Using Statewide Survey Data to Support Local-Scale Management of Michigan Trout Streams

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Abstract—Building upon insights from state fishery managers and multi-decadal studies on trout populations, the state of Michigan embarked on a statewide program to monitor trends in wild trout populations and to assess the status of fish assemblages and habitats in all streams. Initiated in 2002, the Stream Status and Trends Program (SSTP) provides a rich set of information from standardized surveys across Michigan. Data from SSTP surveys support public-facing tools which inform stakeholders (biologists, anglers, various publics) of trends in highly-valued trout populations and provide an empirical basis for managing individual stream reaches. Launched in 2014, the Stream Fish Population Trend Viewer allows users to assess trends in wild trout abundance, growth, and survival using data from fixed (index) electrofishing sites throughout the state. The Michigan Stream Evaluator, scheduled for release in 2017, provides comparisons of habitat and fish assemblage conditions at individual sites to benchmarks computed from surveys in streams having similar size, temperature, channel gradient, and geographic location attributes. Both tools are refreshed annually with additional survey data.

Introduction

Conserving and managing wild trout populations and fisheries, and aquatic communities in streams in general, pose challenges on several levels to fisheries biologists. Trout populations are dynamic through time, being shaped by short- and long-term changes in flow, temperature, and water quality conditions (Lobón-Cerviá 2004; Zorn and Nuhfer 2007a). Longer-term climatic and hydrologic changes further complicate patterns in trout recruitment, growth, survival, and ultimately, population interactions and trajectories (Poff and Ward 1989; Wenger et al. 2011). Even for hydrologically stable, groundwater-fed streams, 10-20 years of annual population estimate data are needed just to characterize baseline variability in trout populations (Wiley et al. 1997).

Trout populations live in a diverse array of habitats, ranging from high mountain lakes and streams, to low-gradient groundwater-fed rivers (Frissell et al. 1986). Even among groundwater-influenced streams in the Great Lakes region, flow stability, reach-scale stream gradient and power can vary over several orders of magnitude, resulting in myriad combinations of stream habitat and fish assemblages across the region (Zorn et al. 2002). In addition, the streams in which trout reside are constantly changing as stream channel habitats are shaped and altered by natural and human-induced geomorphic processes (Ward and Stanford 1983; Poff et al. 1997).

In water-rich Midwestern states like Michigan, there are tens of thousands of kilometers of trout stream habitat. Wild trout production from these streams dwarfs that of state fish hatcheries, making these streams a tremendously valuable resource. Demands on Michigan's fishery managers are diverse though, with upwards of 180,000 stream trout anglers, and major fisheries in the Great Lakes and over 10,000 inland lakes. With so much trout water and so many fisheries to protect and manage, much of the challenge for biologists is to make sense of stream survey data for an individual water body (or location) that may be sampled only once every couple decades. Some basic questions need to be answered. For example, to what degree do conditions at the site, reach, and catchment scales influence what the survey data show? How is the observed population shaped by regional climatic or hydrologic processes that similarly affect populations across the region? What are typical stream habitat, fish assemblage, and fish population characteristics for this type of stream? Are conditions out of the ordinary, or in need of specific management action? Answering these questions requires a longer-term, regional perspective that goes beyond typical management unit or political boundaries, and necessitates sampling and analyses coordinated across larger spatial and temporal scales. An improved inventory program was needed so trout managers (with limited local-scale data) could better understand and explain what was driving fish populations at individual stream sites.

Michigan's Stream Status and Trends Program (SSTP; Hayes et al. 2003) was initiated in 2002 to characterize differences among a diverse array of stream systems and to describe trends in key fish populations over time. Ultimately, the intent was to be able to provide the information needed to address questions relating to spatial and temporal variation in stream fish (especially wild trout) populations throughout the state. The SSTP brought the accompanying challenge of conveying the importance of temporal and spatial influences on stream fish populations to interest groups and a public typically less exposed to this broader perspective. Here, we show how data from the SSTP are packaged and delivered to address questions that anglers, the public, and other biologists often ask local fishery managers.

