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Standard Methods for Sampling Freshwater Fishes: Opportunities for International Collaboration.

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Abstract.-- With publication of *Standard Methods for Sampling North American Freshwater Fishes* in 2009, the American Fisheries Society (AFS) recommended standard procedures for North America. To explore interest in standardizing at larger scales to improve communication and collaboration with other continents, a symposium attended by international specialists in freshwater fish sampling was convened at the 145th Annual AFS Meeting in Portland, Oregon, August, 2015. Participants represented all continents except Australia and Antarctica, and were employed by state and federal agencies, universities, non-governmental organizations, and consulting businesses. Currently, standardization is most practiced in North America and Europe. Participants related how standardization has been important for management of long-term data sets, furthering fundamental scientific understanding, and for testing efficacy of large spatial scale management strategies. Academics indicated standardization has been useful in fisheries education because time previously used to teach sampling method development is now devoted to diagnosis and treatment of problem fish communities. Researchers reported standardization allowed increased sample size for method validation and calibration. Group consensus was to retain continental standards, but further explore international standardization, specifically identifying where synergies and bridges exist; and identify means to collaborate with scientists where standardization is limited, but interest and need occur.

Efficient communication of data and findings across large areas is becoming increasingly important. Issues such as climate change (IPCC 2014), widespread distribution of invasive species (Fuller et al. 1999), and cross-boundary fish management strategies (Hubert and Quist 2010) are becoming too large to only be considered on a local level for effective understanding and management. Furthermore, generally reduced budgets for programs and the need to increase sample sizes to meet statistical needs to test management strategies have made collaboration among different fisheries programs important. The ability to compare data over time and throughout areas, via standard sampling, standard indices and standard comparison methods, has revolutionized many areas of fish and fisheries science, such as baseline knowledge of fish populations and ecology (Swingle 1950; Argillier et al. 2012; Emmrich et al. 2012; Jeppesen et al. 2012; Brucet et al. 2013; Emmrich et al. 2014; Arranz et al. 2015), conservation and management of inland fish (Åslund and Degerman 2007; Winfield et al. 2008; Holmgren and Fölster 2010; Winfield et al. 2012; Winfield et al. 2013), and fisheries education (B. Graeb, South Dakota State University and I. Winfield, Lake Ecosystems Group, Centre for Ecology and Hydrology, paper presented at AFS symposium, 2015). Conversely, the inability to compare non-standardized data at large scales and over time has resulted in difficulty in fisheries planning, monitoring population and community trends, and having enough samples to make useful conclusions (Vostradovsky and Tichy, 1999; G. Whelan, Michigan Department of Natural Resources, paper presented at AFS symposium, 2015).

Because of the improved benefits to fisheries biologists, the scale at which standardization has occurred is steadily increasing as is evident from the chronology of the exemplar studies cited above. Historically, in the U.S., Canada and Europe standardization only occurred at state or local levels. However, today continent-wide standards for fish sampling

have been developed and are being increasingly adopted (e.g., CEN 2003, 2006, 2014, 2015; Bonar et al. 2009; European Commission 2015). In other regions of the world, sampling standardization is carried out at vary small scales, and is incipient (Mercado-Silva and Bonar 2013).

Recently, the standardization committee of the Fisheries Management Section (FMS) of the American Fisheries Society (AFS) was tasked with investigating the feasibility of comparing standard data (i.e. data collected in one way so comparisons can be easily made) at an intercontinental scale. The overall goal of the Section was to convene a symposium to: (1) identify the extent of standard inland fisheries sampling programs in different regions of the world; (2) present examples of how standard sampling programs, if present, are currently being used; (3) organize a facilitated discussion among participants to investigate if and how AFS could engage in the development of international inland fish standard sampling programs, and if so, devise how participants in various programs might collaborate in the future. This information would be aggregated into a report of recommendations to the AFS. Here we report the findings from the symposium, and discuss future directions in standard sampling efforts identified by attendees of the discussion section.

<A>Methods

A two-day symposium was planned by the AFS Fisheries Management and AFS International Fisheries Sections within the 145th Annual Meeting of the AFS in Portland, Oregon, in August 2015. An international planning committee consisting of leaders of North American and European standard sampling programs was tasked with selecting speakers. Speakers from each continent, or in some instances subcontinents, who were familiar to the committee as inland

fish sampling experts, were invited. Speakers represented the following regions: North America, Mesoamerica, South America, Europe, South East Asia, and Africa. Representatives from Australia, Russia and Central Asia were invited but could not attend.

