Standard Sampling of Inland Fish: Benefits, Challenges, and a Call for Action

ABSTRACT

There are many examples of how standardization of procedures in production and data collection have led to remarkable advances in industry and science, but standardization is lacking regarding protocols for sampling fish populations in inland, freshwater systems. Reasons given why biologists often resist standardized sampling protocols include perceptions that differences in regions invalidate standard techniques; use of standard sampling is costly and reduces innovation by regional biologists; the variation already present in nature masks any gains introduced by standardization; and historical trend data is lost. We examine these reasons and provide procedures that may serve as a template by describing how development and implementation of standardized sampling protocols were achieved by the Washington Department of Fish and Wildlife. These procedures included obtaining support from high-level management within the agency and input from a wide variety of sources; emphasizing benefits to management biologists; designing procedures to be simple and cost-effective; minimizing variation in catchability and maximizing catch; providing techniques for determining sample sizes; and field testing, reviewing methods, and training crews before implementation. Standardization can provide clear benefits and we discuss the option of developing nation-wide or continent-wide standards with leadership by the American Fisheries Society.

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Standardization of procedures in production and data collection has been responsible for remarkable advances in world history. For example, Henry Ford's motor company became an industrial giant through the development of standard assembly line procedures; Eli Whitney revolutionized military science by the development of standard interchangeable rifle parts; the United States aided commerce by development of standard time zones; and the New York Stock Exchange contributed substantially to ease in financial trading with a standard reporting format. Many of us remember the early days of personal computers when little of the hardware or software was standardized, making it difficult to transfer data or programs. Now, few of us have to spend time dealing with the effects of incompatibility.

Standardization has contributed to advancements of science. Standard methods used to measure barometric pressure, humidity, and wind speed have contributed to our understanding of meteorology. Geological maps are standardized across the United States so geologists have little difficulty deciphering geologic features among various regions of the country. Hundreds of standardized data collection and reporting procedures are used in the medical profession including techniques for measuring blood pressure, cholesterol, white blood cell counts, and body temperature. A wide array of data collection and reporting techniques have been developed for use by inland fisheries biologists (Schreck and Moyle 1990; Murphy and Willis 1996), but many have been reluctant to adopt standardization of methods they commonly use.

While most doctors would question a medical practitioner who was examining and reporting cholesterol in a non-standard format, it is surprising how often standardization of sampling, data collection, and reporting are rejected or contested by fisheries professionals. One would assume that national or regional standard techniques for data collection and sampling would have been established early in the history of the fisheries profession, but this is not the case for most data.

Standardization in fisheries science includes routine sampling of fish populations in inland, freshwater systems to facilitate comparison among waterbodies and to develop trends in individual waterbodies over time. This type of sampling is used most often for monitoring programs in management agencies, although specific research studies can often benefit as well. Such sampling includes making sure sampling gears such as nets, electroshocking units, or trawls are similar and that they are all fished in the same manner (Willis and Murphy 1996). It also includes standardization of reporting procedures.

In the last 30 years, many advances have been made in standardizing data collection and reporting procedures for fish populations. In the 1980s, the Management Section of the American Fisheries Society surveyed how conservation agencies in the United States and Canada sampled sportfish and encouraged standardization (Gablehouse et al. 1992). Indices such as relative weight (Wege and Anderson 1978; Murphy et al.

1991; Blackwell et al. 2000), relative and proportional stock density (Anderson 1980; Willis et al. 1993), relative growth (Hubert 1999) and relative length frequency (Bonar in press) have improved our ability to compare fish population data spatially and temporally. However, it is clear that improvements are still needed. Our purposes are to (1) examine why standard procedures are not more common in the assessment of inland fish populations, (2) describe procedures for developing and implementing standardized sampling protocols that may circumvent resistance to standardization, and (3) discuss the option of developing nationwide standardized sampling programs for inland fish populations.

Why standard sampling is not more common

During our careers, we have seen many fisheries professionals reject standardization of sampling procedures and data collection. This is common, for when we have discussed standardization with other fisheries colleagues, they too have observed opposition to introduction of standardized procedures. Opposition can be explained by suggesting that fisheries biologists are "independent sorts" not given to following regular procedures. Specific reasons for not using standardized procedures may include:

- Sampling standardization reduces our ability to be creative and use our professional skills.
- My region, area, river, or lake is "different" so I cannot use standardized procedures.
- There is so much variation introduced by nature that standardization will not make any difference.
- I know what is best for my area—I do not like to be told what procedures to use by a manager in headquarters.
- There is not enough money available to standardize sampling equipment.
- I have been using a standard protocol to sample a specific water body for years. I do not want to change to conform to state or national standardization and risk developing a data set that cannot be compared with historical data.

