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VOL 38 NO 4
APRIL 2013

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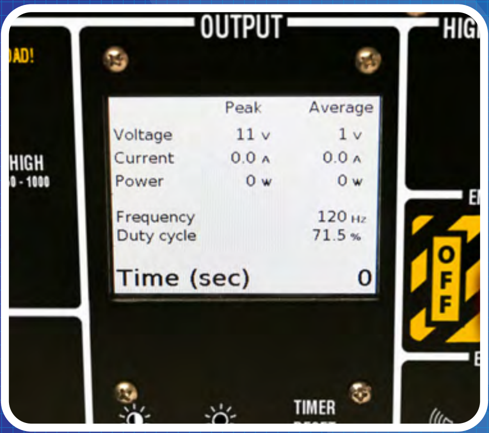

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160 Students use the outside of their hybrid laboratory and lecture building to aid their measurement of the ability of a water pump to lift water through a narrow PVC pipe.

Cover: Electrofishing sample in Atlantic Forest stream in Rio de Janeiro (state), southeastern Brazil. (Bianca de Freitas Terra and Cleivison J. de Carvalho) Photo credit: Victor Mosqueira.

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COLUMN
President's Hook

Getting the Word Out

John Boreman, President

AFS President Boreman may be contacted at: John.Boreman@ncsu.edu

Legend has it that Wanda Landowska, a world-famous 20th-century musician known for her recordings of Bach's music for the harpsichord, claimed that the way she interpreted Bach was the way he meant it to be interpreted. Who could argue? For the rest of us, musical composition, as with any other form of communication, is subject to a range of interpretation. Communication of scientific information is no different. Our means of sharing the results of our scientific investigations is limited by the capabilities of others to read and interpret via the format in which it is communicated.

One of my jobs as an employee of the National Marine Fisheries Service was chief of the Research Coordination Branch of the Northeast Fisheries Science Center. One of the main roles of the branch was to oversee the two-way exchange of information between the center and its partners and stakeholders. During one of my visits to the Boston area, I took a side trip to the Harvard Coop bookstore to look for texts on the dynamics of information exchange; surely, if they existed, with its worldwide reputation for training interpreters of the written word (i.e., lawyers), I figured that Harvard would have them. In the short time I spent at the bookstore I could not find a single one, even with the assistance of a store clerk. Not being deterred, I proceeded to develop my own "Laws of Info-dynamics." Two laws that I remember are (1) scientific information loses content every time it is exchanged; and (2) if scientific information can be misinterpreted it will be misinterpreted. After spending years working at the nexus of marine fisheries science and management, I have come to the realization that scientific information that is good news is almost always easily transmitted and interpreted, whereas bad news is not. I have also come to the realization that effective communication of scientific information has been and would continue to be an ongoing endeavor for my entire career.

An opportunity to continue pursuing this endeavor arose at the most recent American Fisheries Society (AFS) annual meeting in St. Paul, when Julie Claussen caught up with me during a break between sessions and asked me whether I would be interested in forming a special AFS committee to investigate how the AFS can best use social media to communicate scientific and society-specific information. She had been attending a special symposium at the meeting entitled "Science Communication: Information Delivery and the New Face of 21st Century" (organized by Jeremiah Osborne-Gowey and Elden Hawkes), during which the topic of social media was discussed. Of course, my reply was an enthusiastic "Yes!" and I asked her to send me some thoughts that I could craft into a committee charge. In a follow-up e-mail, Julie wrote:

> *Many professional societies are currently using social media as a mechanism for outreach and education, as a way to provide services for their membership, and to attract new members. Within AFS, there are several fisheries scientists and students that are active players in the social media arena and directly see the benefits of its use both on the professional level and at the organizational level.*

She went on to write: "*To stay relevant among its members, as well as within the fisheries science community, AFS should review how it is currently using social media and how it can be further used to meet the society's goals.*" We subsequently agreed that the special committee should be charged with addressing the following questions:

- How are other professional societies strategically using social media?
- How are individual AFS subunits using social media to connect to their members? Is this a method that can be promoted to better serve subunit membership?
- Are there any standards that are needed among the subunits when designing their Facebook pages, running a LinkedIn group or Twitter account, etc.?
- Would it be useful for subunits to have a how-to guide on setting up and using various social media tools?
- How can the AFS use social media to support communication and connect among its members?
- How can the AFS use social media to attract fisheries professionals?
- As a professional society, should the AFS use social media to increase awareness on larger environmental issues?
- How can the AFS effectively use social media to connect with anglers and aquatic resource conservationists?
- Can (and should) the AFS take a more active a role in training new fisheries professionals to be more effective communicators?
- What are the best methods/tools to evaluate AFS success/shortcomings online?

Although the charge for the special committee seems daunting, all of us engaged in scientific and society-specific communications should be asking ourselves many of these same questions. Perhaps we will never possess the capability for perfect interpretation that Wanda Landowska claimed to have achieved, but we should view communication of scientific information and information pertinent to AFS membership as a primary obligation we must fulfill as fisheries professionals to prepare us for the challenges ahead.

LETTER TO PRESIDENT OBAMA

Climate change is at the forefront of issues that the Obama Administration intends to address over the next four years. The President's mention of climate change in his acceptance speech at the Democratic National Convention afforded AFS an opportunity to share our climate change policy statement with him and his senior leadership. The following letter was sent to the President in January, prior to his inaugural address in which he also emphasized the need to address climate change. It was also sent to Congressional leaders involved with climate change legislation.

January 17, 2013

President Barack Obama
The White House
1600 Pennsylvania Avenue NW
Washington, DC 20500

Dear Mr. President:

Established in 1870, the American Fisheries Society is a 9000 member professional scientific association with members employed by state, provincial, tribal and federal agencies, universities, NGOs, and the private sector. Our mission is to advance sound science, promote professional development, and disseminate science-based information for the global protection, conservation, and sustainability of fisheries resources and aquatic ecosystems.

We congratulate you on winning the 2012 presidential election and for mentioning the need to address climate change in your acceptance speech. In the wake of the devastating destruction of superstorm Sandy and, as the most influential leader in the world, you have an opportunity to help our nation prepare for continued disruptions caused by global warming and permanently reduce carbon emissions.

Upgrading our infrastructure, discouraging development of at-risk lands, and transitioning to new technologies can create millions of much-needed jobs, spur green economic growth, and increase the probability of a healthy and prosperous future for our children. Therefore, we urge you to use science-based information to make climate change a priority for your administration and our nation.

Members of the American Fisheries Society have been acutely aware of how climate change is already affecting our aquatic and marine ecosystems, and our predictive modeling forecasts much more serious threats. Consequently, we recently adopted a climate change policy by vote of our membership (see attached). Our policy includes the following statement:

1. Do not delay emission reductions. Encourage reductions in anthropogenic sources of carbon dioxide and other greenhouse gases.
2. Encourage economic mitigation options that indirectly or directly assist with water conservation practices and watershed protection of policies and laws that support wise and sustainable use.
3. Integrate efforts to manage for both fish and wildlife habitat. Develop partnerships with overlapping interests on shared concerns will increase overall effectiveness and temper uncertainty of difficult decisions.
4. Restore historic hydrologic regimes that facilitate historic fish dispersal patterns. Do not support assisted migration or translocation of fish species as a standard operating policy, but consider this tool on a case-by-case basis carefully evaluating possibilities of unintended consequences. In landlocked "island" systems with imperiled or extirpated species, assisted migration may be the only viable management alternative for maintaining ecosystem function.
5. Encourage education efforts aimed at federal and state agencies and the private sector about the general effects of climate change to our aquatic ecosystems. This ensures transparency of the principles and practices employed for either mitigation or adaptation responses to climate change in fisheries.
6. Encourage implementation of national, regional, and local monitoring programs to evaluate the effects of climate change in fisheries. The continuation of long term monitoring (i.e., biological, hydrological, climatic) will be essential in addressing trends.
7. Encourage management and research activities that reduce ecosystem stressors to include but not be limited to: metapopulation expansion through careful consideration (i.e., use or removal) of barriers, prescribed fire in watershed to reduce chances of catastrophic fires, pollution preventive measures, biodiversity protection, and land use practices to mitigate changes to disturbances in hydrology of riparian areas and ameliorate temperature fluctuations for protection of coldwater refugia of trout, salmon, and whitefish.
8. Encourage research activities to characterize climate effects in marine, arctic, and freshwater systems, reduce ecosystem stressors, and optimize harvest quota for commercial fisheries stocks.
9. Support provisions of dedicated funding for climate legislation that would provide for conservation of fish, water and other natural resources affected by climate change.

As you set our nation's course for the next four years, we urge you and your Administration to support science, address the realities of global warming, and further expand efforts to move a clean energy economy forward in the United States. As fisheries scientists and also concerned citizens, we offer our assistance in helping you redirect the Nation from a carbon-based consumptive economy to a more sustainable one.