During the first day and the first half of the second day of the symposium presenters discussed a variety of subjects related to standardization. An initial set of speakers described the extent of fisheries standard sampling programs in different regions of the globe. Their talks included discussions of process with which standards, if they existed, were developed and reviewed, and a description of the main users of inland fisheries data in their regions.

A second set of speakers who were familiar with established standard sampling programs discussed advances in standard sampling, and how advances in gear and data collection strategies were being employed in these programs. Benefits of standard sampling in management, research and education were identified; and disadvantages of not standardizing were also presented.

During the second half of the second day, a facilitated discussion was conducted in a structured decision-making (SDM) format (Hammond et al. 1999) to identify future directions of AFS in collaborating with other continents on standard sampling methods. SDM has been increasingly adopted as a powerful method to facilitate acquisition of information originated in environmental management discussions, which often face multidimensional choices guided by uncertain science, diverse stakeholders and difficult trade-offs (Hammond et al. 1999; Gregory et al. 2012). To guide the discussion, a PowerPoint (Microsoft, Inc.) presentation was prepared that incorporated real-time voting (Turning Technologies, Youngstown, Ohio) to prepare a contingency table ranking objectives and alternatives (Hammond et al. 1999). Participants in the SDM session had electronic vote recorders assigned to them, and each responded to a series of questions to 1) identify characteristics about the sampling frame of the participants, 2) identify

their preferences related to standard sampling and 3) deliberate ideas concerning future directions of standard sampling. Prior to initiating the discussion section, the SDM process was explained to the audience, vote recorders were tested and voting procedures were rehearsed.

The first questions asked of the SDM participants included demographic information. They were asked if a) they were AFS members, b) on which continent the majority of their sampling occurred, c) what type of job they held (management, research, administration, etc.); and d) the type of organization (non-governmental, governmental, education, etc.) for which they worked.

Next the participants were tasked with developing a consequences table for answering the following overall question: "Should AFS work with biologists on other continents to standardize inland fish sampling, and if so, how?" To achieve this goal, participants were first asked to identify elements of a successful standard sampling program (e.g., low cost, high precision and accuracy, ability to validate, etc.). Elements were discussed and those deemed similar by all participants were combined until a list of 10 was obtained. These 10 elements were then ranked by the participants (top three elements selected by each participant) to weight them by importance. Elements and their corresponding weights were entered into the left column of a consequences table (Table 1). Next, participants were queried as to alternative actions that would best address the elements of a successful standard sampling program. Actions were also discussed, and fine-tuned if necessary. Actions were placed across the top row of the table (see Table 1).

To complete the table, each action was ranked by electronic anonymous voting by the participants as to how well it would satisfy each element of a successful standard sampling program. Ranks were identified and entered into the consequences table, with the highest-ranked

159 action for a particular element having the highest number. The rank of each action was then
160 multiplied by the weight of each corresponding element to provide a weighted rank. Weighted
161 ranks for each action were then summed to identify the participants' preferred action.
162
163 <A>Results and Discussion
164 Twenty-two talks were presented at the symposium and the number of attendees varied
165 between 20-60 participants per talk (Mean [SD] = 36[9]). Twenty-seven participants were
166 involved in the final discussion. The degree of standardization by continent varied considerably.
167 North American methods were standardized through the American Fisheries Society. These
168 methods were developed by waterbody type (large standing water, small standing water, large
169 river, wadeable stream, two-story system) for both cold and warm water fish species (Bonar et al.
170 2009). Methods were developed and reviewed through input from 284 biologists from 107
171 different agencies and organizations from across North America. European methods were
172 standardized by CEN/TC230/WG2(“015) of the European Committee for Standardization
173 (CEN/TC230/WG2 2015). With the exception of one standard on method selection (CEN
174 2006), methods from Europe have been developed by individual gear type for electrofishing
175 (CEN 2003), mobile hydroacoustics (CEN 2014) and gill netting (CEN 2015) with the latter
176 being a formal revision of a standard first published in 2005. In Southeast Asia, standardization
177 occurs in large areas systems such as the Mekong River and is implemented via commercial
178 fishery catch data. Standardization of inland fish sampling is currently either non-existent or
179 localized and incipient in South America, Africa, and much of Mesoamerica. We cannot report
180 reliably to the extent of current inland fish standardization across central and northern Asia, east
181 Asia and Australia. Such presentations showed that gears strongly vary across regions and

182 continents and highlighted observed barriers and limitations for developing standardized
183 sampling procedures.