Standard sampling reduces creativity. Fisheries biologists often cite lack of time as a serious concern. However, large amounts of time are spent designing individual sampling programs for routine monitoring purposes. Biologists can become so caught up in the development of methods that they do not have time to address underlying biological problems. Hamilton and Bergersen (1984) stated that the possibility of failure increases as a biologist's thinking focuses on methods rather than problems. Imagine a doctor developing a new pro-

Bruce Bolding and Roger Mosley of the Washington Department of Fish and Wildlife process fish during a survey of a western Washington lake.

cedure to test cholesterol each time he or she examined a different person. Now think about the number of people that could be examined in a day if the doctor had to spend time developing these procedures. Although this sounds ludicrous, this is precisely what fisheries professionals often do when assessing fish populations. Determining how a particular water body will be sampled and what sampling gear to use often takes a substantial amount of a biologist's time.

Use of standard sampling protocols can reduce the amount of time needed to develop sampling procedures for a specific water body, and enhance the time for creative solutions to biological problems and defining management alternatives. This was demonstrated when standardized sampling programs using seines were developed for ponds in Alabama during the 1940s and 1950s (Swingle 1950; Swingle 1956). Seining and reporting the composition of the fish samples in the same manner in each pond enabled pond managers to compare fish populations to a standard, with subsequent guidelines for management. Since the fish samples were collected the same way in every pond, variability was caused primarily by differences among fish populations. The general principles of warmwater pond management developed by Swingle using these standardized techniques were responsible for significant advances in fisheries science.

My region, area, river, lake is "different." Water bodies in various geographic regions can be quite different. It seems counterintuitive that a reservoir in an Arizona desert could be sampled in the same fashion as one in a temperate rain forest in Washington. Because various water bodies are different is one of the best reasons for standardization. If both sampling methods and the environmental and biotic characteristics of regions are different, it will be even more difficult to determine which differences are due to sampling techniques and which differences are due to the actual abundance of fish and the structure of fish populations. For example, standard indexes such as relative weight (Wege and Anderson 1978; Murphy et al. 1991) and relative condition (Le Cren 1951) have been applied widely across the country to great benefit. These indices allow biologists to determine factors affecting fish production within and among different regions of the country. Standardization facilitates communication among biologists, enabling them to identify factors limiting fish populations and possible management actions without needing to decipher variation due to different sampling techniques.

There are so many variables introduced by nature that standardization will not make any difference. Changes in season, weather conditions, turbidity, sunlight, and other environmental conditions can affect the numbers and sizes of fish captured (Hubert 1996; Pope and Willis 1996). Nevertheless, standardization can reduce variation substantially, even in systems that experience significant environmental variation. For example, on the upper Mississippi River, a huge geographic area, biologists were able to remove 14% of the variation in electrofishing catch per unit effort by simply standardizing power of electrofishing units (Burkhardt and Gutreuter 1995). In western Washington lakes, large largemouth bass move into littoral zones in the spring, while yearlings move into these zones in the summer (Bonar, unpublished data). Standardizing sampling by season removes much of the variability introduced by different size groups occupying the littoral zone at different times of year.

I know what is best for my area—I do not like be told what procedures to use. Often those responsible for developing standardized procedures are in headquarters offices, but field biologists are instructed to apply the procedures. Rivalry between headquarters staff and field biologists is common and affects how standardized procedures are implemented. However, headquarters and field biologists can cooperate to strengthen standardized sampling programs. Field biologists often have years of experience and are skilled in the use of assessment methods for fish populations in lakes and rivers in their area. However, headquarters biologists often have a geographic or agency-wide perspective and can access statistical expertise. For example, a standard sampling program that incorporated expertise from both headquarters and field biologists has been used for over 20 years in Washington to assess populations of trout by sampling opening-day catches (Brown 1978). This method was developed by a group of field biologists with review and fine-tuning with input from headquarters and other field biologists.

There is not enough money to standardize. Most standardized sampling equipment consists of items that are commonly used for fish surveys. Costs to standardize usually involve purchasing nets and electrofishing gear of specific designs. Support from managers and research biologists for a standardization of sampling programs can provide political impetus to obtain new equipment, much more so than individual biologists could attain. Arguments can be made that the cost of standardized equipment will be offset by the time saved in developing unique protocols or trying to analyze non-standard data.