Sincerely,

John Boreman

John Boreman, Ph.D.
President
American Fisheries Society (AFS)


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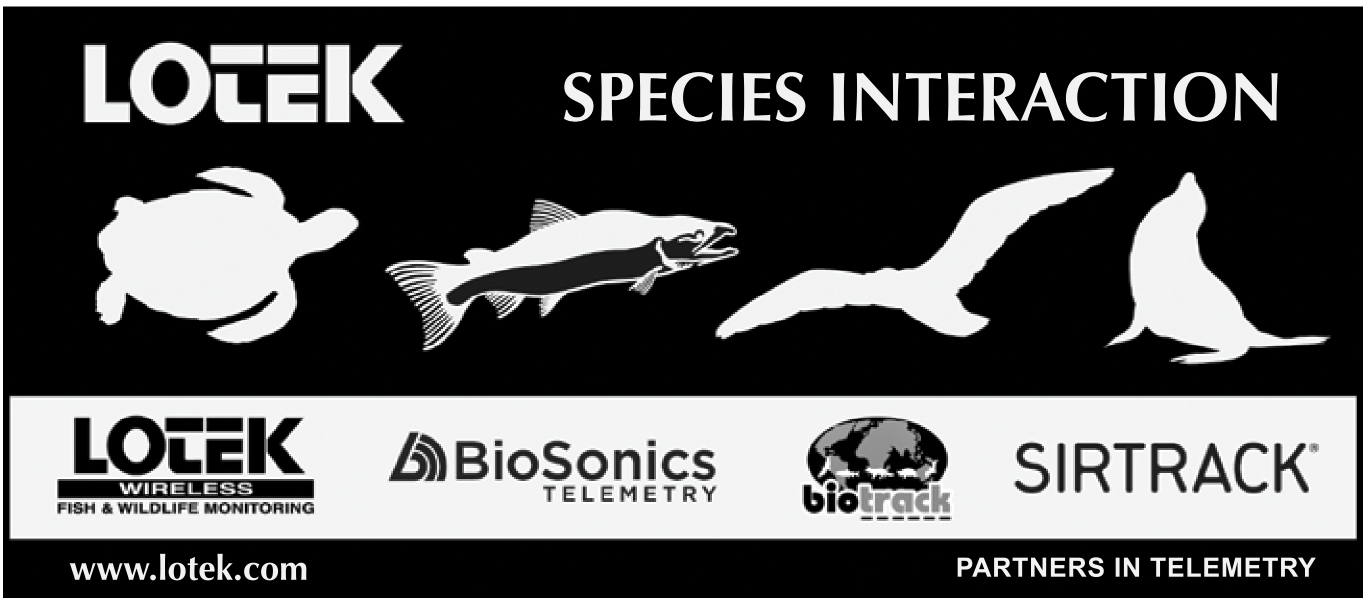
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FEATURE

Sampling Sufficiency for Fish Assemblage Surveys of Tropical Atlantic Forest Streams, Southeastern Brazil

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ABSTRACT: *Knowledge of the adequacy of field sampling protocols is critical for detecting species and assessing biological conditions. Several studies have been conducted to determine the appropriate electrofishing distance for estimating fish assemblage richness in temperate North American streams. We tested whether electrofishing 40 times the mean wetted channel width was sufficient for estimating species richness and developing precise metrics for Atlantic Forest streams in southeastern Brazil. We sampled 32 sites with differing gradients, substrates, and anthropogenic pressures. Our results show that 40 channel widths were not sufficient to estimate species richness in those systems, presumably because of the high number of rare species. However, 40 channel widths were sufficient for applying other metrics of assemblage condition (e.g., number of common species, percentage of tolerant individuals, percentage of Characiform species, percentage of Siluriform species, percentage of water column species, percentage benthic species, Shannon diversity, dominance). This suggests that 40 channel widths are an appropriate sampling distance for applying environmental assessment protocols to Atlantic Forest streams.*

Suficiencia de muestreo para ensambles de peces en ríos del bosque tropical del Atlántico, en el sureste de Brasil

RESUMEN: *el conocimiento sobre la pertinencia de protocolos de muestreo es un aspecto clave para detectar especies y evaluar condiciones biológicas. Se han llevado a cabo numerosos estudios encaminados a determinar la distancia más adecuada para la electro-pesca, aplicada a la estimación de riqueza de ensambles de peces en ríos templados de Norte América. En esta contribución se probó si la electro-pesca aplicada a una distancia de 40 veces el ancho promedio del canal de inundación, era suficiente como para estimar la riqueza específica y desarrollar medidas precisas para los ríos del bosque tropical del Atlántico, en el sureste de Brasil. Se muestrearon 32 sitios con diferentes gradientes, sustratos y grados de presión antropogénica. Nuestros resultados muestran que en esos sistemas, usar 40 veces el ancho del canal no era suficiente como para estimar la riqueza, presumiblemente porque el alto número de especies raras. Sin embargo, 40 veces el ancho sí fue suficiente para conocer otros indicadores de la condición de los ensambles (e.g. número de especies comunes, porcentaje de individuos tolerantes, porcentaje de especies Caraciformes, porcentaje de especies Siluriformes, porcentaje de especies que habitan la columna de agua, porcentaje de especies bentónicas, diversidad de Shannon, dominancia). Esto sugiere que 40 veces el ancho del canal de inundación es una distancia apropiada de muestreo para aplicarla en protocolos de evaluación ambiental en ríos de los bosques tropicales del Atlántico.*

INTRODUCTION

Adequate electrofishing sampling efforts for estimating fish species richness in streams has been studied in several temperate regions of North America (Lyons 1992; Angermeier and Smogor 1995; Paller 1995; Patton et al. 2000; Cao et al. 2001; Reynolds et al. 2003). Most of those researchers reported a range of mean wetted channel widths needed to collect 90% of the fish species expected at a site. Lyons (1992) suggested sampling 5–49 channel widths to estimate species richness in Wisconsin stream sites. Angermeier and Smogor (1995) estimated sampling distances of 22–67 channel widths for Virginia sites, whereas Paller (1995) found that 13–83 channel widths were needed for collecting common species in South Carolina sites. In Arkansas, Dauwalter and Pert (2003b) reported that 46–61 channel widths were necessary for collecting 95% of the species collected by electrofishing 75 channel widths. Reynolds et al. (2003) determined that 40 wetted channel widths were adequate for estimating species richness and for scoring an index of biotic integrity in Oregon sites. This information is important for knowing (1) how many and which species we can find in stream sites and (2) the most cost-effective sampling effort for regional and national monitoring programs (Hughes et al. 2002, 2012; Hughes and Peck 2008).

Several studies have been conducted by electrofishing in Brazilian Atlantic Forest streams, but different protocols have been applied and few researchers reported the effectiveness of their sampling protocols. Mazzoni et al. (2000) evaluated electrofishing adequacy for obtaining fish population density and production data but not richness data. Gerhard et al. (2004) described the spatial variability of fish assemblages in 11 streams by sampling sites that were 30–35 m long. Ferreira and Casatti (2006a) examined fish composition and quantitative structure at four sites in a stream by sampling sites that were 60 m long. Mazzoni et al. (2006) described the distribution and community structure of fishes by sampling an 80-m-long site through use of the three-pass removal method. Rezende et al. (2010) explored meso-habitat use by fish species in a low-diversity assemblage by sampling a 250-m-long site. The lack of a standard sampling protocol in these studies hinders comparisons to and inferences from other similar streams (Bonar et al. 2009).

The Atlantic Forest is considered a global biodiversity hotspot (Myers et al. 2000). The Ministério do Meio Ambiente and others (2000) estimated that 350 different species can be found in Atlantic Forest streams, including 133 endemic species; however, many are undescribed (Abell et al. 2008). These streams also support many rare species, further hindering estimates of true species richness. Although tropical streams have high species richness and consequently can present major difficulties in estimating that richness, these systems need to be monitored and assessed, and biotic indices have been shown to be useful tools for doing so in Brazil (e.g., Bozzetti and Schultz 2004; Ferreira and Casatti 2006b; Casatti et al. 2009). Multimetric indices such as the index of biological integrity (IBI) are widely used in North America and Europe for analyzing and reporting biological condition of fish assemblages at continental scales (e.g., Oberdorff et al. 2002; Pont et al. 2006, 2009; Whittier et al. 2007b). However, in Brazilian water bodies these indices are not required in monitoring programs, although more studies aiming to develop such tools have been conducted in recent years (Araújo 1998; Araújo et al. 2003; Bozzeti and Schulz 2004; Ferreira and Casatti 2006b; Pinto et al. 2006; Baptista et al. 2007; Pinto and Araújo 2007; Mugnai et al. 2008; Casatti et al. 2009; Oliveira et al. 2011; Terra and Araújo 2011).

TABLE 1. Physical characteristics of 32 Atlantic Forest stream sites, southeastern Brazil. Total length sampled is the product of the number of channel widths sampled (40) and the mean width of the channel, with a site length minimum of 100 m.

Site	Latitude (geo/wgs84)	Longitude (geo/wgs84)	Substrate	Mean width (m)	Channel widths sampled	Elevation (m)
2	22°36′49″	43°13′41″	Sand	4	160	24
3	22°35′48″	43°14′17″	Boulder	4	160	50
4	22°36′15″	43°13′16″	Cobble	3	120	15
5	22°33′26″	43°16′38″	Cobble	8	320	56
6	22°33′44″	43°15′21″	Cobble	6	240	88
7	22°36′01″	43°15′57″	Sand	5	200	19
8	22°36′01″	43°15′57″	Cobble	3	120	103
10	22°34′14″	43°19′10″	Sand	6	240	32
11	22°35′04″	43°11′46″	Sand	1	100	26
12	22°35′04″	43°11′46″	Sand	1	100	43
13	22°35′12″	43°11′03″	Sand	8	320	20
14	22°35′02″	43°09′57″	Boulder	8	320	35
15	22°36′11″	43°09′10″	Sand	1.5	100	18
16	22°35′56″	43°08′47″	Sand	1.5	100	14
19	22°35′32″	43°06′44″	Boulder	4	160	43
20	22°34′10″	43°11′56″	Boulder	3	120	82
21	22°34′10″	43°11′59″	Boulder	6	240	101
23	22°34′27″	43°11′46″	Sand	2	100	55
24	22°35′28″	43°05′26″	Boulder	4	160	33
25	22°35′27″	43°04′37″	Cobble	2	100	12
26	22°35′09″	43°04′90″	Cobble	2	100	12
27	22°32′34″	43°03′59″	Boulder	7	280	207
28	22°31′30″	43°01′53″	Boulder	5	200	261
30	22°37′23″	43°13′50″	Sand	3.5	140	11
43	22°35′13″	43°24′26″	Sand	3	120	35
44	22°36′03″	43°24′52″	Cobble	15	500	23
45	22°35′15″	43°25′28″	Boulder	9	360	54
46	22°34′17″	43°23′20″	Cobble	5	200	80
47	22°35′28″	43°24′44″	Sand	5	200	33
49	22°29′56″	42°54′18″	Cobble	7	280	43
50	22°26′07″	42°45′32″	Cobble	16	500	18
54	22°28′25″	42°45′38″	Cobble	9	360	43

The purpose of this study was to determine whether 40 mean wetted channel widths were adequate for assessing fish assemblages in tropical stream sites. Based on studies in temperate streams, we hypothesized that (1) 40 channel widths would suffice for estimating fish species richness and (2) a much shorter distance would suffice for fish assemblage metrics used in Brazilian biotic indices.

