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Developing a Standardized Sampling Program: The Michigan Experience

ABSTRACT

In 1995, the Fisheries Division of the Michigan Department of Natural Resources formed a Resource Inventory Planning Committee to develop a statewide sampling program for inland waters. The goal of this sampling program was to provide information needed for the management and conservation of Michigan's aquatic resources. Because sampling provides information to a variety of users for multiple purposes, the sampling plan we designed included several subprograms, some of which are under local control and some of which are centrally administered with a broad statistical design. Centrally administered subprograms included designs to (1) evaluate stocking success using angler surveys, (2) evaluate the characteristics of lake fish communities across the state, and (3) evaluate the characteristics of stream fish communities across the state. Two of the major topics addressed by the committee were standardization of sampling gear and choice of sampling sites (i.e., particular lakes or stream segments). Although sampling gear standardization generated much discussion, the choice of sampling sites proved to be a much more contentious issue, primarily because it shifted much of the control over choice of sampling sites from local fishery managers to a more centralized system. Balancing the needs for information at a local scale with needs for larger scale data collections remains a challenge, and continues to generate conflict within the Fisheries Division. This is best addressed by explicitly recognizing the tension between these needs and basing the allocation of sampling resources on a rational basis developed by discussion among all organizational levels.

Bonar and Hubert (2002) presented a strong argument for standardized sampling of inland fish populations. In their article, they focused on the need for standardized procedures and protocols to make data comparable across regions, and on the opposition they faced during the development of these standards. In 1995, the Michigan Department of Natural Resources (MDNR) Fisheries Division created a committee comprised of fishery managers, state fishery research biologists, cooperators from other resource agencies, and university faculty to address similar concerns related to sampling inland waters across the state of Michigan. Given the perspectives presented by Bonar and Hubert (2002), we felt it timely to relate the experiences we had and identify additional issues we faced. In particular, we want to highlight the fact that standardization of on-site protocol is only one step, albeit an important one, in the development of a program for broadly assessing inland fisheries. The choice of sampling sites (i.e., lakes or stream segments) is also a critical concern, and in our experience, it was the issue that generated more conflict than protocol and gear standardization.

D. Hayes, E. Baker, R. Bednarz, D. Borgeson, Jr., J. Braunscheidel, J. Breck, M. Bremigan, A. Harrington, R. Hay, R. Lockwood, A. Nuhfer, J. Schneider, P. Seelbach, J. Waybrant, and T. Zorn

Hayes is an associate professor at the Department of Fisheries and Wildlife, Michigan State University, East Lansing, and can be reached at hayesdan@msu.edu. Baker is a research biologist with the Michigan Department of Natural Resources (MDNR), Bednarz is an environmental quality specialist with the Michigan Department of Environmental Quality, Borgeson is a fisheries biologist with the MDNR, Braunscheidel is a fisheries biologist with the MDNR, Breck is a research biologist with the MDNR, Bremigan is an assistant professor at Michigan State University, Harrington is a fisheries biologist with the MDNR, Hay is a fisheries biologist with the MDNR, Lockwood was a statistician with the MDNR and is currently retired, Nuhfer is a research biologist with the MDNR, Schneider was a research biologist with the MDNR and is currently retired, Seelbach is head of Fisheries Research with the MDNR, Waybrant is a fisheries biologist with the MDNR, and Zorn is a research biologist with the MDNR.

The major issues that the Resource Inventory Planning (RIP) Committee was called to address included (1) large reductions in personnel available for field sampling, (2) a progressive divergence in application of sampling methods from the standards specified in the Fisheries Division's sampling manual (Schneider 2000), (3) fluxes in the sampling program's focus over time between broad surveys and index sites, and (4) a perception that too much of the time available for field sampling was being spent on stocking evaluations. Further, the Fisheries Division had recently restated its mission "to protect and enhance the public trust in populations and habitats of fishes and other forms of aquatic life, and promote optimum use of these resources for benefit of the people of Michigan" (Anon. 1994). The breadth of this mission highlighted the need for a reevaluation of the inland fishery sampling program.

