Fish-Based IBI Development for Minnesota Lakes and Use in the Watershed Assessment Process

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Background:

Fish communities are a reflection of the cumulative effects of natural and human-caused influences on the lake. Certain fish species can't survive without clean water and a healthy habitat, while other species are tolerant of degraded conditions. These species are considered "indicators" of lake health. An IBI, short for index of biological integrity, is a tool used to measure a lake's health and identify lakes that may be impacted by watershed disturbance, shoreline degradation, or other environmental stressors.

In the late 1990's, Minnesota Department of Natural Resources (MDNR) Fisheries researchers developed a fish-based IBI (FIBI) for a set of small Central-Minnesota lakes having similar geophysical and chemical features (Drake and Pereira 2002).

From 2005–2012, over 1,000 FIBI surveys were conducted to develop a suite of FIBI tools for additional sizes and types of lakes across Minnesota. FIBI tool development included sampling the entire fish community in a wide range of lakes, from high-quality lakes to those with significantly degraded water quality or shoreline habitat. Statistical analyses were used to construct tools using several measurements of the fish community. When the measurements are analyzed together, they are given an FIBI score that reflects the lake's health.

The FIBI score is an important component of the Minnesota Pollution Control Agency's (MPCA) water quality assessment process. Each year MDNR Fisheries staff complete approximately 130-160 FIBI surveys and assess the status of a similar number of lakes based on the data collected. Lakes are assessed as supporting aquatic life use or non-supporting of aquatic life use (impaired) based on FIBI tools.

Biological assessments provide important information to guide clean water planning, restoration, and protection efforts and complement pollutant-based water quality sampling efforts on lakes. On lakes with low FIBI scores, watershed and shoreline degradation information is used to identify the most likely stressors and to prioritize appropriate restoration activities. FIBI and associated stressor information can also be used by conservation groups, lake associations, and homeowners to guide future lake management actions.

Funding for FIBI tool development and watershed assessment sampling is provided by the Clean Water, Land and Legacy Amendment, MDNR Game and Fish Fund, and the Sport Fish Restoration Project.

FIBI Sampling Methods:

Fish data are collected by MDNR staff with four gears: active gears (seining and electrofishing) for nearshore sampling following the methods of Drake and Pereira (2002) and Drake and Valley (2005), and passive gears (trap nets and gill nets) for sampling littoral and limnetic areas, respectively, using MDNR's lake survey methods (MDNR 2017). The number of sampling stations was determined by oversampling lakes and running simulations to determine the effort required to sample 90% of species richness for each metric (completed in 2012) and is variable based on lake size.

Fish IBI Tool Development:

Fish IBI tool development included several field studies and statistical analyses:

1. Group Lakes:

Minnesota's lakes that fall within lake classes 20–43 based on the Schupp lake classification used by MDNR were partitioned into six distinct groups, and a unique FIBI was developed for four groups. The groupings were based on hierarchical cluster analysis using eight lake attributes that capture "natural differences" across lakes: total area, maximum depth, proportion littoral area, shoreline development index, total alkalinity, volume, area:shoreline ratio, and growing degree days. These groupings allow for comparison of lakes with similar maximum depth, littoral area, shape, shoreline complexity, and geographic position.

2. Classify Fish Species:

Fish species were assigned to categories within three guilds: tolerance, trophic, and special habitat use. The assignment of species into the appropriate guild category was critical to refining the lake FIBI for all lake class 20–43 lakes because FIBI scores are based on the richness or relative abundance of various assemblages of fish. Akaike Information Criterion (AIC) was used on a 600 lake dataset to determine which measures of human-induced stress, if any, best explained the presence/absence of a given species and to

assist in tolerance classification. In addition, several classification schemes and natural history accounts were reviewed, including some narrative descriptions and consultations with subject matter experts to determine species assignments.

3. Metric Development and IBI Tools:

We developed four FIBI Tools for lakes 100–10,000 acres in size and within most areas of the state. Each FIBI has 8–15 metrics, and IBI scores are scaled 0–100. The FIBIs are composed of metrics that are in many cases similar to metrics in the Drake and Pereira (2002) FIBI. Metrics are of three types: species richness, community assemblage, and trophic composition. Metrics were selected based on their response to watershed land use patterns and vegetation quality using Spearman rank correlation analysis and principal components analysis. If two metrics were highly correlated, the metric that best predicted watershed disturbance and/or shoreline disturbance was retained and the redundant metric eliminated. For most groups, species richness and community composition metrics describing intolerant or habitat specialist species were most sensitive to differences in human-induced stress. Because these species were found in the nearshore zone of lakes, effective sampling of the fish in these habitats is essential to the performance of the FIBI. Trap net and gill net-based metrics, however, were essential to the development of trophic composition metrics, with trap nets providing the best insectivore and omnivore metric and the gill nets providing the best top carnivore metrics. In addition, a gill net metric accounting for the presence of intolerant cool- and cold-water species is included for deep lakes within the native range of Cisco. Species richness metrics that were correlated with lake size were adjusted for lake size using a mixed model. Individual metric scores were standardized and then summed. Total scores were normalized to put them on a 0–100 scale for each FIBI.