METHODS

We sampled 32 wadable Atlantic Forest stream sites in southeastern Brazil during the dry seasons of 2010 and 2011 (Table 1). We ensured that the sites had distinctly different gradients, substrates, and anthropogenic pressures (urbanization, sewage discharges, deforestation) so that any method we developed would be appropriate for a wide range of stream types. The sites occurred in five basins that drain to Guanabara Bay, with a combined drainage area of 4,081 km^2 (Japan International Cooperation Agency 1994). This area is bounded by the Serra do Mar, with altitudes of 800–1,800 m. The climate is warm and humid, with an average annual temperature of 22°C and mean annual precipitation near 1,700 mm (Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustenável 2001).

The sample sites began at a randomly chosen point in the Guanabara Bay basin and extended upstream for 40 times the mean wetted channel width or a minimum of 100 m. In each site, 11 equidistant cross-section transects were marked, defining 10 quadrats of the same length (the area of each quadrat area was Width × (Width × 40/10)). At five equidistant points in each

Photo 1. Atlantic Forest stream in Rio de Janeiro (state), southeastern Brazil, 22° 35' 28"S and 43° 05' 26"W. Photo credit: Bianca de Freitas Terra.

Photo 2. Atlantic Forest stream in Rio de Janeiro (state), southeastern Brazil, 22° 32' 34"S and 43° 03' 59"W. Photo credit: Tatiana P. Teixeira Neves.

transect, we recorded substrate type (cobble, boulder, sand). At a central point in each quadrat we measured the following: width, riparian structure (e.g., mid-channel and margin shading), pH, conductivity, dissolved oxygen, temperature, and turbidity, following Peck et al. (2006). We recorded habitat heterogeneity (e.g., flow type, large wood) and human disturbance in the channel and riparian zone (e.g., presence of pasture, crops, pipes, trash) in percentage of occupied area for each quadrat.

We electrofished via alternating current generator (3,000 W, 220 V) with two hoop-shaped (440 mm × 300 mm) electrodes supporting a net (3-mm mesh). Two people, each with an electrode, fished from one quadrat edge to the other, removing all fishes detected in the electric field. We used only electrofishing because it is recognized as being a more widely applicable tool for monitoring fish assemblages than other techniques (Vaux et al. 2000; Hughes et al. 2002; Hughes and Peck 2008; Rabeni et al. 2009). One-pass electrofishing typically estimated species richness and percentage abundance as well as three-pass depletion sampling (Reynolds et al. 2003). Sály et al. (2009) determined that single-pass and double-pass electrofishing produced insignificant differences in species richness, composition, and relative abundances. All of the fish we collected were identified, counted, weighed (measured in grams), and measured for total length (measured in millimeters). Vouchers were fixed in 10% formalin for 48 h, subsequently preserved in 70% ethanol, and then deposited in the reference collections of the Laboratório de Ecologia de Peixes, Universidade Federal Rural do Rio de Janeiro, and Ichthyological Collection of the Instituto de Biologia,Universidade Federal do Rio de Janeiro.

We analyzed richness sampling sufficiency through use of an original sample order curve and a Monte Carlo analysis curve. The sample order approach may be influenced by the starting point if the first one or two quadrats hold many more species than subsequent quadrats. Therefore, we used 999 runs of Monte Carlo analyses for each site to obtain random samples without replacement for 1–10 quadrats. Means across sample sites were plotted for the sample order curve, but box plots and medians were plotted for the Monte Carlo results. We considered rare species as those comprising <1% of observed individuals at a site.

We performed rarefaction analyses (Gotelli and Colwell 2001) for all sites to determine the effect of differences in total abundance on richness. A rarefaction curve was generated for each site, with samples ranging from 50 to 600 specimens, which allowed us to assess the potential increase in species richness as more specimens were included in the sample. However, rarefaction curves estimate species richness for a subsample of the pooled total species richness, based on all species actually discovered (Gotelli and Colwell 2001). Thus, to estimate true or potential species richness at a site, including species not present in any sample, we used four different nonparametric estimators (bootstrap, Chao 1, Chao 2, and second-order jackknife) at each site. We chose those estimators because of their fundamentally different conceptual bases. The bootstrap estimator was proposed by Efron (1979, 1981) and is a resampling procedure where bootstrap samples of size *n* are randomly selected from *n* quadrats with replacement (Hellman and Fowler 1999). Chao 1 (Chao 1984) and Chao 2 (Chao 1987) use the observed number of species in a site, combined with the number of species appearing in only one and two quadrats (singletons and doubletons, respectively). However, the Chao 2 estimator uses only presence and absence data. Calculation of the second-order jackknife (E. P. Smith and van Belle 1984) also involves singletons and doubletons but uses a different model than the Chao models (Hellman and Fowler 1999). We calculated these estimators with PRIMER 6 software (Clarke and Gorley 2006).

We also evaluated the effect of sampling distance on several assemblage metrics. In all but two cases we chose metrics previously used in tropical stream multimetric indices (Table 2). One metric considered occurrence of common species, those contributing >1% of abundance. Two other metrics considered habitat guilds: benthic species and water column species. Those classifications were made by consulting FishBase (Froese and Pauly 2012), contacting experts, and observing behavior and body morphology. Assemblage composition metrics quantified the proportion by number of the two major orders (Characiforms

TABLE 2. Metrics calculated for 32 Atlantic Forest stream sites.

Candidates metrics	References
Number of common species[a]	Kanno et al. (2009)
Percentage of tolerant individuals[b]	Casatti et al. (2009)
Percentage of Characiform species[b]	Ferreira and Casatti (2006b); Pinto and Araújo (2007)
Percentage of Siluriform species[b]	Ferreira and Casatti (2006b); Pinto and Araújo (2007); Araújo et al. (2003)
Percentage of water column species	Bozzetti and Schultz (2004)
Percentage of benthic species	Bozzetti and Schultz (2004)
Shannon diversity index[a]	Magalhães et al. (2008)
Dominance	Casatti et al. (2009); Ferreira and Casatti (2006b)

[a] Metric not previously used in tropical stream multimetric indices.
[b] Modified metric.

and Siluriforms). We also evaluated diversity and dominance metrics using the commonly used Simpson (D) and Shannon (H) diversity indices, which were calculated as

$$D = \sum (n_i/n)^2$$

and

$$H = -\sum (n_i/n) \times \ln(n_i/n)$$

where n_i is the number of individuals of taxon I, and n is the total number of individuals.

A dominance index was calculated as $1 - D$. All diversity and dominance calculations were made using PAST software (Hammer et al. 2001). Our final metric was based on species tolerance to thriving in disturbed systems; such species typically increase or dominate in polluted environments (Ganasan and Hughes 1998; Pinto et al. 2006; Whittier et al. 2007a; Segurado et al. 2011). To classify those species we followed our personal observations (Araújo 1998; Pinto and Araújo 2007).

RESULTS

We collected 61 species from 13 families, including 38 rare species, and between 3 and 30 species per site, including vagile water column, small benthic, water surface, and cryptic hiding species (see Appendix). Considering all 32 stream sites, fish species richness (Monte Carlo analysis and sample order curves) continued to increase with increased sampling distance, suggesting greater species richness than we detected in a distance equal to 40 times the mean wetted channel width and negating hypothesis 1 (Figure 1).There was virtually no difference in the accumulation curve between the Monte Carlo analysis and the sample order analysis, indicating that the initial starting point for site sampling had little effect in this study.

The rarefaction curve that included 50 to 600 individuals from the 32 sampling sites reached an asymptote; that is, showed similar expected fish species richness, even with the addition of new individuals collected (Figure 2). This suggests that collections of 400–500 individuals are needed for reasonably accurate estimates of fish species richness in these streams. The observed and estimated values of species richness were not similar for most sites. The estimators of species richness (bootstrap, Chao1, Chao 2, and second-order jackknife) were well above the observed number of species; sometimes they estimated 10 more species than we observed (Table 3).

After sampling 16–24 channel widths, all of the assemblage metrics we evaluated remained stable; that is, they did not vary even with increasing distance sampled, indicating acceptance of hypothesis 2 (Figure 3). This indicates that those metrics are adequately sampled in <40 channel widths.

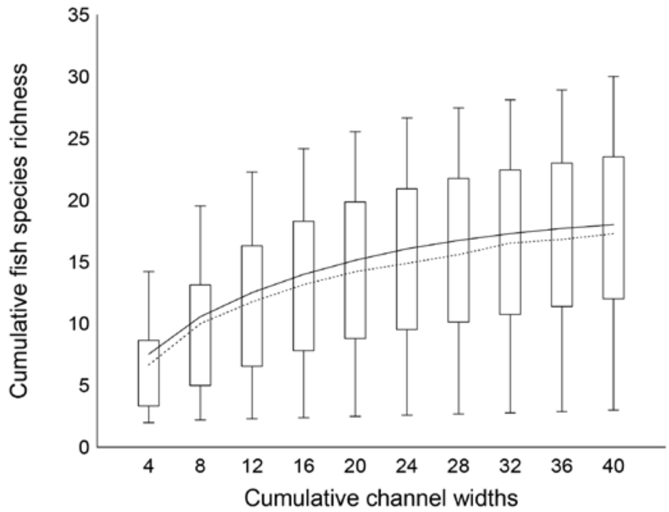

Figure 1. Cumulative fish species richness versus cumulative channel width, averaged for 32 study reaches in Atlantic Forest streams by sample order (dashed line) and Monte Carlo analysis (solid line). In the Monte Carlo results, the line connects the medians; the boxes show the interquartile ranges; and the whiskers show the minimum and maximum values within classes.