The scope of the charge to the RIP Committee was very broad, covering the entire state of Michigan, and including all inland lakes (i.e., excluding the Great Lakes) and streams. Further, the committee was charged to evaluate, and where needed develop, sampling programs for the three principal components of fisheries—people (users), populations of aquatic organisms, and habitat (Nielsen 1999). In this article, we will focus on the sampling of aquatic populations, similar to Bonar and Hubert (2002).

The scale of this charge was daunting given the inland fishery resources in Michigan. Across the state there are more than 5,000 lakes greater than 4 ha in size, 58,000 km of streams, and 2 million licensed anglers. Approximately 60 fishery biologists and technicians are responsible for field sampling. The disparity between the scale of the resource and the personnel available for sampling is not unique to Michigan, and is a critical challenge facing resource managers.

Resource Inventory Plan Development

As recommended by Bonar and Hubert (2002), the RIP Committee had representatives from across the Fisheries Division, and spent a considerable amount of time soliciting input from local biologists regarding the plans being developed. A challenge we faced was trying to balance the size of the committee, keeping it small to promote efficiency, yet having a high level of participation among all levels of Fisheries Division staff. While a consensus was not always reached, there was generally a two-way flow of information between the RIP Committee and field staff. Further, the RIP Committee worked closely throughout the entire process with the Fisheries Division's management team, which is the division's top-level decision making body, to ensure their approval of the conceptual basis and principles we used in developing the resource inventory plan.

One of the key starting points for the RIP Committee was to design a sampling program to provide information for multiple purposes; and, as such, it was unlikely that any single design would meet all these needs. Thus, we defined several qualitatively different types of information requirements within the Fisheries Division, and further recognized the inherent differences between sampling standing waters and streams. Our categorization of information needs included (1) data to evaluate a particular lake or stream prior to specific management actions, (2) data to evaluate management actions taken (including stocking), and (3) data on the general status and trends of aquatic resources to support the Fisheries Division's broad stewardship mission. We did not specifically segregate opportunities that field sampling presents for research or adaptive management; these uses of the data often provide benefits above and beyond immediate management needs. Thus, we believed that designs for these situations would be best handled on a case-specific basis.

Even with the categorization given above, the RIP Committee quickly realized that issues of sampling perspective are paramount in how data are collected and potentially used. For example, local fishery managers generally focus on individual lakes or streams in their district, and often respond directly to angler demands. Thus, they logically seek site-specific information on their "problem" waters to develop management recommendations (Krueger and Decker 1999). Sampling to support this goal tends to result in data that are representative of that particular site and time, but may not be representative of a broader set of lakes or even that site at a random point in time. Moreover, these evaluations tend to focus on game fishes. In contrast, some

Electrofishing is the principle method used for sampling fishes in streams.

management actions (e.g., minimum length limits, bag limits) are typically implemented on a regional or statewide basis. As such, the appropriate level of sampling and analysis is regional or statewide. Here too, the emphasis is often on game fishes, but sampling needs to cover a subset of systems representative of the statewide "population" of lakes or streams. Therefore, the evaluation of statewide actions requires a statistical basis for site selection as well as standardized gears and protocols. Having a statistical basis for site selection provides a basis for comparison among sampled lakes and streams, and allows for extrapolation to systems that are not sampled, but are within the sampling frame. For example, changes in statewide minimum length regulations for largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieu*) were intended to improve the size structure of these top predators, thereby improving the fishery as well as increasing their effectiveness in controlling panfish populations. Determining the success of this regulation requires estimation of the change in size structure across lakes representative of statewide conditions. Another example is the estimation of the proportion of streams in Michigan containing slimy sculpin (*Cottus cognatus*). Samples collected with a sound statistical design allow the estimation of this proportion, as well as measures of variance, and provides a basis for determining the status of slimy sculpin statewide.

To accommodate the different dimensions of information needed, the RIP Committee recommended that available sampling capabilities be allocated among several subprograms of the overall resource inventory plan (Table 1). We partitioned available sampling capabilities into three broad areas: evaluation of management actions, statewide status and trends of aquatic resources, and discretionary sampling. Within each of these broad areas, we defined further subdivisions described below. While we all agreed on the need to partition sampling resources across these competing needs, and agreed that the partitioning outlined in Table 1 was reasonable, the actual percentage allocations were subjected to extensive debate, and continue to generate considerable conflict within the Fisheries Division. Much of the conflict occurs due to the tension between sampling directed and organized at a local level and sampling directed by the Fisheries Division's central staff. Bonar and Hubert (2002) observed similar tensions where local biologists felt they knew what gear and sampling method was best for their region to meet their particular needs, and disliked being told what to do by a central office. The final allocations among the major subprograms presented in Table 1 represent our attempt to align the proportion of sampling devoted to each subprogram with the Fisheries Division's mission. Undoubtedly these proportions will vary over time as the division's mission evolves. Within each of these subprograms, we developed a sampling strategy appropriate to the needs identified for each subprogram.

