GPS unit	Flashlight

Cost

Binoculars	$250
Broadcast unit	$ 75
Batteries	$ 10
Thermometer	$ 10
Flagging tape	$ 10
Metal poles	$125
Flashlight	$ 15
Reflective tape	$ 30
Monitoring kit	$ 25*
Total	$550

* Free to MMP participants

History of Use/Validation

Bird Studies Canada, in partnership with Environment Canada, developed the MMP in Ontario in 1994. With the financial support of the United States Environmental Protection Agency – Great Lakes National Program Office (USEPA-GLNPO) and the Great Lakes Protection Fund, the MMP was launched throughout the US Great Lakes states in 1995. Carried out by a network of dedicated volunteer surveyors, the MMP functions to provide long-term monitoring of marsh-dependent bird and anuran (frog and toad) species in marsh habitats throughout the Great Lakes basin. Data collected by MMP volunteers is used to determine long-term trends in species diversity, occurrence and abundance, and to directly inform and guide conservation, restoration and management programs for marshes and their bird and amphibian inhabitants.

A scientific evaluation of the MMP was completed in 1997, whereby program objectives, monitoring methods and statistical methods were evaluated and verified (Francis and Chabot 1997). Over the past several years, Quality Assurance Project Plans have been produced for the USEPA-GLNPO, which document details of the monitoring procedure, data management and analysis, and quality control/quality assurance procedures (e.g., see Marsh Monitoring Program 2000).

Sources and Additional Reading

Anonymous. 2008. Marsh Monitoring Program Participant's Handbook: Getting Started. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 13 pp.

Anonymous. 2008. Marsh Monitoring Program Participant's Handbook for Surveying Amphibians. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 13 pp.

Anonymous. 2008. Marsh Monitoring Program Participant's Handbook for Surveying Marsh Birds. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 17 pp.

Archer, R.W., S.T.A. Timmermans, and C.L. Robinson. 2006. Monitoring and Assessing Marsh Habitats in Great Lakes Areas of Concern – Final Project Report. Unpublished Bird Studies Canada report submitted to the U.S. Environmental Protection Agency – Great Lakes National Program Office. 301 pp.

Bird Studies Canada. n.d. Marsh Monitoring Program. http://www.bsc-eoc.org/volunteer/glmmp/index.jsp?lang=EN&targetpg=index. Accessed Sept 18, 2008.

Crewe, T.L., Timmermans, S.T.A., and K.E. Jones. 2006. The Marsh Monitoring Program 1995 to 2004: A Decade of Marsh Monitoring in the Great Lakes Region. Published by Bird Studies Canada in cooperation with Environment Canada. http://www.bsc-eoc.org/download/mmp10yrpt.pdf. Accessed Sept 18, 2008.

Francis, C.M. and A. Chabot. 1997. Scientific Evaluation of the Marsh Monitoring Program. Unpublished Bird Studies Canada report submitted to Environment Canada, Environmental Conservation Branch – Ontario Region. 33 pp.

Marsh Monitoring Program. 2000. The Marsh Monitoring Program Quality Assurance Project Plan. Unpublished Bird Studies Canada report submitted to the United States Environmental Protection Agency – Great Lakes National Program Office. 31 pp.

Timmermans, S.T.A., G.E. Craigie, and K. Jones. 2004. Marsh Monitoring Program: Areas of Concern Summary Reports 1995-2002. Unpublished Bird Studies Canada report submitted to Great Lakes Sustainability Fund and Canadian Wildlife Service, Environmental Conservation Branch, Ontario Region, Environment Canada.

1.8. North American Colonial Waterbird Monitoring Manual

Organizations of Origin: US Geological Survey

Years in Use: In development

Summary

The USGS North American Colonial Waterbird Monitoring Manual (Steinkamp *et al.* 2003) is a synthesis of methods from existing monitoring programs, as well as literature regarding survey strategies. It is a comprehensive guide to developing and implementing a breeding bird survey for any colony-nesting seabird or waterbird. The guide covers all steps involved in creating a colonial waterbird monitoring strategy, from locating colonies, both new and extant, to choosing and implementing the most appropriate methods. Of note is the section concerning tree and shrub nesting species, a guild which includes herons, which are a population of interest in many Great Lakes AOCs.

In Pennsylvania, Great Blue Heron monitoring is accomplished through the direct count of nesting birds prior to leaf-out (Brauning 2000). This simple and direct method, used in combination with nest-finding methods and timing suggestions from the Manual, comprises a fairly simple strategy for performing nesting inventories for small colonies of herons.

If Herring Gulls are to be targeting for monitoring, the work of the Canadian Wildlife Service, which has been studying Herring Gull colonies on the Great Lakes since 1974 (Hebert *et al.* 1999), should not be overlooked.

Specialized Personnel Requirements

Ability to identify waterbird species by sight and sound

Equipment Requirements

Binoculars
GPS unit

Cost

Not Available

History of Use/Validation

Though the Manual is still in draft form, the information contained is very useful to managers wishing to develop colonial bird monitoring strategies, as well as a matrix of existing strategies and their associated errors.

Sources and Additional Reading
Brauning, D.W. 2000. Colonial Nesting Bird Study: Project annual report. Pennsylvania Game Commission, Bureau of Wildlife Management, Research Division. http://www.pgc.state.pa.us/pgc/lib/pgc/reports/2000_wildlife/70004-99.pdf. Accessed Sept 25, 2008.

Hebert, C.E., Norstrom, R.J., and D.V. Chip Weseloh. 1999. A quarter century of environmental surveillance: The Canadian Wildlife Service's Great Lakes Herring Gull Monitoring Program. Environ. Rev. 7: 147-166.

Steinkamp, M., Peterjohn, B., Byrd, V., Carter, H., and R. Lowe. 2003. Breeding season survey techniques for seabirds and colonial waterbirds throughout North America. US Geological Survey, Patuxent Wildlife Research Center. Laurel, MD. http://www.waterbirdconservation.org/pubs/PSGManual03.PDF. Accessed Sept 25, 2008.

1.9. River Otter Bridge Surveys

Organization of Origin: Missouri Department of Conservation

Years in Use: Since 1986

Summary
Bridge surveys are a common monitoring method for River Otter presence/absence and distribution data. While these data cannot be directly translated into abundance, changing distributions can infer relative abundance over time. Bridge surveys allow for easy access to potential otter habitat, and are equally effective as are surveys at randomly chosen sites (Gallant *et al.* 2008).

All bridges within a defined area must be identified, and a random selection chosen as survey sites. More sites will yield better information, but exact number of sites used must be determined based on resource allocation. A single site survey consists of four 300-m transects (one along each bank, both upstream and downstream), which are walked by surveyors, and any otter signs are recorded and mapped. It is important to note the bank substrate type, as certain substrates (i.e. rocky banks) greatly reduce the detectability of otter signs.

Bridge surveys are also suitable to track mink distribution.

Specialized Personnel Requirements
Ability to reliably recognize otter (and mink) presence/activity signs

Equipment Requirements
GPS unit

Cost
Not Available

History of Use/Validation
Bridge surveys were developed in 1986 in Missouri as a standardized method to monitor River Otter presence/absence. This method has since been adopted by numerous agencies across the United States and Canada as a cost-effective method of gathering distribution data for otters.

Sources and Additional Reading

Dwyer, C.P. n.d. Population assessment and distribution of River Otters following their reintroduction into Ohio. Ohio Division of Wildlife, Unpublished report, 5 pp.

Gallant, G., Vasseur, L, and C.H. Bérubé. 2008. Evaluating bridge survey ability to detect river otter *Lontra Canadensis* presence: A comparative study. Wildl. Bio. 14(1): 61-69.

1.10. Game Conservancy Trust Mink Raft

Organization of Origin: The Game Conservancy Trust

Years in Use: Pilot project began in 2002

Summary
The Game Conservancy Trust (GCT) Mink Raft is a floating platform with a clay/sand tracking cartridge within a wooden tunnel designed for passive mink monitoring. Complete instructions for constructing rafts are available in source documents, or assembled rafts may be purchased online (www.forshamcottagearks.com).

When choosing sites to place rafts consideration must be given to home range size. Although mink home ranges in the UK have been well studied, little information is available in North America. Caution must be used in placing rafts too close together and recording duplicates of individuals on neighbouring rafts. If possible, greater distances (5-7 km) between rafts are preferential. Rafts can be placed in areas where field signs of mink are already present, though promising sites lacking field signs should not be overlooked.

Rafts should be tethered amongst emergent vegetation where available, and covered with debris to make them cryptic, both to animals and to people. Rafts can be checked bi-weekly, or weekly if desired, and should be "cleared" after each check using a straight edge to smooth the tracking cartridge.

Though rafts are reliable measures of mink presence/absence and distribution, care must be taken if using to estimate population abundance as lack of tracks may yield a false absence if the raft was avoided, thus under-representing the actual population.

Specialized Personnel Requirements
Ability to identify mink tracks

Equipment Requirements
Construction materials as described in source material
Rubber boots/waders
Small ruler or other straight edge

Cost

Construction of raft	$55 USD
Rafts available for purchase from Forsham Cottage Arks (www.forshamcottagearks.com)	$75 USD (+ delivery)

History of Use/Validation
As an introduced species in Europe, the proliferation of American Mink (*Mustela vison*) is of high concern to conservation organizations. The mink raft was developed as a method of tracking population abundance where other methods, such as counting scats, did not perform as accurately (Reynolds *et al.* 2004). The raft may also be used as a trapping device, where efforts may be focused on areas that already display habitation, therefore increasing the likelihood of success.