Methods

The SSTP grew from recognition of existing knowledge gaps and understanding acquired from earlier stream fish ecology studies in Michigan. Analyses of long-term index site data on Brook Trout *Salvelinus fontinalis* and Brown Trout *Salmo trutta* populations in the Au Sable River and Michigan waters highlighted the importance of long-term population index data to trout ecology and management (e.g., Clark et al. 1980; Zorn and Nuhfer 2007a; 2007b). An appreciation of the diversity of Michigan streams and the need to better understand stream-specific influences on fish populations was evident from several studies completed in Michigan during the last two decades (e.g., Wiley and Seelbach 1997; Wiley et al. 1997; Zorn et al. 2002; Wehrly et al. 2003; Seelbach et al. 2006). Combined, these efforts highlighted a fundamental need for understanding what was driving spatial and temporal patterns in fish populations and habitat conditions in Michigan streams.

The design of the SSTP incorporates two different, yet complementary, types of sampling. Fixed (index) site sampling is used for stream types supporting valuable fisheries for wild trout or Smallmouth Bass *Micropterus dolomieu* streams. Wadeable electrofishing reaches (typically 1,000 ft) are sampled in late-summer using a 3-years-on, 3-years-off rotation, to provide broader geographic coverage throughout Michigan while enabling estimates of year-to-year survival of trout at individual sites. The following parameters are measured during years when sampling is scheduled: mark-recapture population estimates by size and age group of trout (1-pass catch rates for Smallmouth Bass); annual estimates of trout growth and survival; and hourly water temperature measurements. Instream, riparian, and woody habitat conditions and fish community composition of electrofishing reaches are measured once per 3-year-on cycle to enable assessment of effects of river- and site-level attributes on fish populations (Wills et al. 2008). Overall, this approach provides high-resolution trend detection, with the regional network of sites providing information on the spatial extent of trends and synchrony among populations (Zorn and Nuhfer 2007).

A stratified random sampling design is used primarily for general resource inventory, with the intent of quantifying fish assemblage and habitat conditions in each type of stream in Michigan. The primary sampling unit for the stratified random sampling design is the river valley segment (Seelbach et al. 2006), a contiguous segment of a stream that is characterized by similar hydrology, water quality, channel morphology, riparian land cover, and fish communities along its length. For the SSTP, individual valley segments were randomly ordered for sampling by field crews. We expect that it will take several decades before the entire list of segments has been sampled. Surveys at random sites involved sampling the fish assemblage in the sample reach via single-pass electrofishing, hourly water temperature measurements, and collection of data describing instream, riparian, and woody habitat conditions within the sample reach (Wills et al. 2008). Data from all SSTP surveys are entered into the Michigan Department of Natural Resources (MDNR) Fisheries Division's centralized database, the Fish Collection System (FCS). Seeing the value of the standardized sampling approach and thorough data collection procedures, MDNR Fisheries Division staff and other partners have completed many additional surveys using SSTP random site protocols, providing additional survey data for use.

The SSTP initiated use of standardized data collection protocols for stream surveys across the state and centralized storage of survey information. After the SSTP was initiated, several years were needed for data to accumulate in the FCS to reach a "critical mass" for use in development of decision support tools. In addition, a modest amount of external funding had to be acquired to support the additional expertise needed for tool development.

Stream Fish Population Trend Viewer (TV)- Stream survey data for Brook Trout, Brown Trout, Rainbow Trout *Oncorhynchus mykiss*, Coho Salmon *Oncorhynchus kisutch*, and Smallmouth Bass at fixed sites are queried to provide annual estimates of total biomass density, numerical density (numbers per acre by age and size class), and mean length-at-age and annual survival for age classes with adequate sample sizes. These data are annually extracted and summarized from the FCS for use in the TV via MS-Access ODBC queries. Average values for each parameter at that site are also calculated from surveys since 2002, and represent "long-term" mean values for that parameter at that site. These data allow users

Figure 1. Screen capture from the Stream Fish Population Trend Viewer showing total biomass (pounds/acre) of Brown Trout from most recent surveys at electrofishing index (SSTP fixed) sites in Michigan. Color of dots shows how most recent survey value compares to average value at that site from surveys conducted since 2002. Accessed May 9, 2017.

of the TV to view current status (percent departure from "long-term" average) for a given parameter (e.g., density of age-1 Brown Trout) at all sites in Michigan on a map, and assess the extent to which other populations in the region share a similar status (i.e., the spatial extent of the trend). Data for each parameter measured at fixed sites are also viewable in graph and tabular form, and downloadable as .pdf or .xls files. Historic (pre-2002) data are also available at several fixed sites.