184 Biologists who had undertaken standardized inland fish sampling for years identified real
185 benefits to standardizing on large scales. For example, thousands of acidified rivers and lakes
186 are managed by regular spread of limestone in Swedish watersheds (Svenson et al. 1995), and
187 standard electrofishing and sampling with multi-mesh gillnets was used over a multi-decade
188 period to identify improvements to the fish populations at a national scale in streams and lakes,
189 respectively (e.g. Åslund and Degerman 2007, Holmgren and Fölster 2010). Similarly, continent-
190 wide effects of climate change on lake fish populations and the complicating effects of
191 widespread eutrophication have only been detectable because of the common approach to
192 monitoring now adopted by European countries (Jeppesen et al. 2012). The application of
193 standardized sampling methods led to the intercalibration of ecological quality and integrity of
194 fish communities across Europe (Ritterbush et al, 2015). In Argentina, standardization has been
195 useful in providing a broad picture of fish resources at large spatial scales when samplings were
196 time-restricted (L.G.M. Silva, C. Baigun, Instituto Tecnológico de Chascomus, Argentina, and P.
197 Pompeu, Universidade Federal de Lavras, Brazil, paper presented at AFS symposium, 2015).
198 Education of fisheries students at universities improved with increased method standardization
199 because more time could be spent in fisheries classes diagnosing problems in fish populations
200 versus time spent on method development (e.g., Graeb and Winfield, unpublished). Conversely,
201 lack of standardization hindered data comparisons within large scale initiatives such as the Fish
202 Habitat Partnership in the United States (Whelan, unpublished).

203 Scientists at the symposium identified further work with standardization that might be of
204 highest priority. Speakers noted that a process to incorporate advancements in electrofishing,

various forms of netting, hydroacoustics and other established techniques, and those not yet widely used (e.g., environmental DNA, videography) should be included in future updates of documents describing or regulating standard sampling methods (numerous authors at symposium). Further validation and calibration of methods was also identified as an area needing further work (J.T. Peterson, USGS Oregon Cooperative Fish and Wildlife Research Unit, C.P. Paukert, and A. Rosenberger, USGS Missouri Cooperative Fish and Wildlife Research Unit, and S.K. Brewer, USGS Oklahoma Cooperative Fish and Wildlife Research Unit, paper presented at AFS symposium, 2015). Increasing standardization means that fewer techniques need to be ground-truthed to actual population parameters and calibrated to other standard sampling methods. This results in a higher sample size for calibrating and validating, with associated higher precision and accuracy. Further, focusing on the power standardization can give ground-truthing measures to actual population parameters was identified as an important benefit. Standard procedures in data collection are similarly important when comparing data and such procedures, when combined with standard gear deployment, provide the most and best quality information (A. Loftus, Loftus Consulting; D. Austen, American Fisheries Society, and S.A. Bonar, USGS Arizona Cooperative Fish and Wildlife Research Unit, paper presented at AFS symposium, 2015).

The SDM session helped identify areas AFS should prioritize to further sampling method standardization internationally. The majority of the participants in the SDM session were AFS members, and conducted freshwater fisheries work primarily in North America, although some conducted their work primarily in South America, Europe, and Africa (Figure 1). The greatest percentage of participants were from universities, although state and federal agencies,

consultants, and non-governmental organizations were all represented. Participants ranged from University researchers to students, research biologists, administrators and others (Figure 1).

A list of 10 elements valuable for ranking standard sampling programs, and how well expanding programs beyond continental borders would benefit the profession, was successfully developed by the participants. Highest ranked elements of a standard sampling program that would best benefit the profession included developing methods that could be applied with the highest accuracy, consistency and precision; a program that had the greatest probability of being adopted by users; and a program that was biologically broadly applicable and applicable to the widest set of goals (Table 1).

Considering the elements identified above, discussion participants identified a series of alternatives related to AFS involvement in international standardization efforts:

A. No change to current sampling programs and no coordination among continents;

B. AFS would continue to recommend existing standards, but would communicate with international bodies (e.g. Food and Agriculture Organization of the United Nations, World Council of Fisheries Societies) to investigate need and enthusiasm for international standards;

C. AFS would continue to use existing standards, but will facilitate synergies/bridges, crosswalks, and intercalibration of existing methods for standardization to recommend to the international community;

D. AFS would work in a series of steps. They would (i) continue to use existing AFS standards, and (ii) communicate with international bodies to investigate need for international standards. If need is found then (iii) AFS would examine where synergies/bridges exist (iv) secure funding to develop intercalibration among areas and in collaboration with other groups to help design methods for locations where there is not standardization;

E. AFS would work with others to develop an entire new set of international standards in lieu of existing standards;

F. AFS would encourage continental standards (suitable for different continents), then explore synergies for international standardization.