Evaluation of Management Actions

Historically, all lakes and streams receiving stocked fish in Michigan were sampled on a 6-year rotation. Following workforce reductions in the 1990s, stocking evaluations probably were the largest single component of the Fisheries Division's sampling program, leaving progressively less sampling capability to meet other facets of the division's mission. Although we recommended a departure from the 6-year rotation previously used, stocking evaluations continued to be allocated a large percentage of the available sampling effort. This reflects the fact that stocking is a major management tool in the state of Michigan, but is expensive (approximately 30% of Fisheries Division budget) and warrants careful evaluation of the effectiveness of individual stockings and of the program as a whole.

Our recommended general sampling design was to stratify lakes and rivers according to the expense of the stocking, assigning a high priority to evaluations of expensive stockings, and excluding waters where the total cost of the fish stocked is very low (Table 2). Excluding these low-cost stocked waters from site-specific evaluations was considered appropriate because they represent a small fraction of total cost, individually and collectively. This does not imply that these stockings are without value, because they can produce good returns relative to the number of fish stocked. However, the cost of sampling these lakes would greatly surpass the cost of stocking. Within a stratum, water bodies are sampled randomly without replacement until all have been sampled, thereby ensuring that eventually all but very low-cost stocked waters would be sampled. Strata

Table 1. Proposed allocation of available sampling resources to major subprograms within the MDNR Fisheries Division's resource inventory plan. Although sampling for each subprogram is implemented at the local level, the design and oversight for each subprogram may be locally or centrally administered.

Major subprogram (% allocation subprogram)	Components of subprogram	% allocation	Oversight of subprogram
Evaluation of management actions (40%)	Stocking evaluations	25%	Centralized
	Other management actions	10%	Local
	Environmental regulations (e.g., permitting requests)	5%	Local
Statewide status and trends of aquatic resources "general surveys" (45%)	Lakes	20%	Centralized
	Streams	20%	Centralized
	Anglers	5%	Centralized
Discretionary sampling (15%)	Special projects	15%	Local
	Targeted sampling		
	"Crises"		
	Research sampling		

containing water bodies with a high annual cost of stocking receive a greater sampling allocation, reflecting the fact that decisions made regarding stocking rates on these waters are likely to have a relatively greater economic and social impact than elsewhere.

Stocking traditionally has been evaluated through biological surveys to determine the growth and survival of stocked fish in put-grow-and-take fisheries. Because the goal of stocking is typically to increase angler catches, the RIP Committee recommended that on-site angler surveys should be the primary method used to evaluate how these fisheries respond to stocking. An immediate shift from biological surveys to angler surveys was not practical because of fiscal and personnel constraints, however. The Fisheries Division is currently making the transition from biological surveys to angler surveys for stocking evaluations as sampling resources permit. Because hatchery production is administered centrally within the Fisheries Division, we felt that the sampling program to evaluate stocking should also be centralized (Table 1). Moreover, centralized angler surveys allow for oversight by staff experts who specialize in the design and analysis of angler survey data.

In addition to stocking evaluations, determining the success of other fishery management actions (e.g., site-specific regulations, habitat improvement, rough fish removal) is an essential part of the management process (Krueger and Decker 1999). Unlike stocking, the decision-making process for these management actions is largely under the control of local fishery managers. As such, we felt that the most effective sampling design and sampling protocol would vary, depending on the manipulation and the particular circumstances of the fishery. The RIP Committee, other Fisheries Division staff, and university collaborators serve to consult and assist with designs for particular cases, but sampling under this subprogram is ultimately under the direct control of local biologists (Table 1).