Many conservation organizations in the UK have adopted raft-based methods as relatively easy and cost-effective methods of monitoring mink populations.

Harrington *et al.* (2008) performed a comparison of raft surveys to other sign-based surveys (tracks, scats), and reported that rafts consistently out-performed sign surveys in mink detection.

Sources and Additional Reading

Harrington, L.A., Harrington, A.L., and D.W. Macdonald. 2008. Estimating the relative abundance of American Mink *Mustela vison* on lowland rivers: Evaluation and comparison of two techniques. Eur. J. Wildl. Res. 54: 79-87.

Reynolds, J.C. 2003 (revised 2007). The GCT Mink Raft. The Game Conservancy Trust. http://www.gct.org.uk/uploads/minkrafthighres.pdf. Accessed Sept 16, 2008.

Reynolds, J.C., Short, M.J., and R.J. Leigh. 2004. Development of population control strategies for mink *Mustela vison*, using floating rafts as monitors and trap sites. Biol. Conserv. 120: 533-543.

1.11. *River Otter Hair Snares*

Organization of Origin: University of Wyoming

Years in Use: Published in 2007

Summary

Hair snares are a non-invasive DNA capturing technique that uses modified body snares to harvest hair from a single individual. Hair snares are non-lethal, and become disarmed after a single capture.

Traps should be deployed along riverbanks, trails, at latrine sites, and anywhere else that otter activity is suspected. Traps can be baited with otter lure if desired. Following deployment, traps should be checked every few days, with capture hair removed and placed in a sterile container for lab analysis, and traps subsequently sterilized and reset.

The benefit of a single-capture hair snare is that multiple hairs from one trap can be used in laboratory analysis, allowing for greater accuracy in DNA genotyping, and thus better population estimates.

As with any monitoring method, detectability should always be a consideration, so it should be assumed that snares are only sampling a portion of the existing population.

Specialized Personnel Requirements

Outsourcing for DNA analysis

Equipment Requirements

Modified body snares

Cost

Snare	$3 USD
Hair genotyping	*Unknown*

History of Use/Validation

Hair capture techniques have been used to estimate population densities for several mammal species (marten, bear, badger) since 2000. Previous methods were susceptible to cross-contamination of hair trap sites by several individuals, but the introduction of single-use snares increased the efficiency of this method by increasing the amount of DNA that can be reliably gathered for a single individual from a trap. While other monitoring methods (i.e. sign surveys) only yield presence/absence information, hair snares data can be used to estimate abundance, which can then be used to develop management strategies. This method also has potential for Mink (*Mustela vison*) population monitoring.

Sources and Additional Reading
Depue, J.E., and M. Ben-David. 2007. Hair sampling techniques for River Otters. J. Wildl. Manage. 71(2): 671-674.

1.12. Bald Eagle Nest Monitoring

Organizations of Origin: Various

Years in Use: Various

Summary
Bald Eagle nest monitoring is conducted by a number of government and non-government agencies in the Great Lakes basin, such as the New York State Department of Environmental Conservation, the Ontario Ministry of Natural Resources, and Bird Studies Canada (see *Sources and Additional Reading*). Nest monitoring may be undertaken at different levels of intensity depending on the information desired and the resources available. Monitoring efforts can take any combination of the following three forms:

1. Comprehensive nest monitoring to track population size, trends and productivity;
2. Blood and feather sampling for contaminant analyses; and
3. Tracking movement patterns, habitat use and survival of eaglets with colour banding and/or telemetry.

Nest monitoring is the least invasive method, and therefore the easiest to implement. This type of monitoring may employ professionals or volunteers, and involves keeping records on active territories and nests, onset of incubation, dates of egg hatch (as determined by onset of food delivery to the nest), and number of young produced. Characteristics of nest trees should also be recorded and all nest locations georeferenced. Disturbance rates and threats could also be quantified.

The latter two monitoring efforts are much more labour- and cost-intensive, and require qualified and permit-holding personnel. Further, outsourcing is necessary for contaminant analyses of blood and feather samples. Levels of PCBs and DDT have historically been closely studied in Bald Eagles, but heavy metals such as mercury and lead are of growing concern, especially for adult birds.

Blood and feather samples can be taken from nestlings when the nest is accessed. Obtaining blood samples from adults is very difficult, but adults can be trapped outside of the breeding season by qualified personnel. Contaminant levels in Bald Eagles have been extensively studied around the Great Lakes, and as such there is a large base of data with which to track trends (Donaldson *et al.* 1999, Dykstra *et al.* 2005).

While territory and nest monitoring should occur annually, if contaminant assessment is adopted as part of a monitoring strategy it may only need to be performed periodically (e.g., every five years) to yield useful information.

Beyond nest monitoring, the USGS also conducts a National Midwinter Bald Eagle Survey (see *Sources and Additional Reading*), which tracks over-wintering individuals statewide as a measure of population abundance.

Specialized Personnel Requirements
Qualified bander with appropriate permits for Bald Eagles, as well as required authorizations to take blood and feather samples
Trained and certified tree-climber
Appropriate authorizations and permits for all members of field team
Outsourcing for contaminant analysis

Equipment Requirements
Binoculars
Climbing equipment including a hard hat and appropriate gloves
Banding equipment
Blood sampling equipment

Cost
Not Available

History of Use/Validation
Bald Eagle monitoring programs were initiated in response to the precipitous decline in reproductive success due to the introduction of synthetic chlorinated compounds (i.e. DDT and PCBs) to the environment in the late 1940s. With the creation of legislation banning these chemicals in both the US and Canada in the 1970s, Bald Eagle productivity has increased as levels of bioaccumulative toxins in the environment declined. There is still concern, however, about the detrimental effects of heavy metals and other contaminants on adult birds, so continued monitoring efforts are required to ensure the health of the population.

Sources and Additional Reading
Allair, J. 2008. Southern Ontario Bald Eagle Monitoring Program, 2007 Summary Report. Unpublished report from Bird Studies Canada.

Bird Studies Canada. n.d. Southern Ontario Bald Eagle Monitoring Program. http://www.bsc-eoc.org/baeaont.html. Accessed Oct 14, 2008.

Donaldson, G.M., Shutt, J.L., and P. Hunter. 1999. Organochlorine contamination in Bald Eagle eggs and nestlings from the Canadian Great Lakes. Arch. Environ. Contam. Toxicol. 36:79-80.

Dykstra, C.R., Meyer, M.W., Rasmussen, P.W., and D.K. Warnke. 2005. Contaminant concentrations and reproductive rate of Lake Superior bald eagles, 1989-2001. J. Great Lakes Res. 31(2): 227-235.

Neilson, A.L. and J.S. Pollock. 2001. Bald Eagle populations in the Great Lakes region: Back from the brink. Great Lakes Fact Sheet En XX CW69-17/1-2001E. Environment Canada; Canadian Wildlife Services; Toronto, Ontario. http://www.on.ec.gc.ca/wildlife/factsheets/pdf/fs_bald-eagle_e.pdf. Accessed Sept 18, 2008.

New York State Department of Environmental Conservation. 2008. DEC Bald Eagle Program. http://www.dec.ny.gov/animals/9381.html. Accessed Oct 14, 2008.

U.S. Fish and Wildlife Service. 2007. National Bald Eagle Management Guidelines. http://www.fws.gov/migratorybirds/issues/BaldEagle/NationalBaldEagleManagementGuidelines.pdf. Accessed Oct 14, 2008.

U.S. Geological Survey. 2005. Midwinter Bald Eagle Survey. http://srfs.wr.usgs.gov/research/indivproj.asp?SRFSProj_ID=2. Accessed Oct 14, 2008.

1.13. Red-shouldered Hawk and Spring Woodpecker Survey

Organizations of Origin: Bird Studies Canada/Ontario Ministry of Natural Resources

Years in Use: 1990-2007

Summary

The Red-shouldered Hawk and Spring Woodpecker Survey is a volunteer-based, roadside survey that uses call playback to elicit responses from Red-shouldered Hawks. Surveys are run between late April and early May when hawks are breeding. The protocol was developed primarily for hawks, but woodpeckers were added as they are often overlooked in other breeding bird surveys, and they are more easily detected during hawk breeding season.

Survey routes should be located along secondary roads that pass through as much deciduous woodland as possible. Each route consists of 20 survey stations spaced 1 km apart, for a total route length of 19 km. All routes should be surveyed once annually during the pre-incubation period for Red-shouldered Hawks in the area, as that is when the highest response rate to call playback is expected.

At each station, a CD consisting of six sets of Red-shouldered Hawk calls interspersed with periods of silence is played. Following playback, the surveyor stays at the station for a final two-minute listening period before moving to the next station. The number of adult, immature, and unknown-age raptors seen or heard, and the number of woodpeckers seen, heard calling or drumming are recorded at each stop. Passive acoustic and visual observations of other raptor and woodpecker species are also recorded.