Michigan Stream Evaluator (MSE)- The MSE enables users to access benchmark or typical values for many parameters measured on hundreds of surveys conducted using MDNR SSTP random site protocols. Benchmark values (mean and standard deviation) of various survey parameters are computed via MS-Access ODBC queries of data in the FCS. Survey parameters include numerical density of fishes, density by size class for game species, transect-based instream habitat data, bank and riparian habitat measures, density of logs and woody habitat, and others. The

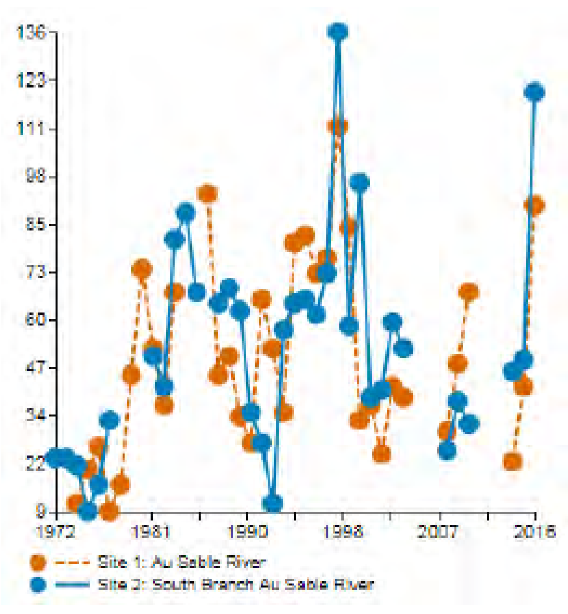

Figure 2. Screen capture from Stream Fish Population Trend Viewer showing numerical density (number/acre on y-axis) of age-1 Brook Trout from surveys since 1972 at fixed sites on the main-stem Au Sable River and South Branch Au Sable River. Accessed May 9, 2017.

MSE includes benchmarks for over 100 survey parameters. Data are stratified in various ways so that benchmarks are computed for the diversity of stream types and regions of Michigan. Strata are based on river catchment size, July mean water temperature, reach gradient, geographic area or region, and accessibility to the Great Lakes.

Users of the MSE can select an individual stream survey, the attributes of benchmark for comparisons. Values of parameters from the chosen survey are displayed, along with mean and standard deviation values computed from benchmark streams. For each parameter, a line graph depicts the difference between observed and benchmark mean values, with the difference standardized (divided) by the benchmark's standard deviation.

The Michigan Department of Technology Management and Budget (DTMB) hosts the TV and MSE on secure Windows-based Servers running Internet Information Services. Microsoft SQL Server, enabled with ESRI ArcGIS Spatial Database Engine houses the GIS and tabular data for both tools. ESRI ArcGIS for Server provides the technology to serve the mapping data. ESRI JavaScript application programming interface powers the mapping and analysis in the TV and MSE. JavaScript charting libraries enable the interactive visualization of fish abundance and habitat specific information. Data for the TV and MSE are updated annually (typically in late winter) after fish sampling and age and growth data from the previous field season have been entered and approved.

Results

Through the TV, the most recent data documenting trends in wild trout abundance, growth, and survival are efficiently summarized and made publicly available in a relatively user-friendly form. Data are available for fixed sites on 16 wild trout streams with Great Lakes access, 19 wild trout streams without Great Lakes access, and 9 Smallmouth Bass streams, with surveys at some locations going back as far as 1947. A link to the TV can be accessed by entering "Stream fish population trend viewer" into an internet search engine.

Map-based outputs of the TV make it easy to assess population trends at a site, and to compare conditions among sites. For example, recent data on total Brown Trout biomass from fixed sites around

Michigan suggests that among trout streams where Brown Trout occur, biomass is generally near or above average in streams in the northern portion of the state, though more than 50% below average in some southwest Michigan trout streams (Figure 1).

Tabular outputs from the TV allow users to explore long-term trends in abundance, growth, and survival of wild trout, and assess similarity in populations within a region. For example, long-term data from the main-stem Au Sable River and South Branch Au Sable River show similar patterns in density of age-1 Brook Trout, suggesting population dynamics may be influenced by larger-scale processes acting on trout populations across the region (Figure 2).