Statewide Status and Trends of Aquatic Resources

One of the critical goals of the Fisheries Division is to serve as a steward of aquatic resources in Michigan. As such, the RIP Committee felt that information documenting the overall status (e.g., spatial distribution, frequency of occurrence, relative abundance, size structure) and trends of these resources is an important component of the overall sampling program. These "general surveys" are intended to provide information about game and non-game fishes across the entire state or a specific region, as well as information on habitat conditions. Beyond providing statewide information, the information collected in general surveys provides additional site-specific information. They inform managers of the need for protection of nongame fishes that often go unnoticed in surveys targeted at specific gamefish species. In addition to fulfilling this need, general surveys also provide site-specific information that can be used to assess the need for management actions, and to inform the public on the status of "their" lake or stream.

Because of the need to generalize across unsampled lakes and streams, the sampling program for general surveys needed to have a firm statistical basis. The core of the program for both lakes and streams is a stratified random sampling design, with strata designed to group waters by size, geographic location, and thermal status (Tables 3 and 4). As with stocking evaluations, we elected to implement random sampling without replacement for this program to ensure that data will be collected from all water bodies in the program in a predictable time period. In effect, this implies that the status of each lake or stream in a stratum will be determined at a regular interval. We felt that this was important because the data collected in this subprogram also provide site-specific information that can be used for local decision-making. At present, the stream sampling design also includes a set of fixed sampling sites, and we are evaluating if the lake sampling program would also benefit from a fixed site component. Fixed sites may provide benefits in terms of more rapid trend detection (e.g., Urquhart and Kincaid 1999), but may have drawbacks in terms of lengthening the time between sampling events for other sites.

Another use of information from general surveys is to provide a better quantitative basis for comparisons among sites within a stratum. It is difficult to determine if a lake or stream's status is "good" without data

Table 2. General sampling design for evaluation of Michigan's stocking program. Intensive creel surveys are designed to provide coverage for two weekend days and three week days per week over 30 weeks per year, and medium intensity creel surveys are designed to provide coverage for approximately one weekend day and one weekday day per week for 30 weeks per year. Sampling frequency refers to the number of lakes or streams where a creel survey is conducted.

Stocking cost over 6-years	Type of creel survey	Sampling frequency	Number of water bodies in stratum
Lakes			
High-cost (>$125,000)	Intensive creel	2 lakes/year	10
Medium-cost ($45,000 to $125,000)	Medium intensity creel	3 lakes/year	19
Low-cost ($15,000 to $45,000)	Medium intensity creel	4 lakes/year	65
Very low cost (<$15,000)	None required	Sampled at manager's discretion	384
Streams			
High-cost (>$125,000)	Intensive creel	1 stream/year	6
Medium-cost ($45,000 to $125,000)	Medium intensity creel	2 streams /year	12
Low-cost ($15,000 to $45,000)	Medium intensity creel	4 streams/year	41
Very low cost (<$15,000)	No creel	Sampled at manager's discretion	88

on the range of conditions that exist in similar water bodies. Managers constantly make comparisons like this, but typically use their own experience to guide their evaluation and interpretation of the samples from an individual lake. Although these evaluations are often reasonable, a major drawback is that the mental models that managers use in making these evaluations are not readily transferable and are typically lost as personnel turns over. Also, these models typically differ among managers, creating discrepancies in their interpretations of the same data. Moreover, these mental models are formed on the basis of experiences that may be biased toward evaluating problem lakes or streams. We feel that having data collected with a sound statistical design will provide the basis for developing a model that resides in a collective institutional memory, and that is based on tangible data rather than individual experiences.

Our intent was to assign equal sampling allocations to streams and lakes, taking the view that each of these resource types is of similar importance in Michigan. These sampling allocations will need to be revisited, however, as sampling protocols continue to be refined and the time required per survey is more precisely deter-

Table 3. Number of Michigan lakes in size, depth, and Great Lakes basin statistical strata, and proposed annual sampling intensity.