4. Threshold Development:

Biological Condition Gradient (BCG) models for fish assemblages in Minnesota lakes were developed by Tetra Tech, Inc. with participation from aquatic biologists from MPCA, MDNR, Midwest Biodiversity Institute, and an independent contractor. The BCG is a conceptual model that describes changes in aquatic communities along a gradient in response to increasing levels of human disturbance and is useful in establishing threshold criteria based on biology. Consistent with MPCA stream threshold setting approach, we have developed thresholds based on the BCG model for impairment and exceptional use categories using the Tiered Aquatic Life Uses (TALU) framework. To date only the impairment thresholds are used in the assessment process. However, identifying lakes with exceptionally high FIBI scores has been useful in Watershed Restoration and Protection Strategies (WRAPS) prioritization, Lakes of Biological Significance, and as one criterion for prioritizing potential MDNR acquisitions.

Watershed Assessments:

FIBI information, scores, and thresholds were incorporated into the MPCA-led watershed assessment process beginning in the winter of 2015 as a pilot year for four watersheds. The FIBI for lakes added a biological component to the criteria used to list a lake as impaired or not impaired. During the first four years, nearly 400 lakes in 17 watersheds were assessed. Previously, assessments focused on chemical parameters and relationships to designated human uses including swimming, drinking, and aesthetic uses.

Stressor Identification:

MDNR FIBI staff consolidate available stressor information for each lake that is assessed as not supporting or is identified as vulnerable to future impairment. Numerous stressors are considered, but most often, the focus is on the impacts of water quality and the shoreline habitat on the fish community. Land use changes associated with urbanization and agriculture can impact fish communities by increasing nutrient loading and sedimentation, resulting in a reduction in aquatic plants and reductions in hypolimnetic oxygen. Shoreline disturbance from development can result in changes to the vegetation, woody habitat, and substrates.

Continuing Work:

MDNR Fisheries staff will continue to conduct approximately 130–160 FIBI surveys annually within the MPCA watershed assessment schedule and summarize the data for the assessments. MDNR Fisheries staff are also using vertical gill nets to sample cold-water fish communities and explore metrics that may be added to an FIBI for deep lakes. The primary fish species of interest are Cisco, which are particularly sensitive to changes in water quality and temperature.

Acknowledgments and Funding:

While a smaller scale effort to develop an FIBI for lakes began in the 1990's by Fisheries researchers, the force behind developing state-wide fish and plant-based IBIs for lakes was funding provided by the passage of the Clean Water, Land and Legacy Amendment to the Minnesota Constitution by Minnesota voters in 2008. The lake IBI development and implementation project receives approximately 1 million dollars annually from the clean water portion of the amendment in recent years. In addition to funding, this effort required comprehensive thinking and coordination. Implementation of FIBI sampling within a watershed assessment framework has involved adjustments to survey methods, survey schedules, and staffing across 25 fisheries management areas as well as several Fisheries Research and FIBI Program staff. It has also required close cooperation with other MDNR Divisions and with the MPCA. MDNR Fisheries is committed to fish community sampling in lakes in order to leverage Legacy Amendment dollars, deepen our understanding of lakes as systems, bring more science to TMDL planning, and examine long-term trends in fish communities across the state. Note that some funding for FIBI survey and tool development work was also provided by Game and Fish and Sport Fish Restoration Funds. Melissa Treml, David Staples, and others assisted with several research questions and statistical analyses for FIBI development and scoring. FIBI staff that lead surveys, watershed assessment data compilation, and stressor ID reporting include Derek Bahr, Luke Borgstrom, and Jessica Moore. Tyler Ahrenstorff and Pete Jacobson are exploring incorporating cold-water fish metrics in the FIBI. Scott Niemela, John Sandberg, Pam Anderson, and Will Bouchard have been the primary staff at MPCA assisting with technical aspects of IBI tool and threshold development. Numerous other staff have been and continue to be involved in IBI survey work, BCG model development, and other projects and meetings related to FIBI development.

References

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