Example output from the MSE demonstrates its utility for placing survey results into a broader context. Here, results from a survey on the West Branch Sturgeon River were compared to benchmark values computed from 12 surveys conducted on similar streams in Michigan's Northern Lower Peninsula (Figure 3). The West Branch Sturgeon River was considerably wider than most surveys in its class, and had a notably greater percent coverage of rooted aquatic plants. Woody habitat, particularly the density of large logs, was somewhat lower than average. Total fish and small Brown Trout density were slightly higher than benchmark values, while density of all salmonids larger than 7 in was below average.

Water Body Name	V Seg #	Survey #	Region	Size	Temp	Gradient	G Lks Access
West Branch Sturgeon River (NLHMU)	12761	8607	NLP	stream	Cold	High	no
Compared to:			NLP	stream	Cold	High, moderate	no

Parameter	Observed	Mean	Sdev	n
Habitat variables				
% pool	0.0	5.6	8.3	12
% riffle	7.3	13.0	15.2	12
Ave width (ft)	37.7	21.6	9.3	12
% undercut banks	69.0	59.5	27.6	11
% rooted plant coverage	13.4	2.3	4.2	11
% sand and finer	50.8	54.6	32.6	12
% gravel and coarser	47.7	44.3	32.0	12
lineal ft of logs ≥ 12 in diameter per acre	144.4	410.9	248.1	12
lineal ft of logs ≥ 6 in diameter per acre	872.1	1740.1	1246.1	12
Density of natural log jams (ft^2 per acre)	336.0	1209.2	1720.6	12
Density of wood complexes (ft^2 per acre)	1654.5	1441.7	1686.4	12
Fish catch data (number per acre)				
Species richness	5.0	8.3	4.5	12
All fish species	419.0	301.3	187.4	12
Blacknose Dace	0.0	106.8	220.9	12
Creek Chub	0.0	83.4	126.2	12
Mottled Sculpin or Slimy Sculpin	64.5	98.3	149.2	12
White Sucker	0.0	36.0	70.5	12
Catch by size group (number per acre)				
Brook Trout < 4 in	17.3	176.5	411.8	12
Brown Trout < 4 in	104.0	65.8	94.5	12
Brown Trout > 12 in	0.0	5.1	13.5	12
All Salmonids > 7 in	20.2	67.0	46.3	12

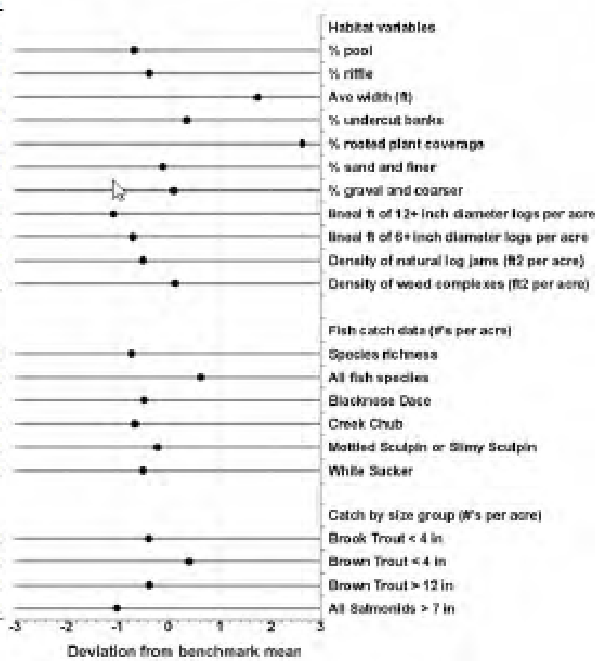

Figure 3. Preliminary graphical and tabular outputs from Michigan Stream Evaluator showing observed fish and habitat sure measurements from a survey on the West Branch Sturgeon River in the Northern Lake Huron Management Unit (NLHMU), compared to benchmark mean and standard deviation (S Dev) values computed from twelve stream segments in Michigan's Northern Lower Peninsula (NLP) having similar size, July mean temperature (Temp), channel gradient, and Great Lakes accessibility (G Lks Access) attributes.