SIZE AND DEPTH CATEGORY		DRAINAGE BASIN ERIE	HURON	MICHIGAN	SUPERIOR	STATEWIDE TOTAL
Large (Area ≥405 ha)	Deep (≥10.6 m)	4	8	24	11	**47**
	Shallow (<10.6 m)	2	12	18	2	**34**
	Unknown depth	0	4	16	6	**26**
	Subtotal	6	24	58	19	**107**
	Approx number sampled/year	1	2	3	1	**7**
Medium (405>Area ≥40 ha)	Deep (≤6.6 m	51	87	273	55	**466**
	Shallow (≥6.6 m)	17	32	93	41	**183**
	Unknown depth	32	68	216	90	**406**
	Subtotal	100	187	582	186	**1,055**
	Approx. number sampled/year	5	10	15	10	**40**
Small (40>Area ≥4 ha)	Deep (≥4.6 m)	107	197	540	204	**1,048**
	Shallow (≤4.6 m)	14	57	128	89	**288**
	Unknown depth	337	783	2,094	806	**4,020**
	Subtotal	458	1,037	2,762	1,099	**5,356**
	Approx. number sampled/year	5	10	15	10	**40**
Total		**564**	**1,248**	**3,402**	**1,304**	**6,518**
Approx. total no. sampled/year		**11**	**22**	**33**	**21**	**87**

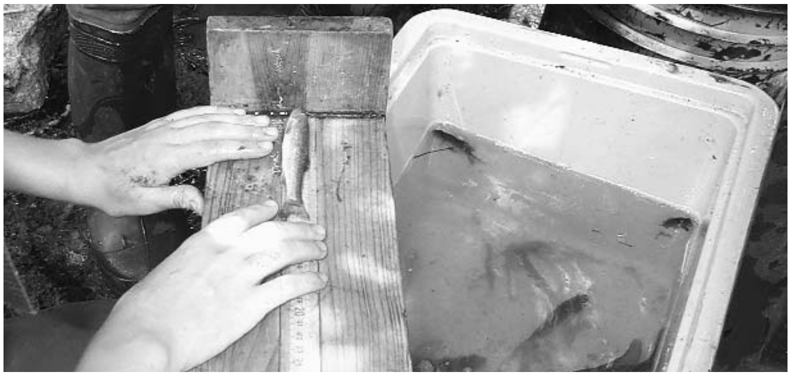
Table 4. General sampling design for Michigan streams. Random sites (within valley segments) are stratified by stream size (as measured by drainage area). Table entries indicate the number of valley segments within a stratum with the approximate number of sites to be sampled annually in parentheses. Fixed sites are sampled on a three-year on/off rotation and are stratified by geographical location within Great Lake basin and fish community type (LL=landlocked, GL=Great Lake access). Table entries indicate the number of fixed sites in the entire rotation, with approximately half of these sites sampled each year.

RANDOM SITES

Stream type	DRAINAGE BASIN ERIE	HURON	MICHIGAN	SUPERIOR	STATEWIDE TOTAL
SMALL <60 km^2	248 (1–2)	599 (4–5)	766 (8–9)	240 (3)	**1,865 (17–18)**
MEDIUM 60-600 km^2	41 (2)	126 (6–7)	189 (10)	63 (3–4)	**421 (22)**
LARGE 600-1600 km^2	12 (1)	45 (2)	68 (4–5)	18 (1–2)	**145 (9)**
VERY LARGE >1600 km^2	12 (0–1)	20 (2)	51 (2–3)	6 (1)	**89 (6)**
Total	**313 (5)**	**790 (15)**	**1,074 (25–26)**	**327 (9)**	**2,504 (54–55)**

FIXED SITES

FISH, stream type	DRAINAGE BASIN ERIE	HURON		MICHIGAN			SUPERIOR	STATEWIDE TOTAL
		NORTHERN	SOUTHERN	NORTHERN	CENTRAL	SOUTHERN		
WILD TROUT, small, LL	0	4	2	4	4	4	3	**21**
WILD TROUT, small, GL	0	2	2	2	4	4	4	**18**
STOCK-WILD TROUT MIX, small	1	0	2	2	1	2	3	**11**
WILD TROUT, med., LL	0	6	0	2	4	0	0	**12**
WILD TROUT, med., GL	0	0	0	0	4	0	2	**6**
SMALLMOUTH BASS, med.	3	0	3	2	0	4	0	**12**
Total	**4**	**12**	**9**	**12**	**17**	**14**	**12**	**80**



General surveys provide information on the size structure of game and non-game fishes.

mined. We allocated less effort to sampling anglers not because we perceived them to be of lower importance, but because we believed they could be sampled via a mail survey which would take much less personnel time than field sampling.