Specialized Personnel Requirements
Ability to identify hawks and woodpeckers by sight and sound

Equipment Requirements
Binoculars
Red-shouldered Hawk Broadcast CD
Broadcast unit (e.g., portable CD player and external amplified speakers)
GPS unit

Cost

Binoculars	$250
Broadcast unit	$ 75
Broadcast CD	$ 25
Total	$350

History of Use/Validation
The Red-shouldered Hawk and Spring Woodpecker Survey was developed in 1990 by Bird Studies Canada in cooperation with the Ontario Ministry of Natural Resources. The objective was to monitor population trends of Red-shouldered Hawks, Pileated Woodpeckers and Yellow-bellied Sapsuckers to determine whether forest management practices were affecting these species. The survey ran for 16 years in Ontario, and data gathered over the course of the project contributed to down-listing the Red-shouldered Hawk from species of Special Concern to Not at Risk in Canada (COSEWIC 2006).

Sources and Additional Reading
Badzinkski, D. 2007. Red-shouldered Hawk and spring woodpecker survey: 1990-2006 Final Report. Bird Studies Canada, produced for Ontario Ministry of Natural Resources, Terrestrial Assessment Unit. 35 pp.

COSEWIC. 2006. COSEWIC assessment and update status report on the Red-shouldered Hawk *Buteo lineatus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. http://dsp-psd.pwgsc.gc.ca/Collection/CW69-14-8-2006E.pdf. Accessed Sept 25, 2008.

2. Fish Tumors and Other Deformities

A single method is suggested as the best practice to monitor fish tumors and deformities, based on the scientific literature. Though other monitoring methods can be useful for tracking population degradation (see Section 1.6, DELTs Anomaly Index), tumor prevalence may be under- or over-represented on the whole due to differential causes and rates of formation of tumors in the fish community at-large (Baumann 1992).

2.1. Brown Bullhead Tumor Monitoring

Organization of Origin: Pennsylvania Sea Grant
Pennsylvania Department of Environmental Protection

Years in Use: Preliminary studies began in the 1980s

Summary
Standard Operating Procedures for Brown Bullhead tumor monitoring are described in a comprehensive field manual developed by Pennsylvania Sea Grant and the Pennsylvania Department of Environmental Protection (PADEP) (Rafferty and Grazio 2006). Brown Bullheads have been chosen as the study species as their life history (bottom-dwelling, very small home range) and sensitivity to toxins makes them good indicators of local contamination. However, while a causal relationship has been demonstrated between contaminants and liver tumors in some fish species (Baumann 1992), the relationship between chemical contamination and Bullheads with tumors (internal and external) is currently only correlative (J. Grazio, pers. comm.).

Fish collection can be conducted by electrofishing or other methods (trap nets, hoop nets, seining, etc.) if more appropriate for the area to be sampled. Collected fish should be held in a well-aerated holding tank until processing is possible. Processing will include: weight and length measurement; external anomaly examination; otolith-based ageing; necropsy; and biopsy of anomalies. Best results will be achieved with use of fish greater than 3 years of age, as younger fish tend not to present liver tumors, even in highly polluted water.

Specialized Personnel Requirements
Experienced electrofisher (if electrofishing is the chosen sampling method)
Some training in fish dissection beneficial

Equipment Requirements*

Electrofishing equipment and permits	10% buffered formalin
Insulated waterproof gloves	Measuring board
Chest waders	Gram scale balance
Polarized sunglasses	GPS unit
Digital camera	Dissection kit

*see Rafferty and Grazio (2006) for full equipment list

Cost

Not available

History of Use/Validation

Intensive examination of fish tumors began in Pennsylvania after the 1991 designation of Presque Isle Bay (PIB), PA, as an Area of Concern. As the only remaining Beneficial Use Impairment in PIB, much attention has been turned to fish tumors and the development of standardized methods to assess and track their incidence. The methods presented are a culmination of many years of field studies, and the professional recommendations gathered through three fish tumor conferences hosted by PA Sea Grant, PADEP, and the US Environmental Protection Agency – Great Lakes National Program Office (the proceedings of which are available on the PA Sea Grant website: http://seagrant.psu.edu/publications/aor.htm).

Sources and Additional Reading

Baumann, P, C. 1992. The use of tumors in wild populations of fish to assess ecosystem health. J. Aquat. Ecosyst. Health, 1: 135-146.

Baumann, P.C., Smith, I.R., and C.D. Metcalfe. 1996. Linkages between chemical contaminants and tumors in benthic Great Lakes fish. J. Great Lakes Res. 22(2): 131-152.

Rafferty, S.D. 2006. Development of Standardized Criteria for the Assessment of Brown Bullhead Lesions and Deformities in Areas of Concern conference proceedings. Pennsylvania Sea Grant, Erie, PA. http://seagrant.psu.edu/publications/proceedings/3rdFishTumorProceedings.pdf. Accessed Oct 9, 2008.

Rafferty, S. and J. Grazio. 2006. Field manual for assessing internal and external anomalies in Brown Bullhead (*Ameiurus nebulosus*). EBO 07-267. Pennsylvania Sea Grant, Pennsylvania Department of Environmental Protection, Erie, PA. http://seagrant.psu.edu/publications/technicaldocs/BullheadFieldManual.pdf. Accessed Oct 1, 2008.

3. Bird and Animal Deformities or Reproductive Problems

Various agencies have extensively studied deformities and reproductive problems due to chemical contamination in the Great Lakes basin. The Canadian Wildlife Service, for example, has been studying chemical contaminants in Herring Gull eggs in the Great Lakes for over 25 years. Though further studies on gulls may be redundant, other programs, such as Bald Eagle monitoring (see Section 3.3) rely at least in part on volunteer involvement, so co-ordination of RAP efforts with these programs would be mutually beneficial.

Because the target species for this Impairment are high-level predators, monitoring can be conducted either directly, by monitoring the target organisms themselves, or indirectly by monitoring contaminant loads in prey fish (see Section 3.1). Direct monitoring of wildlife is most reliable as there is some uncertainty surrounding the proportion of fish in wildlife diets. However, as fish capture rates tend to be higher than those for target wildlife species, more data can be collected in a shorter time period. Decisions must be made on a case-by-case basis as to which method is best for an area, considering the available time investment and quality of data desired.

Three suggested monitoring/assessment methodologies to evaluate the status of this BUI are summarized below.

3.1. Fish Flesh Criteria for Piscivorous Wildlife

Organization of Origin: New York State Department of Environmental Conservation

Years in Use: Published in 1987

Summary
The Fish Flesh Criteria report (Newell *et al.* 1987) reports criteria developed for acceptable levels of 19 contaminants in fish for the protection of piscivorous wildlife along the Niagara River. Instead of looking directly at wildlife of interest, these criteria suggest indirect assessment of wildlife effects through measuring contaminant levels in fish. Of particular interest are criteria established for PCBs and DDT, which relate to Mink and Bald Eagles, respectively.

The following criteria are recommended as “highest acceptable levels” for protection of sentinel species:

PCB in fish flesh for Mink: 0.13 mg/kg
DDT in fish flesh for Bald Eagles: 1.5 mg/kg

Further, more stringent criteria are recommended for the general protection of all wildlife:

PCB in fish flesh: 0.11 mg/kg
DDT in fish flesh: 0.2 mg/kg

These general criteria take into account other animals included in the study that have higher sensitivity to contaminants but are not necessarily present in the Areas of Concern. As such, using the former species-specific criteria should be acceptable.

Sampling for this parameter can occur in conjunction with sampling for other fish-related BUIs. While sampling, other pertinent data such as species, size, location, etc., should also be recorded (as outlined by Sloan *et al.* 2005).

For an example of fish sampling protocol, see Section 1.4.

Specialized Personnel Requirements
Knowledge of fish sampling methodologies
Outsourcing for contaminant analysis

Equipment Requirements
Fish sampling equipment (see Section 1)

Cost
Not Available

History of Use/Validation
The criteria laid out by Newell *et al.* (1987) are an important reference for assessing the health status of New York wildlife. They are also used by the New York State Department of Health to advise restrictions on human consumption of fish.

Sources

Newell, A.J., Johnson, D.W., and Allen, L.K. 1987. Niagara River biota contamination project: Fish flesh criteria for piscivorous wildlife. Tech. Rep. 87-3. Bureau of Environmental Protection, Division of Fish and Wildlife, New York State Department of Environmental Conservation. Albany, NY. http://www.dec.ny.gov/docs/wildlife_pdf/niagarabiotacontamproj.pdf. Accessed Sept 24, 2008.

Sloan, R.J., Kane, M.W., and L.C. Skinner. 2005. Of time, PCBs and the fish of the Hudson River. Bureau of Habitat; Division of Fish, Wildlife and Marine Resources; New York State Department of Environmental Conservation. Albany, NY. http://www.dec.ny.gov/docs/wildlife_pdf/hrpcbtrend.pdf. Accessed Oct 2, 2008.

3.2. Mink Jaw Lesions

Organization of Origin: n/a

Years in Use: n/a

Summary

The ingestion of polychlorinated biphenyls (PCBs) has been shown to cause jaw lesions in mink populations in both laboratory and natural settings (Render *et al.* 2000, Beckett *et al.* 2005). Further, there is a strong correlation between PCB levels found in tissue, and the severity of jaw lesions. While it is impossible to examine for lesions in live animals, necropsies of carcasses from trappers can be a reliable tool for evaluating PCB levels in an area in question.