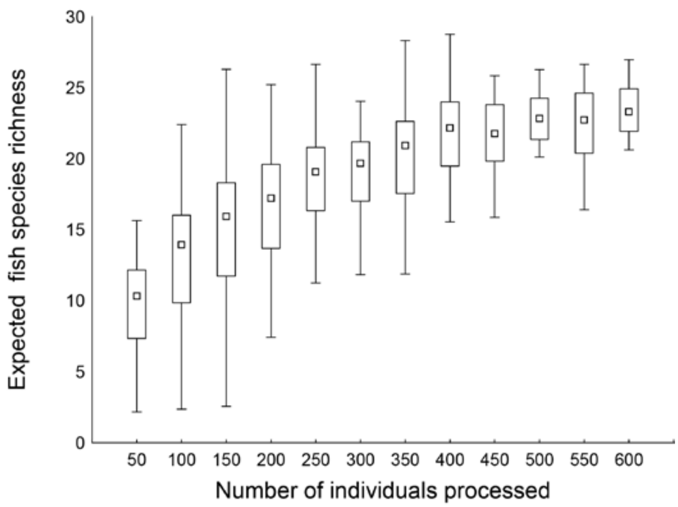

Figure 2. Expected richness according to rarefaction analysis of fish assemblages of different sizes from 32 Atlantic Forest stream sites. The small squares are medians; rectangles show the interquartile ranges; and the whiskers show the minimum and maximum values within classes of expected richness.

TABLE 3.Characteristics of fish assemblages collected in 32 Atlantic Forest stream sites.

				Richness estimators				
Site	Number of fish caught	Rare	S/D	Observed species richness	Bootstrap	Chao 1	Chao 2	Jackknife 2
2	392	7	3/3	18	19.7	19.5	18.8	18.8
3	318	3	3/3	12	13.2	12.0	16.5	16.4
4	336	8	3/3	21	23.9	25.2	27.1	30.1
5	640	11	5/3	23	25.7	41.0	27.5	30.4
6	676	10	3/3	21	23.5	21.0	27.0	29.1
7	910	14	2/3	26	29.2	28.0	36.7	37.5
8	227	3	3/3	15	16.3	15.0	17.3	18.7
10	1,086	13	3/3	29	31.1	31.3	30.6	32.2
11	227	6	4/2	12	14.8	12.0	12.0	25.6
12	71	0	4/2	4	4.4	4.0	4.0	5.7
13	975	9	4/4	25	26.7	26.0	29.0	30.4
14	1,214	7	4/4	18	19.3	18.3	18.4	17.8
15	314	5	4/4	21	23.1	22.0	22.3	23.5
16	87	0	4/4	15	18.4	47.0	35.3	28.9
19	67	0	4/4	8	8.8	8.0	10.0	10.7
20	254	1	4/4	3	3.3	3.0	3.0	4.7
21	202	1	4/4	3	3.3	3.0	3.0	4.7
23	245	6	3/2	18	21.0	19.5	24.1	27.1
24	201	6	3/2	16	18.9	16.0	16.0	29.6
25	168	3	3/2	8	9.4	8.0	8.0	14.8
26	498	5	3/2	18	20.7	18.0	30.3	28.5
27	365	3	3/2	12	13.5	12.0	20.0	18.1
28	117	0	3/2	6	6.1	6.0	6.0	5.3
30	216	5	4/2	8	9.9	8.0	20.5	15.8
43	175	2	4/2	18	19.5	18.7	18.3	16.4
44	1,110	12	4/2	24	25.8	24.0	26.7	28.7
45	969	9	4/2	24	25.6	24.0	24.9	25.5
46	208	5	4/2	18	19.6	20.3	19.1	20.3
47	447	13	4/3	29	32.3	29.1	30.8	32.1
49	819	14	4/3	27	29.5	28.1	36.0	35.8
50	374	8	4/3	23	25.9	25.7	31.2	32.8
54	230	14	5/3	30	34.7	32.3	40.1	44.4

S = singletons; D = doubletons

DISCUSSION

Our results show that 40 channel widths are not sufficient to estimate true species richness in Atlantic Forest streams, presumably because of the high number of rare species. However, 40 channel widths are sufficient for assessing other metrics of assemblage condition (e.g., number of common species, percentage of tolerant individuals, percentage of characiform species, percentage of siluriform species, percentage of water column species, percentage of benthic species, Shannon diversity, dominance). This suggests that 40 channel widths are appropriate for developing metrics useful for assessing the biological condition of Atlantic Forest streams. Site lengths of 40 channel widths were also reported by Reynolds et al. (2003) as adequate to estimate 90% of species richness in western Oregon streams and this value is similar to those determined by others developed from temperate stream studies (Lyons 1992; Angermeier and Smogor 1995; Paller 1995; Patton et al. 2000; Dauwalter and Pert 2003b). In small Amazon Forest streams with high numbers of rare species, Dos Anjos and Zuanon (2007) suggested sampling reaches approximately 60 times the mean wetted width to estimate species richness. The inconsistent occurrences of rare species produce detection discontinuities in streams and rivers, and according to Kanno et al. (2009) these discontinuities are the primary factor affecting the distance requirements to accurately estimate species richness. Reynolds et al. (2003) and Hughes and Peck (2008) recommended sampling 40 channel widths in streams but argued that this distance is often insufficient to capture rare species at a site, because those species require collecting more individual fish. Although those authors did not suggest excluding rare species from all analyses, because of the sampling costs involved they felt that it was prudent to minimize their importance in large-scale regional assessments of stream fish assemblages, such as those of national and statewide monitoring programs.

The high number of rare species we observed is associated with high differentiation in among-sites richness (beta diversity). According to Magurran (2004), beta diversity increases as the similarity in species composition among sites decreases; therefore, it is a measure of the extent to which the diversity of two or more spatial units differs. In our sites the mean species richness (α diversity) was 17.3 ± 7.8, whereas the total number of species collected (β diversity) was over three times greater (61 species). In basins with high variability in species composition among sites, K. L. Smith and Jones (2008) found that sampling larger numbers of shorter distances should improve the rates of species accumulation. In contrast, they noted that sampling larger sites would probably increase rates of species accumulation in basins with high travel costs or lower turnover among reaches. Studying relatively homogeneous U.S. Great Plains streams, Fischer and Paukert (2009) reported that fewer sites were needed to estimate segment richness as site length increased but that a greater number of shorter sites could produce the same number of species with less total sampling effort. Thus, the adequacy of sampling distances for estimating species richness probably needs to be considered by region or basin, depending upon objectives and the prevalence of numerically rare species (Kanno et al. 2009).

Index of biological integrity metrics commonly used in Brazil were stable when we sampled 25 times the mean wetted channel widths of sites (Figure 3). This suggests that sampling 25 channel widths can generate sufficiently robust data for biological assessments of Atlantic Forest streams based on multimetric indices. According to Hughes and Gammon (1987), an index such as IBI is a much less variable indicator than species richness. In addition, Hughes and Herlihy (2007) found that about half the site length was needed for an IBI compared to that for total richness in temperate rivers. Wan et al. (2010) reported that IBI metrics calculated as relative abundances were less affected by missing rare taxa than those based on species richness. But we also found that collecting 400–500 individuals per site provided a reasonably accurate estimate of empirical species richness. This is a number of individuals similar to the 30 times the expected number of species that Dußling et al. (2004) concluded were needed for precise species richness estimates. Dauwalter and Pert (2003a) reported that deviations in sampling effort can result in inaccurate IBI scores and site assessments, and Dolph et al. (2010) found that both the number of rare taxa and the number of individuals collected affected IBI scores in Minnesota streams. Presumably the IBIs used in those studies included multiple richness metrics that tend to vary considerably with sampling effort. Thus, even when using a multimetric index, it is important to standardize sampling effort by considering the distance sampled or the number of individuals collected as well as sampling gear and sampling protocol (Hughes and Peck 2008; Bonar et al. 2009; Rabeni et al. 2009).

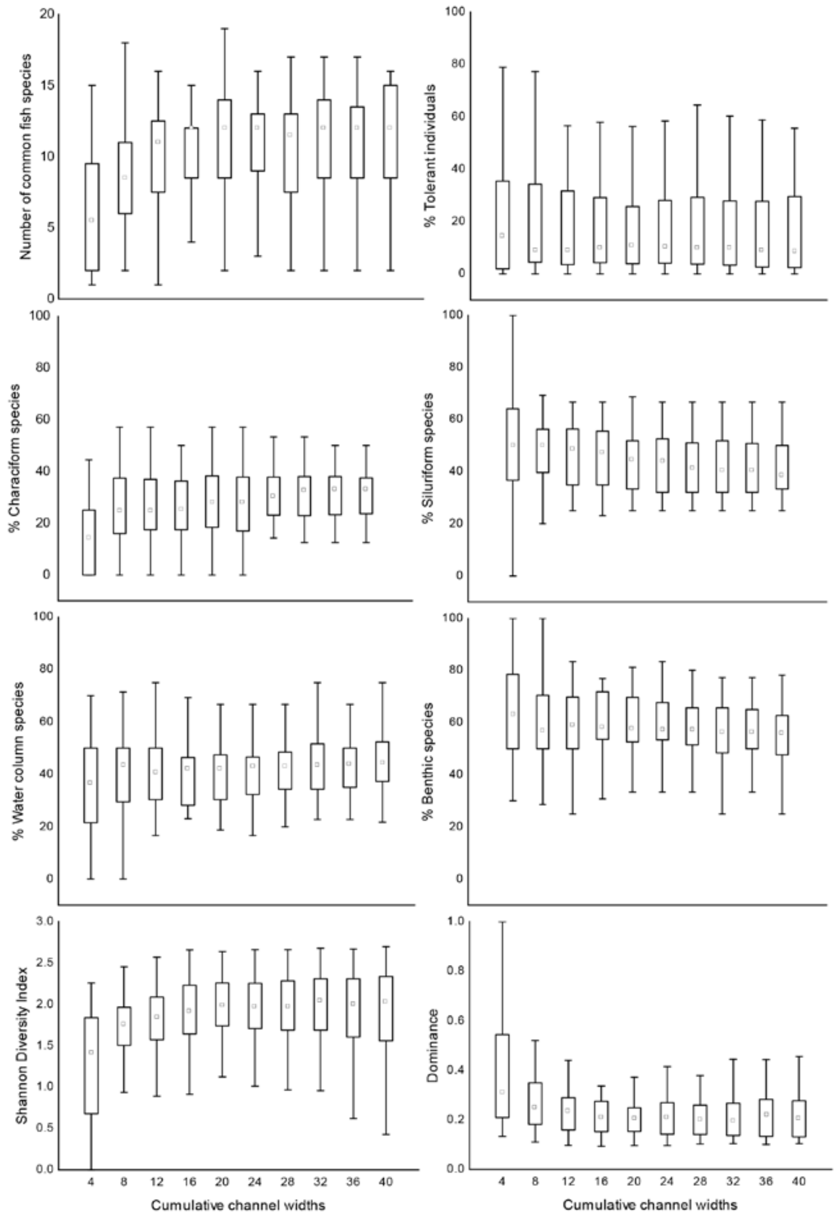

Figure 3. Cumulative fish assemblage metrics versus cumulative site lengths in 32 Atlantic Forest stream sites. The small squares are medians; rectangles show the interquartile ranges; and the whiskers show the minimum and maximum values within classes of each metric.