I have been sampling a water body using a specific technique for many years. Why change? There are definite benefits obtained by using consistent data collection methods when monitoring trends. Different sampling methods are associated with different amounts and types of bias. Changing gears and their associated sampling bias during a study to conform to a standardized national or regional sampling protocol risks developing data sets that are incompatible with those collected previously. Decisions can be made to exclude these waterbodies from a standard national or regional protocol on an individual basis. Alternatively, a small amount of additional sampling or analysis may be all that is required to define the relative biases of different gears or protocols and to enable assessment of trends with long-term data sets. In other situations, both data collection methods can be used for a period of time, the relationship among data collected using historical methods and new standardized methods can be tested.

Important considerations when developing standardized procedures

We use an example from the Washington Department of Fish and Wildlife to illustrate factors that can be considered when developing a standardized inland, freshwater fish sampling program. The Standard Sampling Guidelines for Ponds and Lakes (SGPL) in Washington was developed in response to increased warmwater sportfish sampling responsibilities for the department (Bonar et al. 2000). The full text of this procedure is available from Fish Management Program, Washington Department of Fish and Wildlife, Olympia or can be accessed at the department's web site www.wa.gov/wdfw.

Warmwater fish populations had been sampled intensively throughout the state for several decades by regional biologists. In the late 1990s, four stock assessment teams were also charged with assessing the status of warmwater sportfish populations in lakes and ponds across the state so that management biologists could incorporate these data into management plans. Several steps were followed to standardize the sampling program and ensure that the procedures were sound.

Support for the program was obtained from high-level management within the agency. The decision to develop the SGPL was made by headquarters staff and supported by field biologists. The task to lead development of this protocol was given to the Inland Fisheries Research Unit. The commitment of managers at high levels within the agency to develop and use standardized sampling was crucial for implementation of the protocol by agency biologists.

Input was obtained from a wide variety of sources. The SGPL was developed using information obtained from (1) previous sampling guidelines for Washington (Zook 1978; Fletcher et al. 1993), (2) two short courses on warmwater fisheries and standardized sampling provided by outside experts (William Davies and David Willis), (3) intensive literature searches, (4) studies comparing warmwater sampling techniques conducted in Washington (Fletcher et al. 1993; Divens et al. 1998), (5) personal communication among warmwater field biologists in Washington, and (6) communications with warmwater fisheries experts outside of Washington. Compilation of information from a wide variety of sources allowed the benefits and drawbacks of various sampling techniques to be defined.

Methods were simple. Standard techniques that are unclear or complex are likely to be discarded or followed haphazardly. Therefore, considerable effort was taken to design SGPL procedures so that they were easy to comprehend and that underlying assumptions and justifica-

Bruce Bolding and Marc Divens of the Washington Department of Fish and Wildlife measure fish during a survey of Chambers Lake.

tions were clear. The SGPL procedure was published in a manual with justifications and details provided in footnotes. Appendices included additional information on procedures that needed extensive explanation, such as estimating sample sizes for various degrees of precision or standardizing power of electrofishing gear. The SGPL was designed so biologists could begin to use it in the shortest time possible.

Benefits to management biologists were emphasized. Management biologists could have been required to use standard methods without explanation; however, unless this charge was combined with information on the management benefits of the techniques, resentment was expected to develop and enhance the possibility that techniques would not be followed. Management benefits of the SGPL were emphasized continually in staff meetings, in conversations with management biologists, and in field operations. Benefits emphasized included better prediction of fishing opportunities for anglers, identification of factors limiting fish populations, and comparison of fish stocks in lakes across the state.

Procedures were field-tested. Standardized procedures that are not field-tested and later prove to be impractical can jeopardize the credibility of an entire program. Procedures in the SGPL were field tested for one year following development. At the end of the year, biologists who developed SGPL accompanied population assessment teams on sampling trips and sought suggestions to fine-tune the sampling procedures.

Procedures were designed to be cost effective. Management agencies operate under limited budgets, so field techniques cannot be costly, either in terms of equipment or time. Standard equipment for the SGPL surveys consisted of an electrofishing boat, gill nets, and trap nets. Although the initial cost of electrofishing boats was relatively high, the savings in staff time on technique development and data analysis rapidly paid for the cost of the boats.