Specialized Personnel Requirements

Contracted lab personnel
Licensed mink-trapper to supply carcasses

Equipment Requirements

Out-sourcing for necropsy required

Cost

Not Available

History of Use/Validation

It has been known since the early 1970s that PCB exposure was detrimental to mink health. While many studies have found correlation between persistent environmental contaminants and physiological problems in mink, it wasn't until 2000 that a causal relationship was experimentally demonstrated between PCBs and jaw lesions (Render *et al.* 2000). Studies have conclusively demonstrated that jaw lesions in wild mink populations can be used as a measure of environmental PCB exposure with relative confidence (Beckett *et al.* 2005).

Sources

Beckett, K.J., S.D. Millsap, A.L. Blankenship, M.J. Zwiernik, J.P. Giesy and S.J. Bursian. 2005. Squamous epithelial lesion of the mandibles and maxillae of wild mink (*Mustela vison*) naturally exposed to polychlorinated biphenyls. Environmental Toxicology and Chemistry 24(3):674-677.

Render, J.A., Aulerich, R.J., Bursian, S.J., and R.F. Nachreiner. 2000. Proliferation of maxillary and mandibular periodontal squamous cells in mink fed 3,30,4,40,5-pentachlorobiphenyl (PCB 126). J. Vet. Diagn. Invest. 12, 477–479.

3.3. Bald Eagle Nest Monitoring

Organizations of Origin: Various

Years in Use: Various

Summary

Bald Eagle nest monitoring is conducted by a number of government and non-government agencies in the Great Lakes basin, including the New York State Department of Environmental Conservation, the Ontario Ministry of Natural Resources, and Bird Studies Canada (see *Sources and Additional Reading*). Nest monitoring may be conducted at different levels of intensity depending on the information desired and the resources available. Monitoring efforts can take any combination of the following three forms:

1. Comprehensive nest monitoring to track population size, trends and productivity;
2. Blood and feather sampling for contaminant analyses; and
3. Tracking movement patterns, habitat use and survival of eaglets with colour banding and/or telemetry.

Nest monitoring is the least invasive method, and therefore the easiest to implement. This type of monitoring may employ professionals or volunteers, and involves keeping records on active territories and nests, onset of incubation, dates of egg hatch (as determined by onset of food delivery to the nest), and number of young produced. Characteristics of nest trees should also be recorded and all nest locations georeferenced. Disturbance rates and threats could also be quantified.

The latter two monitoring efforts are much more labour- and cost-intensive, and require qualified and permit-holding personnel. Further, outsourcing is necessary for contaminant analyses of blood and feather samples. Levels of PCBs and DDT have historically been closely studied in Bald Eagles, but heavy metals such as mercury and lead are of growing concern, especially in adult birds.

Blood and feather samples are taken from nestlings when the nest is accessed. Obtaining blood samples from adults is very difficult, but adults can be trapped outside of the breeding season by qualified personnel. Contaminant levels in Bald Eagles have been extensively studied around the Great Lakes, and as such there is a large base of data with which to track trends (Donaldson *et al.* 1999, Dykstra *et al.* 2005).

While territory and nest monitoring should occur every year to establish trends, if contaminant assessment is adopted as part of a monitoring strategy it may only need to be performed periodically (e.g., every five years) to yield useful information.

Beyond nest monitoring, the USGS also conducts a National Midwinter Bald Eagle Survey (see *Sources and Additional Reading*), which tracks over-wintering individuals statewide as a measure of population abundance.

Specialized Personnel Requirements

Qualified bander with appropriate permits for Bald Eagles, as well as required authorizations to take blood and feather samples
Trained and certified tree-climber
Appropriate authorizations and permits for all members of field team
Outsourcing for contaminant analysis

Equipment Requirements

Binoculars
Climbing equipment including a hard hat and appropriate gloves
Banding equipment
Blood sampling equipment

Cost

Not Available

History of Use/Validation

Bald Eagle monitoring programs were initiated in response to the precipitous decline in reproductive success due to the introduction of synthetic chlorinated compounds (i.e. DDT and PCBs) to the environment in the late 1940s. With the creation of legislation banning these chemicals in both the US and Canada in the 1970s, Bald Eagle productivity has increased as levels of bioaccumulative toxins in the environment decline. There is still concern, however, about the detrimental effects of heavy metals and other contaminants on adult birds, so continued monitoring efforts are required to ensure the health of the population.

Sources and Additional Reading

Allair, J. 2008. Southern Ontario Bald Eagle Monitoring Program, 2007 Summary Report. Unpublished report from Bird Studies Canada.

Bird Studies Canada. n.d. Southern Ontario Bald Eagle Monitoring Program. http://www.bsc-eoc.org/baeaont.html. Accessed Oct 14, 2008.

Donaldson, G.M., Shutt, J.L., and P. Hunter. 1999. Organochlorine contamination in Bald Eagle eggs and nestlings from the Canadian Great Lakes. Arch. Environ. Contam. Toxicol. 36:79-80.

Dykstra, C.R., Meyer, M.W., Rasmussen, P.W., and D.K. Warnke. 2005. Contaminant concentrations and reproductive rate of Lake Superior bald eagles, 1989-2001. J. Great Lakes Res. 31(2): 227-235.

Neilson, A.L. and J.S. Pollock. 2001. Bald Eagle populations in the Great Lakes region: Back from the brink. Great Lakes Fact Sheet En XX CW69-17/1-2001E. Environment Canada; Canadian Wildlife Services; Toronto, Ontario. http://www.on.ec.gc.ca/wildlife/factsheets/pdf/fs_bald-eagle_e.pdf. Accessed Sept 18, 2008.

New York State Department of Environmental Conservation. 2008. DEC Bald Eagle Program. http://www.dec.ny.gov/animals/9381.html. Accessed Oct 14, 2008.

U.S. Fish and Wildlife Service. 2007. National Bald Eagle Management Guidelines. http://www.fws.gov/migratorybirds/issues/BaldEagle/NationalBaldEagleManagementGuidelines.pdf. Accessed Oct 14, 2008.

U.S. Geological Survey. 2005. Midwinter Bald Eagle Survey. http://srfs.wr.usgs.gov/research/indivproj.asp?SRFSProj_ID=2. Accessed Oct 14, 2008.

4. ***Degradation of Benthos***

When selecting monitoring methods, it is important to consider regional relevance. Certain suites of monitoring methodologies, such as the Rapid Bioassessment Protocols (Section 1.4), were designed to have wide-ranging applicability. Others have been developed by state agencies (i.e. Michigan Department of Environmental Quality Procedure #51, Section 1.3) which, though similar to the more broadly applicable protocols, have slight modifications to make them state- or region-specific. If available, state- or region-specific protocols may be considered preferential, but more general protocols should not be discounted as a viable option in their absence.

All protocols described below involve sampling the natural substrates present, but artificial substrates may be used where natural sampling is difficult (i.e. deep water). Artificial substrates are advantageous because there is better standardization in terms of sampling and habitat type. However, they require a greater time commitment from deployment to colonization, and may not accurately represent the benthos because substrate type and time elapsed may affect macroinvertebrate community structure.

Three suggested monitoring/assessment methodologies to evaluate the status of this BUI are summarized below.

4.1. Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers (Procedure #51)

Organization of Origin: Michigan Department of Environmental Quality

Years in Use: Revised in 2002

Summary
Michigan's Qualitative Biological and Habitat Survey Protocols consist of three separate monitoring and assessment protocols for wadeable streams and rivers (fish, benthic macroinvertebrates, habitat) along with all necessary data collection forms, QA/QC procedures, and extensive lists of taxonomic references to aid in organism identification.

Benthic Macroinvertebrate Sampling Protocol

Macroinvertebrate sampling should be conducted to ensure that all habitats in a given reach are sampled in relative proportion to their representation within that reach. Using a triangular dip net, both high and low velocity areas should be sampled, with emphasis placed on gravel, cobble and boulder substrates.

From the organisms collected, a subsample of 100 should be hand-picked, to ensure that invertebrates from all size classes are collected and subsequently identified to the appropriate taxonomic level (see source document, Appendix H)

Analysis is completed using a set of nine metrics provided by the source documentation, and comparing the resulting score to a measured reference condition.

For summaries of other aspects of the Qualitative Biological and Habitat Survey Protocols, see Section 1.3 (fish protocols) and Section 7.5 (habitat protocols).

Specialized Personnel Requirements
Minimal macroinvertebrate sampling training required
Qualified macroinvertebrate taxonomist

Equipment Requirements

Triangular dip net	Gridded pans
Sieve bucket	Forceps
Sample containers	Specimen vials
Hip/chest waders	Dissecting microscope
GPS unit	Taxonomic keys

Cost
Not Available

History of Use/Validation
MDEQ's Procedure #51 is a synthesis of several methods used by the U.S. Environmental Protection Agency (EPA), the Ohio EPA, and the state of Illinois, adapted and tested for use specifically in the state of Michigan. It was developed as a method to more vigorously assess the impacts of non-point source stressors, and can be used as a combined unit for habitat assessment. Its three component parts can also be used independently depending on the monitoring objectives. This monitoring procedure is currently used as part of Michigan's Five Year Basin Cycle Monitoring plan.

Sources and Additional Reading
Michigan Department of Environmental Quality. 2002. Qualitative biological and habitat survey protocols for wadeable streams and rivers (Procedure #51). Surface Water Quality Division; Great Lakes Environmental Assessment Section.