In Europe, the standard sampling issue is partially resolved by a European standard electrofishing effort of 100 m in wadable streams (Comite Europeen de Normalisation 2003). However, Sály et al. (2009) determined that species richness estimates required >100 m in Hungarian sites with 6–17 species. Erős et al. (2008) reported that asymptotes in species richness were reached in the Danube River, Hungary, after electrofishing 10 wetted channel widths or 5,000 m. Working in 4- to 7-m-wide Belgian streams, Van Liefferinge et al. (2010) found that an electrofishing distance of 452 m was needed to capture 90% of the species present in homogeneous sites, but 380 m was sufficient for heterogeneous sites. These results suggest that the increased effort should be expended in sampling a greater distance versus intensively sampling a shorter distance, probably to incorporate more macrohabitats.

If Brazilian regulatory agencies are interested in consistent and cost-efficient tools to monitor Atlantic Forest streams, they may consider multimetric indexes and 40 channel width site lengths for making biological assessment using fish. However, we advise caution in using IBI metrics based on species richness, such as number of native species, number of characiforms, number of water column species, or number of rare species. Those metrics, although not true estimators of species richness, are closely related to expected species richness and more subject to sampling error than proportional metrics. Therefore, we advise using metrics based on relative abundances, such as percentage of characiform species or individuals or percentage of water column species or individuals. Mebane et al. (2003) and

Whittier et al. (2007b) concluded the same for Western U.S. rivers and wadable streams, respectively.

We conclude that a sampling effort of 40 channel widths is sufficient for assessing fish assemblages via an IBI composed of proportional metrics but insufficient for estimating species richness in Atlantic Forest streams, thereby supporting our second hypothesis but not our first. To collect 95%–99% of all species expected at an Atlantic Forest site, one would likely need to sample a sufficient distance to produce 500+ individuals, but additional research with perhaps as many as 80–100 channel widths may be needed to document such a level of sampling effort.

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APPENDIX. List of species collected in 32 Atlantic Forest stream sites, southeastern Brazil.

Species	Individuals caught
Order: Characiforms, Family: Crenuchidae	
Characidium interruptum Pellegrin, 1909	11
Characidium vidali Travassos, 1967	917
Order: Characiforms, Family: Characidae	
Astyanax cf. *bimaculatus* (Linnaeus, 1758)	19
Astyanax giton Eigenmann, 1908	456
Astyanax hastatus Myers, 1928	290
Astyanax intermedius Eigenmann, 1908	197
Astyanax janeiroensis Eigenmann, 1908	536
Astyanax parahybae Eigenmann, 1908	33
Astyanax sp.	2
Astyanax sp. 1	2
Astyanax sp. 2	14
Astyanax taeniatus (Jenyns, 1842)	1997
Brycon opalinus (Cuvier, 1819)	8
Bryconamericus microcephalus (Miranda Ribeiro, 1908)	1
Bryconamericus ornaticeps Bizerril & Perez-Neto, 1995	442
Bryconamericus tenuis Bizerril & Auraujo, 1992	1
Deuterodon sp.	28
Deuterodon sp. 2	37
Hyphessobrycon reticulatus Ellis, 1911	71
Mimagoniates microlepis (Steindachner, 1877)	378
Oligosarcus hepsetus (Cuvier, 1829)	6
Order: Characiforms, Family: Erythrinidae	
Hoplerythrinus unitaeniatus (Spix & Agassiz, 1829)	1
Hoplias malabaricus (Bloch, 1794)	50
Order: Siluriforms, Family: Callichthyidae	
Callichthys callichthys (Linnaeus, 1758)	2
Corydoras nattereri Steindachner, 1876	49
Scleromystax barbatus (Quoy & Gaimard, 1824)	1158
Order: Siluriforms, Family: Loricariidae	
Ancistrus multispinis (Regan, 1912)	287
Hemipsilichthys gobio (Lütken, 1874)	94
Hisonotus notatus Eigenmann & Eigenmann, 1889	5
Hypostomus affinis (Steindachner, 1877)	74
Hypostomus sp.	43
Kronichthys heylandi (Boulenger, 1900)	90
Loricariichthys castaneus (Castelnau, 1855)	6
Neoplecostomus microps (Steindachner, 1877)	28
Parotocinclus maculicauda (Steindachner, 1877)	193
Pseudotothyris obtusa (Miranda Ribeiro, 1911)	47
Rineloricaria sp. 1	1162
Rineloricaria sp. 2	212
Schizolecis guntheri (Miranda Ribeiro, 1918)	478
Order: Siluriforms, Family: Heptapteridae	
Acentronichthys leptos Eigenmann & Eigenmann, 1889	402
Pimelodella lateristriga (Lichtenstein, 1823)	272
Rhamdia quelen (Quoy & Gaimard, 1824)	347
Rhamdioglanis transfasciatus Miranda Ribeiro, 1908	258
Order: Siluriforms, Family: Trichomycteridae	
Homodiaetus passarellii (Miranda Ribeiro, 1944)	8
Listrura nematopteryx de Pinna, 1988	1
Trichomycterus cf. zonatus (Eigenmann, 1918)	980
Order: Gymnotiforms, Family: Gymnotidae	
Gymnotus sylvius Albert & Fernandes-Matioli, 1999	7
Gymnotus pantherinus (Steindachner, 1908)	64
Order: Cyprinodontiforms, Family: Rivulidae	
Kryptolebias brasiliensis (Valenciennes, 1821)	46
Order: Cyprinodontiforms, Family: Poeciliidae	
Phalloceros aff. *anisophalos*	10
Phalloceros harpagos Lucinda, 2008	221
Poecilia reticulata Peters, 1859	1015
Poecilia vivipara Bloch & Schneider, 1801	392
Xiphophorus sp.[a]	8
Order: Synbranchiforms, Family: Synbranchidae	
Synbranchus marmoratus Bloch, 1795	95
Order: Perciforms, Family: Cichlidae	
Cichla kelberi Kullander & Ferreira, 2006[a]	2
Cichlassoma sp.[a]	1
Crenicichla lacustris (Castelnau, 1855)	3
Geophagus brasiliensis (Quoy & Gaimard, 1824)	569
Oreochromis niloticus (Linnaeus, 1758)[a]	3
Order: Perciforms, Family: Gobiidae	
Awaous tajasica (Lichtenstein, 1822)	9

[a] Alien species.

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REFERENCES

Abell, R., M. L. Thieme, C. Revenga, M. Bryer, M. Kottelat, N. Bogutskaya, B. Coad, N. Mandrak, S. C. Balderas, W. Bussing, M. L. J. Stiassny, P. Skelton, G. R. Allen, P. Unmack, A. Naseka, R. Ng, N. Sindorf, J. Robertson, E. Armijo, J. V. Higgins, T. J. Heibel, E. Wikramanayake, D. Olson, H. L. López, R. E. Reis, J. G. Lundberg, M. H. S. Pérez, and P. Petry. 2008. Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. Bio Science 58:403–414.

Angermeier, P. L., and R. A. Smogor. 1995. Estimating number of species and relative abundances in stream-fish communities: effects of sampling effort and discontinuous spatial distributions. Canadian Journal of Fisheries and Aquatic Sciences 52:936–949.

Araújo, F. G. 1998. Adaptation of the index of biotic integrity based on fish assemblages in the Paraíba do Sul River, RJ, Brazil. Brazilian Journal of Biology 58:547–558.

Araújo, F. G., I. Fichberg, B. C. Pinto, and M. G. Peixoto. 2003. A preliminary index of biotic integrity for monitoring condition of the Rio Paraíba do Sul, Southeast Brazil. Environmental Management 32:516–526.

Baptista, D. F., D. F. Buss, M. Egler, A. Giovanelli, M. P. Silveira, and J. Nessimian. 2007. A multimetric index based on benthic macroinvertebrates for evaluation of Atlantic Forest streams at Rio de Janeiro State, Brazil. Hydrobiologia 575:83–94.

Bonar, S., W. Hubert, and D. Willis, editors. 2009. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Bozzetti, M., and U. H. Schulz. 2004. An index of biotic integrity based on fish assemblages for subtropical streams in southern Brazil. Hydrobiologia 529:133–144.

Cao, Y., D. P. Larsen, and R. M. Hughes. 2001. Evaluating sampling sufficiency in fish assemblages: a similarity-based approach. Canadian Journal of Fisheries and Aquatic Sciences 58:1782–1793.

Casatti, L., C. P. Ferreira, and F. Langeani. 2009. A fish-based biotic integrity index for assessment of lowland streams in southeastern Brazil. Hydrobiologia 623:173–189.

Chao, A. 1984. Non-parametric estimation of the number of classes in a population. Scandinavian Journal of Statistics 11:265–270.

Chao, A. 1987. Estimating the population size for capture–recapture data with unequal catchability. Biometrics 43:783–791.

Clarke, K. R., and R. N. Gorley. 2006. PRIMER v6: user manual/tutorial. PRIMER-E, Plymouth, UK.

Comite Europeen de Normalisation. 2003. Water quality—sampling of fish with electricity. CEN, European Standard EN 14011:2003 E, Brussels, Belgium.

Dauwalter, D. C., and E. J. Pert. 2003a. Effect of electrofishing effort on an index of biotic integrity. North American Journal of Fisheries Management 23:1247–1252.