Methods were designed to minimize variation in catchability and maximize catch. Catch-per-unit-effort indexes are commonly used in standardized sampling programs. Catch per unit effort can be represented by

$$C/f = qN$$

where C is the number of fish caught, f is the unit of effort expended, q is catchability or probability of capturing an individual fish with one unit of effort, and N is the number of fish in the population (Gulland 1969). Catchability (q) generally changes with season, time of day, weather patterns, environmental conditions, and design of gear. Reducing variability in q is desired to obtain precise measures of C/f. Therefore, field procedures and gear types were standardized. Net sizes, mesh sizes, materials for net construction, electrofishing electrodes, and electrofishing power were standardized, as were the season, and times of day when sampling was to be conducted, and the habitat types (i.e., stratification) where sampling was to occur.

Sampling gears and procedures that maximize catch (C) provide large sample sizes for indices of population structure and dynamics, such as proportional stock density, relative weight, and relative growth. Divens et al. (1998) identified sampling equipment that maximized C of common warmwater sport fishes in Washington, as did information from the literature (e.g., Bagenal 1978; Sigler and Sigler 1990; Murphy and Willis 1996). This information was also used to develop standards for gears as well as when, where, and how to sample.

Procedures for determining needed sample sizes were provided. Detecting changes in fish populations over time is a goal of standardized sampling programs. The ability to detect changes is governed by sample variability and sample size. Guidelines for sample sizes needed to detect specific magnitudes of change in population size were given in the SGLP. Equations were provided to calculate needed sample sizes when previous samples were available to compute the anticipated variance in C/f. When no previous data were available, appendix tables incorporating the average variance in C/f among Washington lakes following the standard sampling protocols enables estimates of needed sample sizes to be made.

Methods were reviewed before implementation. Inaccurate or imprecise data limit conclusions that can be made, compromise evaluation of temporal trends, and reduce overall utility. The SGLP was reviewed by two agency statisticians before implementation to assess the data quality. Stock assessment teams, regional biologists, and warmwater fisheries sampling experts from across the United States reviewed the SGPL. These reviews helped identify procedures that were impractical or needed modification. Most warmwater fishery managers in Washington readily accepted the final procedures because field biologists provided substantial input during development.

Crew training. Once the procedures are developed, stock assessment teams were trained in the techniques and a manual detailing the procedures was provided to each team. Additionally, the authors of the protocol accompanied field crews during surveys to observe and correct any deviations from the protocols.

A call for action

Evidence points to the benefits of standardized sampling on a national or regional scale. Even more ambitious than national or regional standardization is standardization on a continental scale. Nationwide standardized procedures for water quality measurements in the United States have been available for some time (Eaton et al. 1995), and standardized procedures for inland fish sampling have been designed for large regions (e.g., Peterson et al. 2002; D. V. Peck et al. National Exposure Research Laboratory, Research Triangle Park, NC, unpublished draft). Standardizing fish sampling protocols across North America could provide all of the benefits we have mentioned, as well as the ability to compare fish populations across large regions, evaluate the results of management practices in various states, improve communications by fisheries professionals, standardize computerized data storage and analysis, and save money by purchasing gear types produced en masse. Because state and provincial protocols can differ, large reservoirs and river systems that border several states would be especially suited to a national or continental protocol.

Different options are available to standardize fish population sampling techniques. Many sampling programs have already been developed and some might be adopted with few changes for application across North America. The benefits to development of a protocol by an international organization, such as the American Fisheries Society, would be the ability to bring together experts from federal, state, provincial, and local organizations that have a wide variety of expertise in various sampling topics. We suggest that the American Fisheries Society with support from affected Sections, i.e., Fisheries Administrators, Fisheries Management, Early Life History, Introduced Fish, and Native Peoples Fisheries, accept this challenge.

Implementing standardized protocols would require overcoming a great deal of inertia. It would also require initiative by mid-level managers and area biologists to use the extra time freed by standardized sampling to concentrate on in-depth, critical analysis of data and not simply stopping at data collection and recording. Perhaps rewards through funding, equipment, or professional society benefits could encourage organizations throughout North America to adopt standard sampling protocols. So could access to data for comparative purposes on Internet databases. Possibly, the American Fisheries Society, along with federal, state, and provincial natural resource agencies, could coordinate to encourage participation in a program that could be daunting but provide significant benefits to fisheries across North America.

University of Arizona students David Ward, Paul Matson, and Chuck Schade collect fish during a standard survey of an Arizona river.

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