Similar to Bonar and Hubert (2002), we felt that an important component of developing a resource inventory plan was to standardize sampling procedures and gears where possible. In contrast to their experience, we judged it was best to address this concern toward the end of the overall resource inventory design process. When couched within the overall inventory plan, our experience regarding gear and protocol standardization differed from theirs. For general surveys, all of the field biologists we worked with supported the need for standardized methods, and lamented the observation that the protocols already specified in the division's sampling manual were not consistently followed. While there was disagreement on some of the particular details, everyone recognized the value of having comparable data collections when the intent is to use the information on a regional or statewide basis. For fish surveys conducted for special purposes, we recognize that some situations call for use of standard methods, whereas other situations (e.g., continuation of long-term data sets) may be best accommodated by deviating from the standards developed.

A brief summary of the standardized sampling gear and minimum levels of fish sampling effort for lakes is provided in Table 5. Two of the critical components of our sampling protocol include (1) using multiple gears to enhance our ability to sample all game and nongame fishes, and (2) requiring a greater amount of effort in larger lakes. The initial implementation of this sampling in 2002 suggested that the number of days to complete the fishery component of inland lake surveys may be underestimated, and some adjustments to sampling intensity may be required in order to complete surveys in a timely fashion.

Stream fish sampling protocols were somewhat less complex because of the general reliance on electrofishing in streams. At randomly selected sites, a single pass barge electrofishing catch per unit effort (CPUE) is used to index relative abundance in most streams. In streams less than 4.5 m wide a backpack electrofisher may be used, and a boat electrofisher may be used in large unwadeable streams. In streams less

Table 5. Summary of proposed fish sampling gears and minimum sampling intensity for inland lake surveys. Large-mesh fyke and trap nets have 3.8 cm mesh in pot, 5 cm mesh in heart, and have 1.8 x 33.5 m leads. Gill nets have five 7.6-m panels in the following stretched mesh sizes: 3.8, 5, 6.4, 7.6, and 10 cm. Seines are 1.5 x 7.6 m with 0.5 cm mesh. Small mesh fyke nets have 1.3 cm mesh and a 0.6 x 7.6 m lead.

	LAKE AREA (HA)					
	4–20	**20–40**	**40–202**	**202–404**	**404–2023**	**>2023**
Large-mesh fyke or trap net	3 nets 1 night	2 nets 2 nights	3 nets 2 nights	3 nets 3 nights	4 nets 3 nights	8 nets 4 nights
Gill net	2 nets 1 night	2 nets 2 nights	2 nets 2 nights	2 nets 3 nights	3 nets 3 nights	6 nets 4 nights
Seine	2 sites	3 sites	4 sites	5 sites	6 sites	10 sites
Boat boom shocking (preferred)	not required	3 10-min transects	3 10-min transects	3 10-min transects	3 10-min transects	3 10-min transects
OR						
Small-mesh fyke (if boom shocking is not possible)	2 nets 1 night	2 nets 2 nights	2 nets 2 nights	2 nets 2 nights	boom shocking	boom shocking
Anticipated days to complete survey (excluding boom shocking)	2 days	3 days	3–4 days	4–5 days	4–5 days	5 days (2 crews)

The Fisheries Division is responsible for stewardship of game and non-game fishes. Sound sampling designs provide the information needed to support this aspect of the Division's mission.

than 4.5 m wide, sampling sites are 152 m in length. In small streams (as defined in Table 4) greater than 4.5 m wide, sampling sites are 244 m long. In medium and large streams, sampling sites are 366 and 457 m in length, respectively. In very large streams, sampling sites comprise 1,609 m along one shoreline.

At fixed sites in coldwater systems, mark-recapture sampling with a barge electrofisher is conducted to provide population estimates of trout species as well as measures of CPUE of other fishes. In cool and warmwater streams, single pass CPUE is used to index the relative abundance of all fishes. Sampling sites at fixed locations are generally 305 m long, except where prior data are available for a site with a different length.

Discretionary Sampling

Our final major subcategory is for discretionary sampling. Although this is a catch-all grouping with an assortment of informational needs, the RIP