4.2. Rapid Bioassessment Protocols

Organization of Origin: United States Environmental Protection Agency

Years in Use: Since 1989

Summary

The Rapid Bioassessment Protocols (RBPs) consist of four separate biological monitoring and assessment protocols (habitat, periphyton, benthic macroinvertebrates, fish) for wadeable streams and rivers, along with all necessary data collection forms, QA/QC procedures, and extensive lists of taxonomic references to aid in organism identification.

<u>Benthic Macroinvertebrate Sampling Protocols</u>

Depending on the habitat present in the sample stream, one of two protocols can be used. The single-habitat approach is best suited to areas in which reference streams have a dominance of riffle/run habitat (cobble substrate). Areas with reference streams displaying variable habitat structure should be sampled using the multi-habitat approach.

Single-habitat method

- uses a 1 m kick net
  1) select a 100 m reach to be sampled
  2) starting downstream, take two or three samples at varying stream velocities in each riffle
  3) empty collected organisms and smaller debris into sample containers to be hand-picked in the lab (all samples can be combined)
  4) samples should be preserved in 95% ethanol
  5) habitat assessment must be completed after sampling is complete (see Section 7.6)

Multi-habitat method

- uses a D-frame dip net
  1) select a 100 m reach to be sampled
  2) perform a cursory determination of different habitat proportions within area; habitats should be sampled proportional to their representative surface-area within the total sampled area
  3) starting downstream, collect a total of 20 samples along the entire reach, dividing samples proportionally amongst the different habitats
  4) empty collected organisms into sample containers to be hand-picked in the lab (all samples can be combined)
  5) samples should be preserved in 95% ethanol
  6) habitat assessment must be completed after sampling is complete (see Section 7.6)

Laboratory processing

1) wash samples and spread in gridded enamel pans
2) randomly select four squares and remove contents to separate dishes
3) sort organisms from debris, slide-mounting appropriate organisms (*Chironimidae, Oligochaeta*) for identification
4) identify organisms to lowest practical level
5) select appropriate metrics from list provided for macroinvertebrate scoring

For summaries of other aspects of the RBPs, see Section 1.4 (fish protocols) and Section 5.1 (periphyton protocols).

Specialized Personnel Requirements

Minimal training to perform macroinvertebrate sampling
Qualified taxonomist to perform organism identification

Equipment Requirements

D-frame dip net/Standard kick net	Gridded pans
Sieve bucket	500 micron sieve
95% ethanol	Forceps
Sample containers	Specimen vials
Hip/chest waders	Dissecting microscope
GPS unit	Compound microscope
Taxonomic keys	Fiber optics light source

Cost

Not Available

History of Use/Validation

The RBPs are a synthesis of several methods used by various state agencies presented as a guide to implementing basic and cost-effective biological monitoring practices, or augmenting existing practices (Barbour *et al.* 1999). Since their inception in 1989, the RBPs have been extensively tested and revised across the USA.

Sources and Additional Reading

Barbour, M.T., Gerritsen, J., Snyder, B.D., and J.B. Stribling. 1999. Rapid Bioassessment Protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, Second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. http://www.epa.gov/owow/monitoring/rbp/. Accessed Sept 16, 2008.

4.3. Large River Bioassessment Protocols

Organization of Origin: United States Environmental Protection Agency

Years in Use: Development began in 1998

Summary

The Large River Bioassessment Protocols (LRBPs) consist of four separate monitoring and assessment protocols (habitat, periphyton, benthic macroinvertebrates, fish) along with reviews and comparisons of a number of methods for each indicator, descriptions of the quality of data gathered at each step, and suggestions for taxonomic references to aid in organism identification.

Benthic Macroinvertebrate Sampling Protocol

The LRBP suggests a proportional multi-habitat sampling method, using shoreline transects, which are thought to be the most productive areas.

A sample reach 500 m in length should be established, with 6 transects extending across the river at 100 m intervals. Along each transect, a 10 m zone (extending 5 m on either side, extending to mid-river or a depth of 1 m) will be designated as the sampling zone, though sampling occurs primarily along the bank. Using a D-frame dip net, six sweeps should be taken within the sample zone divided proportionally between habitat types within the zone. Each zone will yield two samples (one at each bank), though all samples can be combined into one collective sample representing the selected river reach.

The collected sample should be washed, picked, and preserved (preferably in 10% buffered formalin) to be taken to the lab for sorting and identification. Macroinvertebrate community composition can then be applied to a suite of suggested metrics, depending on the measures to be evaluated (Flotemersch *et al.* 2006, Chapter 8)

For summaries of other aspects of the LRBPs, see Section 1.5 (fish protocols), Section 5.2 (periphyton protocols) and Section 7.7 (habitat protocols).

Specialized Personnel Requirements

Qualified taxonomist to perform organism identification

Equipment Requirements

D-frame dip net
Sieve bucket
Preservative solution
Sample containers
Sample preservative
Hip/chest waders, or boat
GPS unit
Gridded pans
500 micron sieve
Forceps
Specimen vials
Dissecting microscope
Compound microscope
Taxonomic keys

Cost

Not Available

History of Use/Validation

The protocol for non-wadeable streams and rivers was developed to address biomonitoring and assessment needs of those waterways that fall outside the scope of wadeable rivers and streams, for which many protocols have been developed. Though some components are still in development (i.e., habitat assessment), the protocols are a general synthesis of methods developed by different state agencies. Because large rivers have high variability in physical and chemical parameters, emphasis is placed on choosing the appropriate method for the river in question.

Sources and Additional Reading

Angradi, T.R. (editor). 2006. Environmental Monitoring and Assessment Program: Great River Ecosystems, Field Operations Manual. EPA/620/R-06/002. U.S. Environmental Protection Agency, Washington, D.C. http://www.epa.gov/emap/greatriver/EMAPGREFOM.pdf. Accessed Sept 19, 2008.

Flotemersch, J.E., Stribling, J.B., and M.J. Paul. 2006. Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers. EPA 600-R-06-127. US Environmental Protection Agency, Cincinnati, Ohio. http://www.epa.gov/eerd/rivers/non-wadeable_full_doc.pdf. Accessed Sept 19, 2008.

5. ***Eutrophication or Undesirable Algae***

Two protocols for the direct measurement of algal communities are presented here; the main difference between the protocols is the size of the waterway being sampled. Wadeable streams should be surveyed using the Rapid Bioassessment Protocols (RBPs, Section 5.2), whereas non-wadeable rivers should be surveyed using the Large River Bioassessment Protocols (LRBPs, Section 5.2).

Either protocol can be adapted to incorporate use of an artificial substrate if the natural substrate is not conducive to sampling (i.e., too deep, or boulder substrate). Artificial substrates, however, are known to produce a less heterogeneous community structure than do natural substrates, so results obtained from artificial substrates cannot be compared to those derived from natural substrates. Therefore, it is important that the same method is applied consistently across a study area, to allow comparisons.

If using the natural substrate, sampling can be of a single habitat, or many habitats present in the stream. Multi-habitat sampling will give the best representation of benthos, but inter-stream differences in water quality are better reflected in single-habitat sampling

5.1. Rapid Bioassessment Protocols

Organization of Origin: United States Environmental Protection Agency

Years in Use: Since 1989

Summary
The Rapid Bioassessment Protocols (RBPs) consist of four separate monitoring and assessment protocols (habitat, periphyton, benthic macroinvertebrates, fish) for wadeable streams and rivers, along with all necessary data collection forms, QA/QC procedures, and extensive lists of taxonomic references to aid in organism identification.

Periphyton Sampling Protocols

Two protocols are presented for assessing algal population diversity, one involving laboratory analysis ("lab-based" below), and one with analysis performed while in the field ("field-based" below). The latter is a much coarser assessment, but has the benefits of requiring less taxonomic experience from the investigators.

Lab-based:

1) collect algae using any scraping or brushing tools (i.e. stainless steel spoons, toothbrushes) and transport to lab for analysis

2) analyze for both diatom and non-diatom relative abundance and taxa richness
3) choose appropriate metrics from the list provided (including six that infer ecological condition) for periphyton scoring

Field-based:

1) set three transects through chosen habitat, and randomly choose three points along each transect
2) using a viewing bucket, characterize macroalgal biomass, microalgal cover, and density of algae on substrate at each location

A habitat assessment for the sampled reach should be completed following periphyton collection (see Section 7.6)

For summaries of other aspects of the RBPs, see Section 1.4 (fish protocols) and Section 4.2 (benthic macroinvertebrate protocols).

Specialized Personnel Requirements

Lab-based protocol	Qualified laboratory technician Qualified periphyton taxonomist
Field-based protocol	Qualified periphyton taxonomist

Equipment Requirements

Lab-based	Enamel pan	Compound microscope
	Petri dish and spatula	Slides and coverglasses
	Forceps	Tissue homogenizer/blender
	Pipettes and bulbs	Magnetic stirrer
	Sample containers	Hot plate
	Sample preservative	Fume hood
	Periphytometer (if using artificial substrate)	Oxidation reagents
Field-based	Viewing bucket (see Barbour *et al* 1999)	

Cost

Not Available

History of Use/Validation

The RBPs are a synthesis of several methods used by various state agencies presented as a guide to implementing basic and cost-effective biological monitoring practices, or augmenting existing practices (Barbour *et al.* 1999). Since their inception in 1989, the RBPs have been extensively tested and revised across the US.