Discussion

The TV and MSE tools provide an efficient means to summarize and present data collected across a broad region in an ecologically meaningful way that benefits local fishery managers, managers of river habitats, anglers, and the public. The tools provide relatively simple diagnostic information, though they represent the culmination of years of technical work, including landscape-scale classification efforts, long-term population dynamics studies, statewide coordinated sampling efforts, over 10 years of coordinated sampling efforts, database management and queries, and integration of databases, GIS technology, and website development. Relatively simple tools built upon technical programs fit well with the diverse set of decision support tool users including agency, university, and tribal biologists; tech-savvy trout anglers; aquatic non-profits; citizen scientists; and interested publics. We anticipate these tools will greatly aid the MDNR in its efforts to openly share science and technical data, and to foster collaboration with others, a goal recently identified in Michigan's statewide Inland Trout Management Plan (Zorn et al. *Under review*).

The TV supports wild trout management, research, and angler outreach by placing the latest survey data directly in the users' hands. The data delivery interface, modeled after the USGS's state-level real-time daily streamflow webpages (e.g., https://waterdata.usgs.gov/mi/nwis/rt), provides the latest trout trend information for Michigan in a simple, user-friendly manner. The parameters available (abundance, growth, and survival) are key drivers of populations and important for evaluating effects of environmental or management changes, particularly those associated with flow, water quality, or sport fishing regulations. Since population trends for a given stream reach often are consistent upstream and downstream of survey locations (Wills et al. 2008), and often in nearby waters (Zorn and Nuhfer 2007b), the TV can help managers to better interpret an individual survey, since it will show whether populations in the region at that time are trending high, low, or average.

Data are provided for many of Michigan's most popular trout streams, and therefore are of great interest to fishery managers, tackle shops, anglers, and guides. The regional perspective of the TV provides all with a broader view of regional trends in trout populations, thus heightening the awareness of climatic and other larger-scale processes that drive trout population dynamics in the state (Zorn and Nuhfer 2007b). Data on riverine Smallmouth Bass populations also supports an improved understanding of dynamics of this popular sport fish. Furthermore, the ability to export or download data at individual sites enables users to satisfy their curiosity through more detailed exploration of trends in fish abundance, growth, and survival.

The easy-to-use MSE represents a breakthrough for biologists managing streams because it provides geographically-relevant, empirical benchmarks for comparison with individual survey results. The strata used in computing benchmarks (size, temperature, gradient, region) represent key large-scale factors that drive spatial variation in local stream habitat conditions and fish assemblages in Michigan and elsewhere (Zorn et al. 2004; Zorn and Wiley 2006; Steen et al. 2008). As a tool focusing on entire fish assemblages as well as habitat, the MSE provides a basis for examining relationships between stream habitat characteristics (summary strata and field-measured variables) and the distribution and abundance of many fish species, including invasive species.

The MSE is especially useful as a means of characterizing expectations for a stream reach, and flagging measured parameters that exceed expectations (positively or negatively) and may deserve further inquiry. It can be used to address management questions related to fish populations (e.g., Are juvenile Brook Trout densities unusually low at the site?) or fish habitat (Is the reach unusually sandy or lacking in large woody habitat?). By computing benchmarks from survey data for similar river segments, the MSE can provide useful characterizations of expected fish communities and habitats for river segments where surveys do not exist or recent surveys are unavailable. This information can prove especially useful to managers when they need to assess damage to habitats or fish populations (e.g., fish kills) and pre-impact survey data are limited or unavailable.

We expect the TV and MSE tools to remain durable and robust over time. Both tools will be updated annually via queries and maintained on state servers. Trout population datasets for some sites in the TV are among the longest-running trout population data sets in the country, and increased accessibility to the data will only increase their utility. The hundreds of surveys in the MSE may be somewhat limiting, given the diversity of stream types in Michigan, but this information base will only improve over time, as SSTP random site surveys accumulate and managers make increased use of SSTP random site sampling protocols on discretionary surveys. Strata used in the MSE should be useful over the long-term since they represent foundational landscape factors that structure stream habitat and explain spatial variation in habitat and fish assemblage characteristics in streams across the region (Seelbach et al. 2006; Zorn and Wiley 2006). Data used in these projects can be refreshed efficiently by a skilled biologist and data analyst, and efficiency of data refreshes should increase over time with increased use of standardized methods, improved data entry forms, and database updates.

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