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

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

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67 Efficient communication of data and findings across large areas is becoming increasingly  
68 important. Issues such as climate change (IPCC 2014), widespread distribution of invasive  
69 species (Fuller et al. 1999), and cross-boundary fish management strategies (Hubert and Quist  
70 2010) are becoming too large to only be considered on a local level for effective understanding  
71 and management. Furthermore, generally reduced budgets for programs and the need to increase  
72 sample sizes to meet statistical needs to test management strategies have made collaboration  
73 among different fisheries programs important. The ability to compare data over time and  
74 throughout areas, via standard sampling, standard indices and standard comparison methods, has  
75 revolutionized many areas of fish and fisheries science, such as baseline knowledge of fish  
76 populations and ecology (Swingle 1950; Argillier et al. 2012; Emmrich et al. 2012; Jeppesen et  
77 al. 2012; Brucet et al. 2013; Emmrich et al. 2014; Arranz et al. 2015), conservation and  
78 management of inland fish (Åslund and Degerman 2007; Winfield et al. 2008; Holmgren and  
79 Fölster 2010; Winfield et al. 2012; Winfield et al. 2013), and fisheries education (B. Graeb,  
80 South Dakota State University and I. Winfield, Lake Ecosystems Group, Centre for Ecology and  
81 Hydrology, paper presented at AFS symposium, 2015). Conversely, the inability to compare  
82 non-standardized data at large scales and over time has resulted in difficulty in fisheries  
83 planning, monitoring population and community trends, and having enough samples to make  
84 useful conclusions (Vostradovsky and Tichy, 1999; G. Whelan, Michigan Department of Natural  
85 Resources, paper presented at AFS symposium, 2015).

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

90 have been developed and are being increasingly adopted (e.g., CEN 2003, 2006, 2014, 2015;  
91 Bonar et al. 2009; European Commission 2015). In other regions of the world, sampling  
92 standardization is carried out at vary small scales, and is incipient (Mercado-Silva and Bonar  
93 2013).

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

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#### 107 <A>Methods

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

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

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

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

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

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

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

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

156         To complete the table, each action was ranked by electronic anonymous voting by the  
157 participants as to how well it would satisfy each element of a successful standard sampling  
158 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,

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

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

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

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

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

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

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

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

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

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

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

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

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

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

278         In summary, consensus of symposium participants was that the AFS led a very important  
279 process in North America to improve fish sampling methods but there is a need to collaborate  
280 with biologists on other continents during continued development of standard inland fish  
281 sampling programs. Continental standards should be retained, but biologists should look for  
282 bridges and synergies among them, such developing as common methods to sample species  
283 found on multiple continents, or intercalibration of specific methods. A potential result of such  
284 collaboration and methods standardization in other continents when different but common  
285 fishing gears are used, could be the publication of specific guidelines to reinforce and support the  
286 need to use standard assessments. Those already using continental standards should help  
287 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



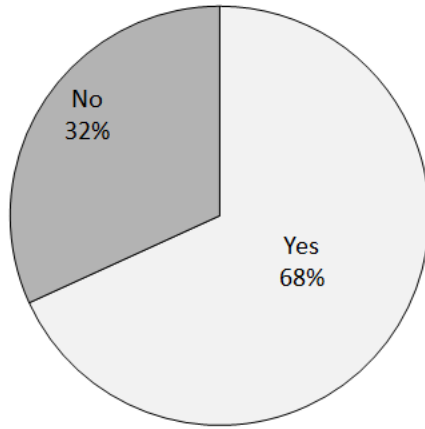
Biologically broadly applicable and applicable to the widest set of goals	15	1	15	3	45	6	90	4	60	2	30	6	90
Facilitate data sharing	11	1	11	3	33	6	66	4	44	2	22	5	55
Easy / understandable to apply	7	1	7	3	21	5	35	5	35	2	14	6	42
Can be used on a long term basis	1	2	2	4	4	3	3	6	6	1	1	5	5
Low environmental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

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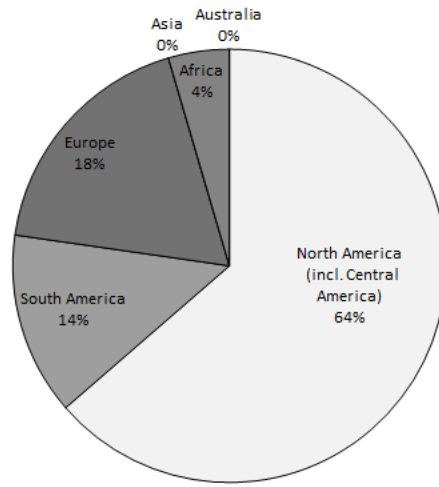
## Figure Captions

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.

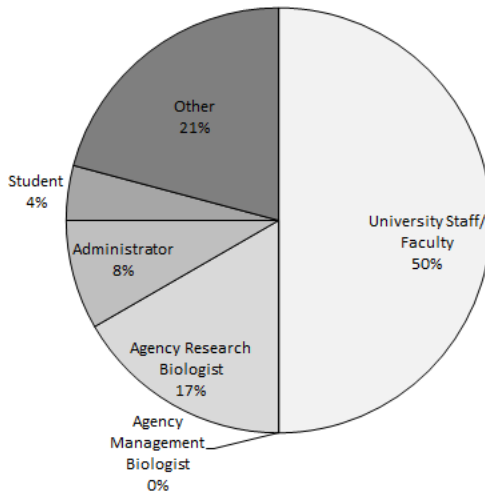
**Are you a member of AFS?**



**On which continent do you do most of your inland (freshwater) fisheries work?**



**What best describes your position?**



**What best describes the organization for which you work?**

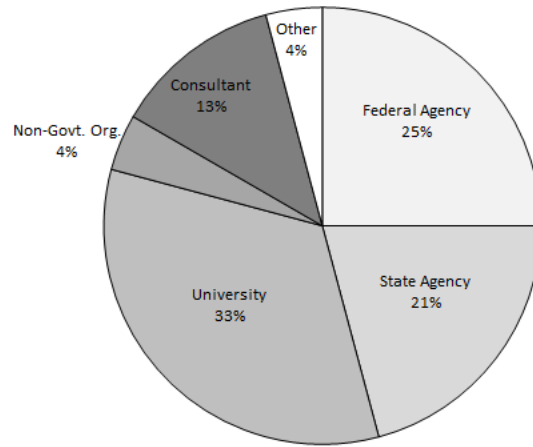


Figure 1.