Dauwalter, D. C., and E. J. Pert. 2003b. Electrofishing effort and fish species richness and relative abundance in Ozark Highland streams of Arkansas. North American Journal of Fisheries Management 23:1152–1166.

Dolph, C. L., A. Y. Sheshukov, C. J. Chizinski, B. Vondracek, and B. Wilson. 2010. The index of biological integrity and the bootstrap: can random sampling error affect stream impairment decisions. Ecological Indicators 10:527–537.

Dos Anjos, M. B., and J. Zuanon. 2007. Sampling effort and fish species richness in small terra firme forest streams of central Amazonia, Brazil. Neotropical Ichthyology 5:45–52.

Dußling, U., R. Berg, H. Klinger, C. Wolter, and R.-D. Wilken. 2004. Assessing the ecological status of river systems using fish assemblages. Pages 1–84 *in* C. Steinberg, W. Calmano, and H. Klapper, editors. Handbuch angewandte limnologie,VIII-7.4, 20. Ecomed, Landsberg am Lech, Bavaria.

Efron, B. 1979. Bootstrap methods: another look at the jackknife. Annals of Statistics 7:1–26.

Efron, B. 1981. Nonparametric estimates of standard error: the jackknife, the bootstrap and other methods. Biometrika 68:589–599.

Erős, T., B. Tóth, A. Sevcsik, and D. Schmera. 2008. Comparison of fish assemblage diversity in natural and artificial rip-rap habitats in the littoral zone of a large river (River Danube, Hungary). International Review of Hydrobiology 93:88–105.

Ferreira, C. P., and L. Casatti. 2006a. Influence of habitat structure on fish from a stream in a micro-watershed pasture, São Paulo, Brazil. Brazilian Journal of Zoology 23:642–651.

Ferreira, C. P. and L. Casatti. 2006b. Stream biotic integrity assessed by fish assemblages in the Upper Rio Paraná basin. Biota Neotropica 6:1–25.

Fischer, J. R., and C. P. Paukert. 2009. Effects of sampling effort, assemblage similarity, and habitat heterogeneity on estimates of species richness and relative abundance of stream fishes. Canadian Journal of Fisheries and Aquatic Sciences 66:277–290.

Froese, R., and D. Pauly, editors. 2012. FishBase. Available: http://www.fishbase.org. (April, 2012).

Ganasan, V., and R. M. Hughes. 1998. Application of an index of biological integrity to fish assemblages of the rivers Khan and Kshipra, India. Freshwater Biology 40:367–383.

Gerhard, P., R. Moraes, and S. Molander. 2004. Stream fish communities and their associations to habitat variables in a rainforest reserve in southeastern Brazil. Environmental Biology of Fishes 71:321–340.

Gotelli, N., and R. K. Colwell. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4:379–391.

Hammer, Ø., D. A. T. Harper, and P. D. Ryan. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1).

Hellman, J. J., and G. W. Fowler. 1999. Bias, precision, and accuracy of four measures of species richness. Ecological Applications 9:824–834.

Hughes, R. M., and J. R. Gammon. 1987. Longitudinal changes in fish assemblages and water quality in the Willamette River, Oregon. Transactions of the American Fisheries Society 116:196–209.

Hughes, R. M., and A. T. Herlihy. 2007. Electrofishing distance needed to estimate consistent index of biotic integrity (IBI) scores in raftable Oregon rivers. Transactions of the American Fisheries Society 136:135–141.

Hughes, R. M., A. T. Herlihy, W. J. Gerth, and Y. Pan. 2012. Estimating vertebrate, benthic macroinvertebrate, and diatom taxa richness in raftable Pacific Northwest rivers for bioassessment purposes. Environmental Monitoring Assessment 184:3185–3198.

Hughes, R. M., P. R. Kaufmann, A. T. Herlihy, S. S. Intelmann, S. C. Corbett, M. C. Arbogast, and R. C. Hjort. 2002. Electrofishing distance needed to estimate fish species richness in raftable Oregon rivers. North American Journal of Fisheries Management 22:1229–1240.

Hughes, R. M., and D. V. Peck. 2008. Acquiring data for large aquatic resource surveys: the art of compromise among science, logistics, and reality. Journal of the North American Benthological Society 27:837–859.

Japan International Cooperation Agency. 1994. The study on recuperation of Guanabara Bay ecosystem. Tokyo, Kokusai Kogyo Co.

Kanno, Y., J. C. Vokoun, D. C. Dauwalter, R. M. Hughes, A. T. Herlihy, T. R. Maret, and T. M. Patton. 2009. Influence of rare species on electrofishing distance when estimating species richness of stream and river reaches. Transactions of the American Fisheries Society 138:1240–1251.

Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management 12:198–203.

Magalhães, M. F., C. E. Ramalho, and M. J. Collares-Pereira. 2008. Assessing biotic integrity in a Mediterranean watershed: development and evaluation of a fish-based index. Fisheries Management and Ecology 15:273–289.

Magurran, A. E. 2004. Measuring biological diversity. Blackwell Publishing, London.

Mazzoni, R., N. Fenerich-Verani, and E. P. Caramasch. 2000. Electrofishing as a sampling technique for coastal stream fish populations in the southeast of Brazil. Revista Brasileira de Biologia 60(2):205–216.

Mazzoni, R., N. Fenerich-Verani, E. P. Caramaschi, and R. Iglesias--Rios. 2006. Stream-dwelling fish communities from an Atlantic rainforest drainage. Brazilian Archives of Biology and Technology 49:249–256.

Mebane, C. A., T. R. Maret, and R. M. Hughes. 2003. An index of biological integrity (IBI) for Pacific Northwest rivers. Transactions of the American Fisheries Society 132:239–261.

Ministério do Meio Ambiente, Conservation International do Brasil, Fundação SOS Mata Atlântica, Fundação Biodiversitas, Instituto de Pesquisas Ecológicas, Secretaria do Meio Ambiente do Estado de São Paulo, and SEMAD/ Instituto Estadual de Florestas-MG. 2000. Assessment and Priority Actions for Conservation of Atlantic Rain Forest and Southern Fields Biodiversity. Ministério do Meio Ambiente, Brasília.

Mugnai, R., R. B. S. Oliveira, A. L. Carvalho, and D. F. Baptista. 2008. Adaptation of the *indice biotico esteso* (IBE) for water quality assessment in rivers of Serra do Mar, Rio de Janeiro State, Brazil. Tropical Zoology 21:57–74.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.

Oberdorff, T., D. Pont, B. Hugueny, and J. P. Porcher. 2002. Development and validation of a fish-based index (FBI) for the assessment of French rivers: a framework for environmental assessment. Freshwater Biology 46:399–415.

Oliveira, R. B., D. F. Baptista, R. Mugnai, C. M. Castro, and R. M. Hughes. 2011. Towards rapid bioassessment of wadeable streams in Brazil: development of the Guapiaçu-Macacu multimetric index (GMMI) based on benthic macroinvertebrates. Ecological Indicators 11:1584–1593.

Paller, M. H. 1995. Relationships among number of fish species sampled, reach length surveyed, and sampling effort in South Carolina coastal plain streams. North American Journal of Fisheries Management 15:110–120.

Patton, T. M., W. A. Hubert, F. J. Rahel, and K. G. Gerow. 2000. Effort needed to estimate species richness in small streams on the Great Plains in Wyoming. North American Journal of Fisheries Management 20:394–398.

Peck, D. V., A. T. Herlihy, B. H. Hill, R. M. Hughes, P. R. Kaufmann, D. J. Klemm, J. M. Lazorchak, F. H. McCormick, S. A. Peterson, P. L. Ringold, T. Magee, and M. R. Cappaert. 2006. Environmental Monitoring and Assessment Program—Surface Waters Western Pilot Study: field operations manual for wadeable streams. U.S. Environmental Protection Agency, Office of Research and Development, EPA 600/R-06/003, Washington, D.C.

Pinto, B. C., and F. G. Araújo. 2007. Assessing of biotic integrity of the fish community in a heavily impacted segment of a tropical river in Brazil. Brazilian Archives of Biology and Technology 50(3):489–502.

Pinto, B. C., F. G. Araújo, and R. M. Hughes. 2006. Effects of landscape and riparian condition on a fish index of biotic integrity in a large southeastern Brazil river. Hydrobiologia 556:69–83.

Pont, D., R. M. Hughes, T. R. Whittier, and S. Schmutz. 2009. A predictive index of biotic integrity model for aquatic-vertebrate assemblages of Western U.S. streams. Transactions of the American Fisheries Society 138:292–305.

Pont, D., B. Hugueny, U. Beir, D. Goffaux, A. Melcher, R. Noble, C. Rogers, N. Roset, and S. Schmutz. 2006. Assessing river biotic condition at the continental scale: a European approach using functional metrics and fish assemblages. Journal of Applied Ecology 43:70–80.

Rabeni, C. F., J. Lyons, N. Mercado-Silva, and J. T. Peterson. 2009. Warmwater fish in wadeable streams. Pages 43–58 *in* S. A. Bonar, W. A. Hubert, and D. W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Reynolds, L., A. T. Herlihy, P. R. Kaufmann, S. V. Gregory, and R. M. Hughes. 2003. Electrofishing effort requirements for assessing species richness and biotic integrity in western Oregon streams. North American Journal of Fisheries Management 23:450–461.

Rezende, C. F., M. Moraes, L. R. Manna, R. P. Leitão, E. P. Caramaschi, and R. Mazzoni. 2010. Mesohabitat indicator species in a coastal stream of the Atlantic rainforest, Rio de Janeiro-Brazil. Revista de Biología Tropical 58:1479–1487.

Sály, P., T. Erős, P. Takács, A. Specziár, I. Kiss, and P. Bíró. 2009. Assemblage level monitoring of stream fishes: the relative efficiency of single-pass vs. double-pass electrofishing. Fisheries Research 99:226–233.

Segurado, P, J. M. Santos, D. Pont, A. Melcher, D. Garcia Jalon, R. M. Hughes, and M. T. Ferreira. 2011. Estimating species tolerance to human perturbation: expert judgment versus quantitative approaches. Ecological Indicators 11:1623–1635.

Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustenável. 2001. Fluminense Watershed and Rivers—Informational Summary by Macro Region. Planágua, Rio de Janeiro, Brazil.

Smith, E. P., and G. van Belle. 1984. Nonparametric estimation of species richness. Biometrics 40:119–129.

Smith, K. L., and M. L. Jones. 2008. Allocation of sampling effort to optimize efficiency of watershed-level ichthyofaunal inventories. Transactions of the American Fisheries Society 137:1500–1506.

Terra, B. F., and F. G. Araújo. 2011. A preliminary fish assemblage index for a transitional river reservoir system in southeastern Brazil. Ecological Indicators 11:874–881.

Van Liefferinge, C., I. Simoens, C. Vogt, T. J. S. Cox, J. Breine, D. Ercken, P. Goethals, C. Belpaire, and P. Meire. 2010. Impact of habitat diversity on the sampling effort required for the assessment of river fish communities and IBI. Hydrobiologia 644:169–183.

Vaux, P. D., T. R. Whittier, G. DeCesare, and J. P. Kurtenbach. 2000. Evaluation of a backpack electrofishing unit for multiple-lake surveys of fish assemblage structure. North American Journal of Fisheries Management 20:168–179.

Wan, H., C. J. Chizinski, C. L. Dolph, B. Vondracek, and B. N. Wilson. 2010. The impact of rare taxa on a fish index of biotic integrity. Ecological Indicators 10:781–788.

Whittier, T. R., R. M. Hughes, G. A. Lomnicky, and D. V. Peck. 2007a. Fish and amphibian tolerance values and an assemblage tolerance index for streams and rivers in the Western USA. Transactions of the American Fisheries Society 136:254–271.

Whittier, T. R., R. M. Hughes, J. L. Stoddard, G. A. Lomnicky, D. V. Peck, and A. T. Herlihy. 2007b. A structured approach to developing indices of biotic integrity: three examples from Western USA streams and rivers. Transactions of the American Fisheries Society 136:718–735.

FEATURE

Supporting Undergraduate Education with Realistic Laboratory Exercises and Research Experience

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ABSTRACT: *Higher education programs can offer hands-on experiences in the form of laboratory or field exercises, experiential learning, and undergraduate research opportunities to students, though at an increased cost in terms of financial, material, and personnel requirements. In a climate where institutions seek to streamline their dwindling budgets, it could be tempting to eliminate some of these programs to focus on more traditional classroom-based education. This outcome, if combined with the traits of the typical "millennial generation" student, raises the possibility that current and future student cohorts will lack practical experience in core areas. We argue that despite the challenges of garnering funding and institutional support, it is both possible and beneficial to provide undergraduates with the hands-on experiences, experiential learning, and exposure to research and management topics that enrich their education and better prepare them for entry-level positions or graduate school. We describe a multitiered approach for doing so and include examples from successful programs at Colorado State University and Florida Gulf Coast University.*

Apoyo a la educación superior con ejercicios realistas en laboratorio y experiencia en investigación

RESUMEN: *los programas de educación a nivel superior pueden ofrecer contacto directo con la práctica en forma de ejercicios de campo o laboratorio, aprendizaje por experiencia, y oportunidades de investigación para estudiantes no graduados, sin embargo esto se ha logrado a un costo creciente en términos de recursos humanos, materiales y financieros. En un clima en el que las instituciones buscan optimizar sus magros presupuestos, pudiera resultar atractivo la eliminación de algunos de estos programas y enfocarse en una educación más tradicional en las aulas. Este resultado, si se combinase con los atributos del típico estudiante de la "generación del milenio", aumentaría la posibilidad de que las cohortes de estudiantes del presente y del futuro adolezcan de una experiencia práctica en áreas críticas. Se argumenta que a pesar de los retos de encontrar fondos y apoyo institucional, es posible y también benéfico darles a los estudiantes de nivel superior experiencias directas, aprendizaje por experiencia y contacto con investigación sobre tópicos de manejo, enriqueciendo su educación y preparándolos mejor para que opten por un puesto básico o por un posgrado. Para lograr esto, aquí se describe un enfoque multi-niveles y se incluyen ejemplos de programas exitosos en la Universidad del Estado de Colorado y en la Universidad de la Costa Oeste de Florida.*

INTRODUCTION

Hands-on laboratory experiences and research opportunities often "hook" or help retain undergraduates, especially in science fields such as fisheries (Locks and Gregerman 2008; Fechheimer et al. 2011). These same exercises and experiences help distinguish the applied nature of fisheries biology from other biological fields. Graduates from programs that forego these opportunities may be at a competitive disadvantage because they lack practical experience; their employers may have to devote additional resources to training.

Additionally, the students of today, often referred to as the "millennial generation" (Howe and Strauss 2000), possess broad character traits that may require a reformulation of instructional approaches. Many of these students are part of the generation that has been characterized as having "nature-deficit disorder" (Louv 2005) because they lack experience with the outdoors during their formative years (Hubert 2011). As Millenbah et al. (2011) elegantly summarized, the millenials are more sheltered than prior generations and have a strong sense of entitlement, often to the point of assuming that they should be positively rewarded regardless of performance, in part because of the price they (or their parents) pay for higher education. The millenials are also team oriented and technologically proficient, at least for the types of technology they commonly use. They are confident and used to success both within and outside of the academic realm. Nevertheless, the millenials are under pressure to perform, because of both the expectation of success and the increased financial burden many undertake to attend college (Millenbah et al. 2011), leading to a need to carefully partition their time and energy between courses and other areas. The U.S. Department of Education reported that 40% of full-time college students were employed, with 14.9% working fewer than 20 h per week, 17.2% working 20–34 h per week, and 6.6% working more than 35 h per week. The percentages for part-time students were higher, with 73% holding jobs; of those, 28.3% worked 20–34 h per week, and 32.8% worked 35 or more hours per week (Aud et al. 2012). This additional workload limits the amount of time available for these students to devote to course-based activities. The annual U.S. Department of Education survey highlights one reason to make learning more effective during scheduled class times—incorporating labs and active hands-on learning provides educators with the means to do so.

Millenbah et al. (2011) suggested that postsecondary instructors need to be willing to provide more in-depth instruction on the value of individual and experimental research and that universities show the "worth" of their programs to students interested in a career in natural resources, whether on the biological or engineering side. At the same time, university programs also need to maintain a view of the target, in this case the skills that fisheries professionals view as important. These were outlined by Gabelhouse (2010) and include field techniques, technical writing and oral communication, fish culture, research methods, and experimental/survey design.

One factor that further complicates the picture is the general state of budgets for institutions of higher education. These budgets have declined in recent years and, in many cases, the institutions have sought to partially offset the lost revenue with tuition increases (Kelderman 2008; Jackson et al. 2010). As the institutions streamline their programs to reduce expenses, one area that may be reduced or eliminated altogether is the provision of hands-on experiences, including those in biological science courses involving live animals such as fisheries biology (University of California–Office of the President 2002; Smialek 2011). Such a trend would further exacerbate the problem of providing undergraduates with quality hands-on research experiences.

Despite these challenges, we argue that it is still possible and beneficial to provide undergraduate students with hands-on experience, experiential learning, and exposure to fisheries research and management. As students take on a greater proportion of the costs associated with their education, one could argue that providing them with such opportunities is a way of giving them a more valuable product than the traditional, classroom-based instruction. Indeed, in light of the recommendations by American Association for the Advancement of Science (2011), providing more of these opportunities can help improve the overall quality of undergraduate education.

A MULTITIERED APPROACH TO INCREASING HANDS-ON EXPERIENCE FOR UNDERGRADUATES

We propose a multitiered approach to providing students with practical experience in fisheries biology, based on our collective experience as faculty, graduate students, and undergraduates. The institutions where we have gained this experience are Colorado State University (CSU), a Carnegie research university with an on-campus enrollment of ~27,000 students; the University of California Davis; the University of California Berkeley; and Florida Gulf Coast University (FGCU), a Carnegie master's college and university with ~12,000 students. The approach consists of (1) including realistic laboratory exercises, (2) encouraging students to gain extracurricular work experience, (3) maintaining active student subunits of professional societies that conduct group projects, (4) collaborative teaching with local agencies, and (5) supporting undergraduate research opportunities. These concepts have been increasingly applied in other science disciplines (see Locks and Gregerman 2008; Dillner et al. 2011; Wei and Woodin 2011) and have been recommended for wildlife biologists (Millenbah and Millspaugh 2003). We will illustrate this approach using examples from the fishery biology and water engineering programs at CSU and FGCU.

Realistic Hands-On Laboratory Exercises

Students have long benefited from laboratory exercises that reinforce key concepts from traditional classroom learning. When possible, laboratory exercises that involve live organisms should be integrated with lecture topics and should take advantage of local fisheries resources to help increase the relevance. At CSU, three of six undergraduate fisheries courses offer weekly laboratory exercises with live fish, and two of the remaining courses have weekend field trips that allow students to work with live fish. The three courses with weekly labs that frequently use live fish are FW204, Introduction to Fishery Biology; FW402, Fish Culture; and FW405, Fish Physiology.

The drawbacks to using live fish include the regulatory burden, cost, and the increased logistics associated with live animal laboratories. From a regulatory standpoint, most universities will require an institutional animal care and use committee (IACUC) protocol that describes, in detail, how fish will be procured, handled, and used in the laboratory exercises. Most instructors will already have experience with the preparation of such protocols because of their research programs, and modifying them for laboratory exercises is not overly difficult. Indeed, if graduate students are involved with the courses (either taking the courses or as graduate teaching assistants), the preparation of the protocols can provide training for teaching assistants and can become one of the topics of instruction. At CSU, each course that includes a live animal component has at least one IACUC protocol that applies directly to the laboratory exercises, along with state collection permits, where necessary.