Sources and Additional Reading
Barbour, M.T., Gerritsen, J., Snyder, B.D., and J.B. Stribling. 1999. Rapid Bioassessment Protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, Second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. http://www.epa.gov/owow/monitoring/rbp/. Accessed Sept 16, 2008.

5.2. Large River Bioassessment Protocols

Organization of Origin: United States Environmental Protection Agency

Years in Use: Development began in 1998

Summary
The Large River Bioassessment Protocols (LRBPs) consist of four separate monitoring and assessment protocols (habitat, periphyton, benthic macroinvertebrates, fish) along with reviews and comparisons of a number of methods for each indicator, descriptions of the quality of data gathered at each step, and suggestions for taxonomic references to aid in organism identification.

Periphyton Sampling Protocol

A sample reach 500 m in length should be established, with six transects extending across the river at 100 m intervals. Along each transect, a 10 m zone (extending 5 m on either side, extending to mid-river or a depth of 1 m) will be searched for suitable periphyton habitat. Twelve samples (one on each side of the six transects) should be taken from the most suitable substrate (i.e. well-developed algal assemblage and minimal sediment), placed in a 500-mL bottle, mixed thoroughly, and kept on ice. A portion of the samples should also be preserved with 10% buffered formalin.

Analysis of chlorophyll *a* and ash-free dry mass (AFDM) can be used to estimate total algal biomass in the study reach. For metric application, algae must be correctly identified and enumerated, and while procedures are available for both soft-bodied algae and diatoms, the latter alone can often be used as an indicator of river condition.

For summaries of other aspects of the LRBPs, see Section 1.5 (fish protocols), Section 4.3 (benthic macroinvertebrate protocols) and Section 7.7 (habitat protocols).

Specialized Personnel Requirements
Qualified laboratory technician
Qualified periphyton taxonomist

Equipment Requirements

Enamel pan
Petri dish and spatula
Forceps
Pipettes and bulbs

Sample containers
Sample preservative Compound
microscope
Slides and coverglasses

Cost

Not Available

History of Use/Validation

The protocol for non-wadeable streams and rivers was developed to address biomonitoring and assessment needs of those waterways that fall outside the scope of wadeable rivers and streams, for which many protocols have been developed. Though some components are still in development (i.e. habitat assessment), the protocols are generally a synthesis of methods developed by different state agencies. Because large rivers have high variability in physical and chemical parameters, emphasis is placed on choosing the appropriate method for the river in question.

Sources and Additional Reading

Angradi, T.R. (editor). 2006. Environmental Monitoring and Assessment Program: Great River Ecosystems, Field Operations Manual. EPA/620/R-06/002. U.S. Environmental Protection Agency, Washington, D.C. http://www.epa.gov/emap/greatriver/EMAPGREFOM.pdf. Accessed Sept 19, 2008.

Flotemersch, J.E., Stribling, J.B., and M.J. Paul. 2006. Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers. EPA 600-R-06-127. US Environmental Protection Agency, Cincinnati, Ohio. http://www.epa.gov/eerd/rivers/non-wadeable_full_doc.pdf. Accessed Sept 19, 2008.

6. ***Degradation of Aesthetics***

The evaluation of aesthetics is a somewhat subjective task, but concrete factors must be found in order to reliably quantify the impairment of an area. Aesthetic impairment can occur in a variety of forms such as: litter and debris, water pollution, excessive algal growth, and excessive turbidity. Any monitoring method must, therefore, have a multi-faceted approach to cover such diverse factors. Chemical water quality analysis, point-source pollution monitoring, and basic community river clean-ups are a few ways in which aesthetics can be tracked and improved, and are all facets of the suggested approach for monitoring aesthetics.

6.1. Riverwatch Program

Organization of Origin: Buffalo Niagara Riverkeeper

Years in Use: Since 2005

Summary

The Riverwatch Program uses citizen volunteers to promote watershed stewardship through pollution monitoring and clean-up, public awareness, and education. Volunteers visit their waterway at least 12 times per year and identify any problems associated with pollution, habitat or public access. Any detectable issues (e.g., oil sheen on the water, litter, foul smells, poorly maintained access points, illegal dumping, etc.) are recorded and reports are returned to Buffalo Niagara Riverkeeper, where problems will be assessed and appropriate actions taken. Volunteers are also required to attend a number of workshops throughout the year, run by trained professionals, to keep their knowledge and skills current.

Beyond these mandatory duties, opportunities exist for volunteers to engage in other facets of waterway stewardship, including semi-annual shoreline clean-ups and chemical water quality sampling. Should an individual choose to monitor water quality, they are supplied with instructions and equipment to measure air temperature, water temperature, phosphorus, nitrate, dissolved oxygen, biochemical oxygen demand, pH and turbidity. The Riverwatch Program currently uses relatively simple and non-toxic colorimetry kits to measure these parameters, though there are plans to adopt use of probes for greater accuracy. Volunteers can also take water samples for coliform bacterial analysis, but those tests are performed by Riverkeeper staff.

Quality control measures are included in the sampling protocols. There is potential to develop similar volunteer-based programs in other AOC regions, comprising any monitoring elements described above depending on the nature of their local aesthetic impairments.

Specialized Personnel Requirements
Qualified professional to train volunteers in water quality testing
Qualified laboratory technician

Equipment Requirements

Colorimetry kit	Coliform analysis equipment
Thermometer	Sample bottles

Cost

LaMotte low-cost water quality sampling kit	$40
Thermometer	$10
Idexx Quanti-Tray bacterial counter*	Unknown

*used by Buffalo Niagara Riverkeeper

History of Use/Validation
Modeled after a government-funded volunteer water quality monitoring program in Oregon, the Riverwatch Program uses visual and chemical pollution monitoring to track the state of waterways at a relatively low cost. Despite its relatively recent initiation in New York State, volunteer participation is already almost 100 individuals.

Sources and Additional Reading
Drake, Robbyn. n.d. Riverwatch Captain's Manual. Buffalo Niagara Riverkeeper, Buffalo, NY. http://www.bnriverkeeper.org/programs/riverwatch/Riverwatch%20Captains%20Manual.pdf. Accessed Oct 20, 2008.

7. ***Loss of Fish and Wildlife Habitat***

Habitat assessment can be performed directly with quantitative measurement, or indirectly through the use of bioindicators. Examples of each of these approaches are summarized below.

When choosing monitoring methods, consideration must be given to regional relevance. Certain suites of monitoring methodologies, such as the Rapid Bioassessment Protocols (Section 1.4), were designed to have wide-ranging applicability. Others have been developed by state agencies (i.e. Michigan Department of Environmental Quality Procedure #51, Section 1.3) which, though similar to the more broadly applicable protocols, have slight modifications to make them state- or region-specific. If available, state- or region-specific protocols may be considered preferential, but more general protocols should not be discounted as a viable option in their absence.

Tracking bioindicators of habitat condition can be especially useful when combined with fish or wildlife population monitoring activities. Bioindicator selection should be based on biotic communities present in the study area, as well as the availability of personnel with specialized knowledge (e.g., macrophyte taxonomy) who can facilitate implementation of those strategies

Qualitative methodologies may not yield data as robust as quantitative studies, but are generally less time consuming and require fewer specialized personnel, making them a practical option if resources are limited.

7.1. Framework for Guiding Habitat Rehabilitation in the Great Lakes

Organization of Origin: Canadian Wildlife Service

Years in Use: First edition published in 1995

Summary

The Framework for Guiding Habitat Rehabilitation in the Great Lakes (the Habitat Framework) provides scientifically sound guidelines for ensuring adequate habitat to meet the needs of fish and wildlife in wetlands, rivers, and forests. Parameters examined for each of the three habitats are as follows:

Wetlands	Percent wetlands in watershed and subwatersheds; Amount of natural vegetation adjacent to the wetland; Wetland type, location, size, and shape

Rivers	Percent of stream naturally vegetated; Amount of natural vegetation adjacent to stream; Total suspended sediments; Percent of an urbanizing watershed that is impervious; Fish communities
Forests	Percent forest cover; Size of largest forest patch; Percent of watershed that is forest cover 100 m and 200 m from forest edge; Proximity to other forested patches; Fragmented landscapes and the role of corridors; Forest quality – species composition and age structure; Forest shape

Along with each of these parameters is an in-depth explanation of the rationale behind development of the accompanying guideline, which allows for modification based on the goals identified for a specific area.

In addition to guidelines for habitat rehabilitation, the appendices to the source document include examples of successful use of the framework, as well as some additional assessment methods (see Section 1.1)

Specialized Personnel Requirements
Sound knowledge of geomorphology, hydrology, and soils of the watershed
Experience in completing surveys of forest structure
Experience in Global Information System (GIS) application
Experience in water quality sampling

Equipment Requirements
GPS Unit
Multiprobe

Cost
Not Available

History of Use/Validation
The Habitat Framework was developed in 1995 for Remedial Action Plan and Public Advisory Committees to help guide rehabilitation of Canadian Areas of Concern (AOCs). It has been widely used in the process of selecting appropriate fish and wildlife targets, as well as implementing programs which will maintain or improve habitat to a point of supporting viable populations. In addition to use within AOCs, parts of the Framework have been used to create conservation strategies for watersheds and natural heritage sites. The Habitat Framework was professionally reviewed and updated in 2003.