Clear support existed among the SDM participants for AFS to engage the international community on standard sampling (Table 1). However, participants were not in favor of developing new international standards in lieu of existing continental standards. Retaining existing continental standards and examining opportunities to identify synergies, bridges and "crosswalks" among standard sampling methods from different continents was favored. In addition participants favored supporting other continents which had not yet developed standard procedures; however, residents of those continents would need to take the lead in developing standard procedures or at least request the help from AFS or international bodies.

A move toward finding bridges among continental standardization programs would provide many benefits. Fish communities and species ecological features within a continent are largely similar and standardization at this (or lower) scale is very important. However, intercontinental comparability may be less often required. As one participant suggested, there are few times biologists would need to compare a population of fish in a lake in the United Kingdom with one in Central Africa. However, intercontinental standardization would have value in specific cases, such as for closely related species (e.g., yellow perch *Perca fluviatilis* and Eurasian perch *Perca flavescens*) or species found on multiple continents (e.g. common carp *Cyprinus carpio*) and for invasive species which spread across multiple continents (e.g. mosquitofish *Gambusia affinis*). Furthermore, a general awareness of international standardization is of value, especially for new sampling and monitoring programs in the areas

where no standards are available. Collaboration among continents could also help define minimal requirements to be set on all continents, provide recommendations for new methods having no local standards, promote methods that participants agree are clearly better than others, examine worldwide factors affecting fish and fisheries (e.g., climate change), and assist countries or continents that have no current standards to develop them.

In summary, consensus of symposium participants was that the AFS led a very important process in North America to improve fish sampling methods but there is a need to collaborate with biologists on other continents during continued development of standard inland fish sampling programs. Continental standards should be retained, but biologists should look for bridges and synergies among them, such developing as common methods to sample species found on multiple continents, or intercalibration of specific methods. A potential result of such collaboration and methods standardization in other continents when different but common fishing gears are used, could be the publication of specific guidelines to reinforce and support the need to use standard assessments. Those already using continental standards should help developing nations develop standards where needed.

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Table 1. Consequences table for a structured decision making (SDM) session held at the international standard sampling symposium to decide how the American Fisheries Society should proceed in fomenting standard sampling methods internationally. Elements of a successful standard sampling program, and action alternatives to best address these elements were developed by the participants. Importance of different elements was defined by weights assigned by the participants. The audience then voted on how well each action alternative met each element, by ranking (Rank) them from highest to lowest (e.g., 6 = best, 1 = worst). Weights were multiplied by ranking (Wd) and highest total score shows the best alternatives. Alternatives were as follows: A: No change and no coordination among continents; B: AFS uses existing standards, but AFS communicates with international bodies (FAO, WCFS) to investigate need and enthusiasm for international standards; C: AFS uses existing standards, but facilitates synergies/bridges, crosswalks, intercalibration of existing methods for standardization to recommend to the international community; D: AFS works in a series of steps. We (1) use existing AFS standards, (2) communicate with international bodies to investigate need for international standards. If need is found we then (3) examine where synergies/bridges exist (4) secure funding to develop intercalibration among areas and in collaboration with other nations, help design methods for locations where there is not standardization; E: AFS works with others to develop an entire new set of international standards in lieu of existing standards; F: AFS to encourage continental standards (suitable for these different continents), then explore synergies for international standardization.

Objective	Weight (%)	Rank A	Wd A	Rank B	Wd B	Rank C	Wd C	Rank D	Wd D	Rank E	Wd E	Rank F	Wd F
Greatest probability of being adopted by users	15	2	30	6	90	3	45	5	75	2	30	5	75
Comparability to past and future methods	12	1	12	3	36	5	60	6	72	2	24	4	48
Highest accuracy, consistency and precision	21	1	21	3	63	6	126	5	105	2	42	5	105
Validated, known sources and sizes of bias	9	1	9	3	27	6	54	5	45	2	18	4	36
Affordable, cost effective and feasible	7	1	7	4	28	6	42	6	42	2	14	4	28

Biologically broadly applicable and applicable to the widest set of goals	15	1	15	3	45	6	90	4	60	2	30	6	90
Facilitate data sharing	11	1	11	3	33	6	66	4	44	2	22	5	55
Easy / understandable to apply	7	1	7	3	21	5	35	5	35	2	14	6	42
Can be used on a long term basis	1	2	2	4	4	3	3	6	6	1	1	5	5
Low environmental impact	3	1	3	6	18	3	9	5	15	2	6	4	12
SUM			**117**		**365**		**530**		**499**		**201**		**496**

Figure Captions

Figure 1. Demographics of standard sampling international symposium participants in the structured-decision-making workgroup at the discussion section of the AFS standard sampling symposium. All options that members of the group could select are on figure.