Sources and Additional Reading

Environment Canada. 2004. "How Much Habitat is Enough? A Framework of Guiding Habitat Rehabilitation in Great Lakes Areas of Concern". Canadian Wildlife Service. http://www.on.ec.gc.ca/wildlife/docs/pdf/habitatframework-e.pdf. Accessed Sept 23, 2008.

7.2. Great Lakes Coastal Wetlands Monitoring Plan

Organization of Origin: Great Lakes Coastal Wetlands Consortium (GLCWC)

Years in Use: In development since 2002

Summary

The Great Lakes Coastal Wetlands Monitoring Plan (GLCWMP) is collection of standardized and field-tested monitoring protocols for a suite of biological indicators of Great Lakes coastal wetland health, and associated metrics. These protocols include those for vegetation, macroinvertebrates, fish, amphibians, and birds. A publicly-accessible database has been specially designed to house data collected using these protocols. The consistent, basin-wide use of these protocols will therefore better inform Great Lakes researchers and policy-makers about the status and trends of the lakes at a basin-wide scale.

<u>Chemical/physical water quality parameters</u>

In addition to monitoring indicators, it is beneficial to measure certain chemical and physical covariates associated with ecosystem degradation to augment biological monitoring and develop community-based Indices of Biotic Integrity (IBIs). Potential parameters include:

Dissolved oxygen	Chlorophyll *a*	Soluble reactive phosphorus
Temperature	Ammonium-N	Total phosphorus
Turbidity	Nitrite/nitrate-N	Redox potential
Specific conductivity	Chloride	Vegetation type and density
pH	Sulfate	Organic sediment depth

Some measures (turbidity, specific conductivity, chloride) correlate linearly with ecosystem degradation, whereas other chemical measures (ammonium-N, nitrite/nitrate-N, soluble reactive phosphorus) indicate disturbance if values are either extremely high or extremely low.

Covariates can be effectively monitored with a combination of *in situ* measurement using an appropriate multimeter (e.g., YSI multi-probe), and water sampling with subsequent laboratory fluorometry and colorimetry.

Vegetation Community Indicator

Wetlands should be randomly selected from all available wetlands in a given area. Plants should be sampled from the wet meadow zone through to the submergent zone, recording percent cover for emergent, submergent, and floating plants, as well as percent cover for each individual plant species. Substrate, organic depth, water depth, and water clarity should also be recorded.

Directions to calculate metrics are provided to quantify wetland health by the coverage and distribution of invasive plants, the coverage and diversity of submergent and floating plants, and the Floristic Quality Index (FQI).

Macroinvertebrate Community Indicator

Macroinvertebrate sampling should occur in late July through August, when most late instar aquatic macroinvertebrates are present. Samples are taken from the water column using D-frame dip nets in randomly selected locations, with care taken to sample all microhabitats at each location. Only fully inundated vegetation should be sampled to remove variability that can be caused by fluctuating water levels. Macroinvertebrates should be hand-picked from each sample, taking care to select a representative size-range or organisms, and preserved in 70% ethanol for identification. Organisms should be identified to the lowest taxonomic level possible, and voucher specimens sent to experts for confirmation when necessary.

Coastal wetland macroinvertebrate community health is calculated using the IBI described by Uzarski *et al.* (2004). This IBI is calibrated specifically for bulrush (*Scirpus* spp.) and wet meadow plant zones, though a cattail (*Typha* spp.) IBI has been developed for Lake Ontario by Environment Canada and the Central Lake Ontario Conservation Authority (2004a, 2004b). Sampling should still occur in other plant areas if possible, however, as those data can contribute to further IBI development.

Fish Community Indicator

Many methods exist for fish sampling (trap nets, seining, electrofishing, etc.), and the specific characteristics of an area, as well as the goals of the sampling, will dictate the most appropriate method. The GLCWMP describes the methodology for sampling using fyke nets or electrofishing, although the IBI metrics presented are only calibrated for fyke netting. If different methods are to be used, then the metrics should be recalibrated for that method.

Fyke netting:

Fyke nets should be placed in dominant vegetation zones in a wetland, with at least three replications per zone, and left overnight. Care should be taken to ensure the tops of the nets are above the water surface to minimize the chance of air-breathing vertebrates becoming caught and drowning. Nets should be set perpendicular to plant zones, with leads in adjacent plants, to catch fish moving along the edge of the zone.

All fish greater than 25 mm in length should be identified, enumerated, and examined for deformities (see Section 1.6). If taxonomic identification is questionable, a voucher specimen should be preserved and brought back to the lab for verification.

Fish community health is calculated using the IBI described by Uzarski *et al.* (2005). This IBI relates specifically to bulrush (*Schoenoplectus* spp.) and cattail (*Typha* spp.) dominated wetlands, but sampling may occur in other plant zones as well as other metrics will be developed.

<u>Amphibian Community Indicator</u>
See Section 1.7 (Marsh Monitoring Program)

<u>Bird Community Indicator</u>
See Section 1.7 (Marsh Monitoring Program)

Specialized Personnel Requirements
<u>Chemical/physical parameters</u>:
Some training in the use of parametric measurement equipment
Sound knowledge of laboratory and chemical handling safety

<u>Vegetation Community Indicator</u>:
Ability to identify wetland plants

<u>Macroinvertebrate Community Indicator</u>:
Minimal training for field protocol
Qualified taxonomist to perform organism identification

<u>Fish Community Indicator</u>:
Minimal training for field protocol
Experience in fish taxonomy for identification

<u>Amphibian Community Indicators</u>:
See Section 1.7 (Marsh Monitoring Program)

<u>Bird Community Indicator</u>:
See Section 1.7 (Marsh Monitoring Program)

Equipment Requirements

Chemical/physical parameters:

- Multiprobe
- Sample bottles
- Fluorometer
- Syringe with syringe filters
- Cuvettes
- Laboratory tissues
- Colorimeter and associated reagents
- Waders, canoe or boat

Vegetation Community Indicator:

- Camera
- Secchi disk
- Chest waders
- Sampling quadrat
- Depth stick

Macroinvertebrate Community Indicator:

- D-frame dip net
- Forceps/eyedroppers
- Sorting pans
- Sample bottles
- 70% alcohol
- Waders/rubber boots, canoe or boat

Fish Community Indicator:

- Fyke nets
- Buckets
- Filter apparatus
- Chest waders
- Fish processing boards

Amphibian Community Indicators:

See Section 1.7 (Marsh Monitoring Program)

Bird Community Indicator:

See Section 1.7 (Marsh Monitoring Program)

Cost

See Burton et al. (2008) for detailed cost breakdown

History of Use/Validation

The GLCWMP arose from the need for standardized environmental indicators of to better identify and track the status and trends of Great Lakes coastal wetlands on a basin-wide scale. Throughout the 1990s and early 2000s, experts from government, non-governmental organizations, academics, as well as other interested groups, worked to identify these indicators to report coastal wetland conditions and trends at the biannual State of the Lakes Ecosystem Conference (SOLEC). The final indicator suite was resolved following SOLEC 2004. Beginning in 2002, coordinated efforts among several expert researchers were initiated across the Great Lakes basin to field-test selected sampling protocols to monitor these indicators. These indicators and sampling protocols were subsequently revised where necessary, and in addition to a basin-wide coastal wetland inventory, standardized wetland classification scheme, proposed sampling design, database design, cost analysis and implementation plan, were reported as part of the GLCWMP.

Sources and Additional Reading

Burton, T.M., Brazner, J.C., Ciborowski, J.J.H., Grabas, G.P., Hummer, J., Schneider, J., and D.G. Uzarski (eds). 2008. Great Lakes Coastal Wetland Monitoring Plan. Great Lakes Coastal Wetland Consortium, Great Lakes Commission. http://www.glc.org/wetlands/documents/finalreport/Great-Lakes-Coastal-Wetlands-Monitoring-Plan_FINAL.pdf. Accessed Oct 7, 2008.

Uzarski, D.G., T.M. Burton and J.A. Genet. 2004. Validation and performance of an invertebrate index of biotic integrity for Lakes Huron and Michigan fringing wetlands during a period of lake level decline. Aquatic Health and Management, 7:269-288.

Uzarski, D.G., Burton, T.M., Cooper, M.J., Ingram, J.W., and Timmermans, S. 2005. Fish habitat use within and across wetland classes in coastal wetlands of the five Great Lakes: development of a fish-based Index of Biotic Integrity. J. Great Lakes Res. 31(Suppl.1):171-187.

7.3. Qualitative Habitat Evaluation Index

Organization of Origin: Ohio Environmental Protection Agency

Years in Use: Since 1989

Summary

The Qualitative Habitat Evaluation Index (QHEI) was designed to be a relatively quick and easy method to assess stream habitat quality using visual estimation of instream geography (Rankin 1989). It qualitatively measures six metrics (substrate, instream cover, channel morphology, riparian and bank condition, pool and riffle quality, and gradient) which sum to a final score between 0 and 100, where higher scores indicate better quality habitat.

The key to implementing the QHEI is maintaining universal standards in metric description, which is made possible through explicit definitions presented in the revised protocol (Rankin 2006). The QHEI works best if used in conjunction with other community-based indices, as it examines only physical habitat structure, while other parameters (e.g., chemical) may significantly affect the biotic communities present.

Specialized Personnel Requirements

Minimal training in scoring stream characteristics

Equipment Requirements

GPS unit
Depth stick
Digital camera

Cost
Not Available

History of Use/Validation
The QHEI was developed as an alternative to other more expensive and time-consuming methods to assess habitat quality. It has been used in Ohio since 1989. Rather than directly measuring the abundance and health of aquatic organisms, the QHEI uses instream geography to measure the quality of the stream habitat based on the level of beneficial characteristics it displays.

Sources and Additional Reading

Rankin, E.T. 2006. Methods for assessing habitat in flowing waters: Using the Qualitative Habitat Evaluation Index (QHEI). Midwest Biodiversity Institute, *for* Ohio Environmental Protection Agency, Division of Surface Water; Groveport, OH. http://www.epa.state.oh.us/dsw/documents/QHEIManualJune2006.pdf. Accessed Oct 3, 2008.

Rankin, E.T. 1989. The Qualitative Habitat Evaluation Index (QHEI): Rationale, methods, and application. Ohio Environmental Protection Agency, Division of Surface Water, Ecological Assessment Section; Columbus, OH. http://web.epa.state.oh.us/dsw/documents/BioCrit88_QHEIIntro.pdf. Accessed Oct 3, 2008.

7.4. Wetland Macrophyte Index

Organization of Origin: McMaster University

Years in Use: Pilot project began in 1996

Summary
The Wetland Macrophyte Index (WMI) uses wetland macrophyte presence/absence as an indicator of wetland health, and was developed specifically for coastal wetlands with a hydrological linkage to a large lake or bay. Wetland macrophytes are sampled either by random transects along the shoreline, if water is wadeable, or by using 0.75 m^2 quadrats by boat or canoe. Ten to fifteen quadrats should be sampled per wetland, regardless of size, noting species occurrence. After ten quadrats, sampling can be terminated if no new species are found in two consecutive quadrats. All emergent, submergent, and floating plant taxa should be recorded, with emphasis placed on those plants that serve as fish habitat.

The sensitivity of different species to disturbance are described by two parameters, “tolerance of a species to degradation” and “niche breadth” as outlined in Croft and Chow-Fraser (2007), which, along with percent occurrence, are entered into a simple equation to yield the WMI score.

Specialized Personnel Requirements
Experience in wetland plant identification

Equipment Requirements
Wetland Plants guide
Floating quadrat
Waders/canoe

Cost
Not Available

History of Use/Validation
The WMI was developed as a relatively simple, cost-effective, and universal tool to assess the health of coastal wetland marshes around the Great Lakes. Though newly developed, the WMI has been validated through application in two Canadian Areas of Concern (AOCs) undergoing remediation activities: Severn Sound and Hamilton Harbour. Following implementation of Remedial Action Plans in these AOCs, WMI scores indicated significant improvement to coastal wetland health. Further, using historical macrophyte data, the WMI was able to track the ecosystem health decline in Hamilton Harbour over a 50–year duration until remediation activities were initiated.

The WMI is currently being used by Parks Canada in Fathom Five National Marine Park, and a volunteer program is being developed for its use in Georgian Bay coastal wetlands.

Sources and Additional Reading
Croft, M.V. and P. Chow-Fraser. 2007. Use and development of the Wetland Macrophyte Index to detect water quality impairment in fish habitat of Great Lakes coastal marshes. J. Great Lakes Res. 33(SI3): 172-197.

7.5. Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers (Procedure #51)

Organization of Origin: Michigan Department of Environmental Quality

Years in Use: Revised in 2002

Summary
Michigan's Qualitative Biological and Habitat Survey Protocols consist of three separate monitoring and assessment protocols (fish, benthic macroinvertebrates, habitat) for wadeable streams and rivers, along with all necessary data collection

forms, QA/QC procedures, and extensive lists of taxonomic references to aid in organism identification.

Habitat Survey Protocol

Habitat assessment is completed visually using a set of ten metrics (e.g., channel alteration, bank stability, pool substrate characterization), each of which can yield a score between 0 (poor) and 20 (excellent). The metrics are divided, firstly, by the characterization of the stream as a riffle/run stream or a glide/pool stream, and diagnostic metrics are chosen accordingly.

The reach of stream assessed should be at least the length of the reach used for biological monitoring, and can be extended further if necessary. For example, if a given reach has approximately equal representation of riffle/run and glide/pool characteristics, it may be extended so that one stream type assumes dominance and assessment can more easily proceed.

For summaries of other aspects of the Qualitative Biological and Habitat Survey Protocols, see Section 1.3 (fish protocols) and Section 4.1 (benthic macroinvertebrate protocols).

Specialized Personnel Requirements
Minimal training required

Equipment Requirements
Camera
Flow or velocity meter
In situ water quality meter (e.g., YSI multiprobe)
GPS unit

Cost
Not Available

History of Use/Validation
MDEQ's Procedure #51 is a synthesis of several methods used by the U.S. Environmental Protection Agency (EPA), the Ohio EPA, and the state of Illinois, adapted and tested for use specifically in the state of Michigan. It was developed as a method to more vigorously assess the impacts of non-point source stressors, and can be used as a combined unit for habitat assessment. Its three component parts can also be used independently depending on the monitoring objectives. This monitoring is currently used as part of Michigan's Five Year Basin Cycle Monitoring plan.

Sources and Additional Reading
Michigan Department of Environmental Quality. 2002. Qualitative biological and habitat survey protocols for wadeable streams and rivers (Procedure #51). Surface Water Quality Division; Great Lakes Environmental Assessment Section.

7.6. Rapid Bioassessment Protocols

Organization of Origin: United States Environmental Protection Agency

Years in Use: Since 1989

Summary
The Rapid Bioassessment Protocols (RBPs) consist of four separate monitoring and assessment protocols (habitat, periphyton, benthic macroinvertebrates, fish) for wadeable streams and rivers, along with all necessary data collection forms, QA/QC procedures, and extensive lists of taxonomic references to aid in organism identification.

<u>Habitat Assessment</u>

Habitat assessment is completed visually using a set of ten metrics (e.g., frequency of riffles, sediment deposition, bank stability) each of which can yield a score between 0 (poor) and 20 (excellent). The metrics are divided, firstly, by the characterization of the stream as a riffle/run stream or a glide/pool stream, and diagnostic metrics are chosen accordingly.

The reach of stream assessed should be at least the length of the reach used for biological monitoring, and can be extended further if necessary. For example, if a given reach has approximately equal representation of riffle/run and glide/pool characteristics, it may be extended so that one stream type assumes dominance and assessment can more easily proceed.

For summaries of other aspects of the RBPs, see Section 1.4 (fish protocols), Section 4.2 (benthic macroinvertebrate protocols) and Section 5.1 (periphyton protocols).

Specialized Personnel Requirements
Minimal training required

Equipment Requirements
Camera
Flow or velocity meter
In situ water quality meter (e.g., YSI multiprobe)
GPS unit

Cost
Not Available

History of Use/Validation
The RBPs are a synthesis of several methods used by various state agencies presented as a guide to implementing basic and cost-effective biological monitoring practices, or augmenting existing practices (Barbour *et al.* 1999). Since their inception in 1989 the RBPs have been extensively tested and revised across the US.

Sources and Additional Reading
Barbour, M.T., Gerritsen, J., Snyder, B.D., and J.B. Stribling. 1999. Rapid Bioassessment Protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, Second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. http://www.epa.gov/owow/monitoring/rbp/. Accessed Sept 16, 2008.

7.7. Large River Bioassessment Protocols

Organization of Origin: United States Environmental Protection Agency

Years in Use: Development began in 1998

Summary
The Large River Bioassessment Protocols (LRBPs) consist of four separate monitoring and assessment protocols (habitat, periphyton, benthic macroinvertebrates, fish) along with reviews and comparisons of a number of methods for each indicator, descriptions of the quality of data gathered at each step, and suggestions for taxonomic references to aid in organism identification.

<u>Habitat Assessment</u>

Though there is no explicit explanation of habitat assessment protocol given in the LRBP, five different protocols are explored, with emphasis on how each addresses different physical and chemical attributes (i.e. sinuosity, substrate size, dissolved oxygen, etc.).

For summaries of other aspects of the LRBPs, see Section 1.5 (fish protocols), Section 4.3 (benthic macroinvertebrate protocols) and Section 5.2 (periphyton protocols).

Specialized Personnel Requirements
Minimal training required

Equipment Requirements
Variable, depending on physical and chemical characteristics examined

Cost
Not Available

History of Use/Validation
The protocol for non-wadeable streams and rivers was developed to address biomonitoring and assessment needs of those waterways that fall outside the scope of wadeable rivers and streams, for which many protocols have been developed. Though some components are still in development (i.e. habitat assessment), the protocols are generally a synthesis of methods developed by different state agencies. Because large rivers have high variability in physical and chemical parameters, emphasis is placed on choosing the appropriate method for the river in question.

Sources and Additional Reading

Angradi, T.R. (editor). 2006. Environmental Monitoring and Assessment Program: Great River Ecosystems, Field Operations Manual. EPA/620/R-06/002. U.S. Environmental Protection Agency, Washington, D.C. http://www.epa.gov/emap/greatriver/EMAPGREFOM.pdf. Accessed Sept 19, 2008.

Flotemersch, J.E., Stribling, J.B., and M.J. Paul. 2006. Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers. EPA 600-R-06-127. US Environmental Protection Agency, Cincinnati, Ohio. http://www.epa.gov/eerd/rivers/non-wadeable_full_doc.pdf. Accessed Sept 19, 2008.