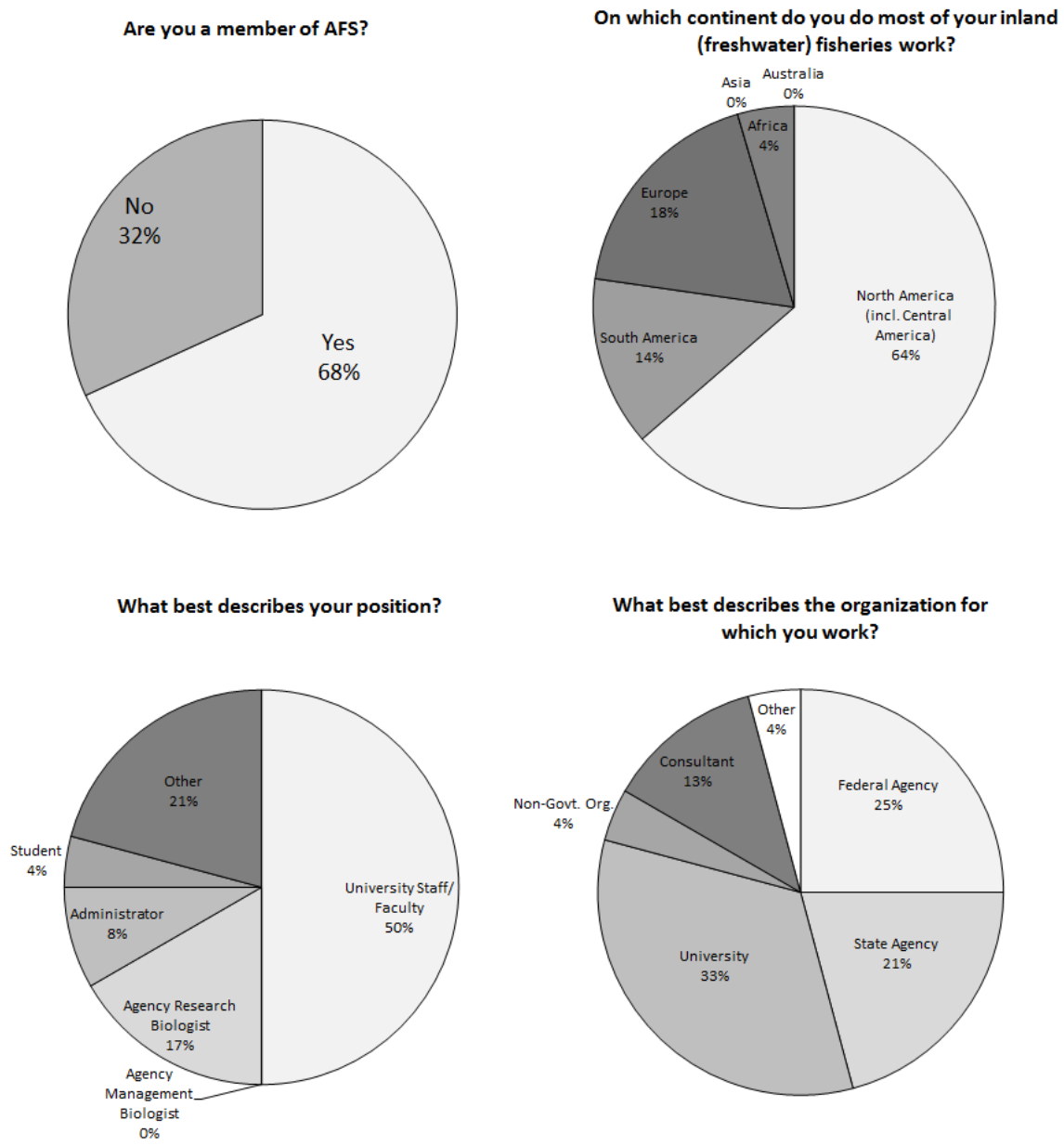
Are you a member of AFS?
No
32%
Yes
68%
On which continent do you do most of your inland (freshwater) fisheries work?
Asia
0%
Australia
0%
Africa
4%
Europe
18%
North America (incl. Central America)
64%
South America
14%
What best describes your position?
Other
21%
Student
4%
Administrator
8%
Agency Research Biologist
17%
Agency Management Biologist
0%
University Staff/ Faculty
50%
What best describes the organization for which you work?
Other
4%
Consultant
13%
Non-Govt. Org.
4%
Federal Agency
25%
University
33%
State Agency
21%

Figure 1.