The logistics associated with live animal laboratory exercises include procuring and holding fish, sometimes for extended periods, so dedicated facility space and equipment is necessary. Again, instructors who also run research programs should be experienced in collecting and holding live fish, but additional planning will be required to allocate sufficient space and equipment for the actual conduct of the laboratory exercises. In the CSU example, rather than have a separate set of equipment that is used exclusively for instruction, the labs in FW204, FW402, and FW405 use the same state-of-the-art equipment used on undergraduate, graduate, and faculty research projects such as multichannel oxygen analyzers, variable-speed swim-

Photo 1. Florida Gulf Coast University students enrolled in CWR 3201, Engineering Fluid Mechanics, use the outside of their hybrid laboratory and lecture building to aid their measurement of the ability of a water pump to lift water through a narrow PVC pipe.

ming flumes, and backpack electroshockers. The labs at CSU typically involve 20–30 students and during a laboratory period, they have access to roughly 1,200 ft^2 of the 4,000-ft^2 Foothills Fisheries Laboratory. At FGCU the engineering building was designed specifically to accommodate lecture and laboratory components in the same classroom. Such integrated classrooms allow for labs and demonstrations to occur during a lecture when the material is most appropriate (Illustration 1). Labs during a long class period (e.g., 2.25 h at FGCU) also aid in keeping students focused and excited; in turn, these longer periods provide more opportunities for nontraditional teaching approaches.

One aspect of hands-on laboratory exercises that has been very well received by students at CSU is the novel exercise, where students are in essence conducting original research on a topic, rather than repeating a "canned" exercise that has a known answer. Such exercises may not always succeed, but even in those cases students learn valuable lessons about the true nature of research. In cases where the exercises do succeed, they can be cast as pilot studies that provide data that are then used in the design of more rigorous studies. For example, students in FW405 measured the jumping ability of Fathead Minnows (*Pimephales promelas*) using Kondratieff-type artificial waterfalls (Illustration 2) at the same time as a graduate project on plains fish passage (Ficke et al. 2011) and were able to demonstrate that Fathead Minnows were closest to Common Shiners (*Luxilus cornutus*) in their ability to jump over instream obstacles. The idea that they are doing something novel and original appeals to most students, even when the experiment does not work. An added benefit of this approach is the exposure of students to the unpredictable nature of real data collection, which can be a valuable experience not easily simulated in a traditional lecture setting. Because some students are frustrated by hypothesis-driven experiments with uncertain outcomes (Trosset et al. 2008), it is important to include experiments with predictable outcomes as part of the curriculum.

Encourage Students to Gain Work Experience

The time commitment and credit-hour limitations placed upon undergraduate curricula normally preclude the inclusion of comprehensive laboratory and field training in all aspects of the activities of a professional biologist, fish culturist, or engineer. In order to provide students with this valuable experience, we recommend that institutions actively encourage students to gain work experience in3 one or more areas of fisheries biology to supplement the experience gained in more formal coursework. Such work experience can be gained in university research labs; with state, federal, or tribal fisheries programs; or with private companies and organizations.

In the CSU example, all students majoring in fish, wildlife, and conservation biology with a concentration in fisheries and aquatic sciences must complete 160 hours of faculty-approved work experience prior to graduation. This requirement has been in place long enough that local and regional agencies (e.g., Colorado Parks and Wildlife [CPU], Wyoming Department of Game and Fish, U.S. Forest Service) regularly send seasonal and temporary job announcements to the fisheries faculty for distribution to students. In a few cases, the agencies can reduce their financial burden by offering work–study positions. The distribution of the announcements is simplified by the use of university-sponsored list servers and the use of the American Fisheries Society (AFS) student subunit list server.

Maintain Active Student Subunits of Professional Societies

Pate et al. (2011) demonstrated the value of an active student subunit of the AFS for providing students with field experience and an introduction to fisheries research and management. We feel that this is crucial to the development of collaborative skills on research or management projects and also allows for interaction with agency personnel that may lead to future partnerships or employment opportunities. Like most student-run organizations, the level of interest and involvement in a student subunit can vary from year to year (Dunkel and Schuh 1998); those with a mixture of undergraduate and graduate students tend to persist and remain active. Some additional benefits of having a vibrant student chapter include recruitment of students from area high schools, retention of students, and student development of professional skills and habits such as attending conferences and seminars.

Student subunits do not and should not operate in a vacuum and should expect some level of assistance from their faculty advisors and parent AFS chapters. The level of faculty involvement necessary will vary, but at the minimum faculty advisors can assist with the procurement of permits (including IACUC permits), provide guidance with project design and logistics, and, in some cases, help with proposal preparation or secure funding. Having a supportive academic department, AFS parent chapter, and AFS division are also helpful, particularly for securing funding for small research or management projects and financing student travel (particularly undergraduate travel) to local chapter and division-level annual meetings to participate and present the results of the subunit's activities. In cases where a student subunit is marginally active, faculty (or agency collaborators) may be able to spark interest by suggesting possible research ideas with important management or scientific implications. At CSU, offering credits for group research can encourage some of the students to participate in these projects, because of the concrete academic benefit. Finally, student subunits are also excellent sources of volunteers for graduate and faculty research projects where additional help is needed on a short-term basis, provided that the researchers are aware of the challenges associated with volunteer help (Leslie et al. 2004).

Collaborative Teaching with Local Agencies

When courses incorporate collaborative teaching with professionals from local agencies, students gain an increased exposure to real-world problems, activities, and solutions while still in a classroom environment. This further demonstrates the worth of the material presented by the instructors, something that is important to the millennial student (Millenbah et al. 2011). The level of collaboration can range from having professionals deliver guest lectures to scheduling joint field activities where students shadow, and are mentored by, the professionals. These joint collaborations can include the development of course modules where students work directly for professionals. The collaborative activities can be part of a regular course or they can take the form of independent or group studies.

One challenge of such collaborations, especially at the more intensive end of the continuum, is the differential amount of time that individual students can allocate to the sponsored activities. Instructors must be careful to reward students in a fair manner, taking such differences in availability into account. Regardless of the level of collaboration and student involvement, including this exposure to the real world can give students a head start when they do tackle similar situations in their professional careers and, at the very least, lets them network with professionals.

For example, in FW204 students receive a number of guest lectures from CPW biologists and fish culturists and from private sector fisheries consultants and fish culturists. At the other end of the spectrum, FW402 students worked with a CPW regional biologist to culture Yellow Perch (*Perca flavescens*) and White Crappie (*Pomoxis annularis*). The students were responsible for preparing research ponds on the CSU Foothills Research Campus to receive fish and developed pond culture plans based on literature searches and discussions with CPW personnel. The CPW regional biologist and students collected broodstock from local waters to stock the ponds. Once fry had been produced, the ponds were harvested and used to stock local waters as part of the biologist's management activities (Illustration 3). Though numbers of fry produced were lower than expected by a production hatchery, students learned valuable lessons and developed contacts within CPW.

Photo 2. Colorado State University students enrolled in FW405, Fish Physiology, use small Kondratieff-type artificial waterfalls to measure the jumping ability of Fathead Minnows as a function of plunge pool depth and weir height.

Support Undergraduate Research

Students who are given the opportunity to participate in research as undergraduates gain valuable experience in the conduct of research and learn more about fisheries because of their greater immersion in the topics relevant to the project. With this in mind, we recognize at least three levels of undergraduate research involvement. The first (and likely most common) level is that of encouraging undergraduates to work as research assistants on graduate or faculty-led research projects either as volunteers or as paid employees. This approach is good for providing undergraduates with the opportunity to learn specific technical methods and, with good mentoring, can lead to a greater understanding of the larger field of fisheries biology. At CSU and the University of California Davis, this was the most common form of undergraduate involvement, and most fisheries labs employed two or more undergraduates per sponsored research project; indeed, without undergraduate assistance, many of the projects would not have been possible.

The second level builds upon the first by encouraging undergraduate students to work on a small aspect of the larger project, often as an independent study or honor's thesis. Reaching this level adds additional learning from data analyses and synthesis of concepts and, thus, greater understanding of the research or management process. Granted, there is a greater burden on both the undergraduate and the graduate students and faculty who work with them, but the advantages are increased

Photo 3. Students enrolled in FW402 prepare to remove spawning substrate (blue spruce trees) from one of the ponds used to raise White Crappie (*Pomoxis annularis*) in a service-learning project with Colorado Parks and Wildlife.

likelihood of the undergraduate collecting data that lead to presentations at professional meetings or submission of a manuscript to a peer-reviewed journal. Brandt et al. (2005), studying the effects of waterfall dimensions and light level on the jumping ability of juvenile Brook Trout (*Salvelinus fontinalis*), provided an example where two undergraduate students worked with a graduate student on a larger Brook Trout jumping project and based their research ideas on observations of Brook Trout behavior in that larger project.

The third level, where the undergraduates are given the opportunity to conduct independent research projects, is the most comprehensive and the least common; it is sometimes referred to as the "apprenticeship model" in the literature (Wei and Woodin 2011). In this case, the student develops the research idea and works with mentors through the entire research project. The end goal of such a project should be a report, or presentation, and, in the case of particularly well-designed studies, peer-reviewed publications. This level of support for undergraduate research provides them with the greatest degree of autonomy and can also provide the greatest academic reward in the form of a first-authored publication.

Each undergraduate research level can require substantially greater commitment of time and resources from the supporting faculty, graduate students, and the undergraduate student. The undergraduates must understand that committing to level 2 and 3 projects may require multiple semesters and coping with the unexpected challenges of research. Thus, students must be carefully counseled on the scope of the project and could require greater assistance on experimental design and proposal preparation.

The role of research mentor for these higher-level projects can fall to graduate students or faculty, but given the demands typically placed on graduate research assistant time, it is probably best for the undergraduate to work closely with a faculty member or Ph.D. candidate. The end reward for mentor, from an academic or career advancement standpoint, is a potential publication in a peer-reviewed journal; the reward from a professional standpoint is having successfully mentored a young scientist through the entire research process. Because of the inexperience of the undergraduate researcher, compared to a typical graduate student, the mentor must be willing to allocate more time and extend the usual timeline for report or manuscript preparation, perhaps even beyond graduation (Wei and Woodin 2011).

Third-level projects oftetn require a dedicated source of funding to pay for research expenses and, ideally, for student travel to attend professional conferences. Funding mechanisms ranging from departmental or faculty discretionary funds to national programs that support undergraduate research such as the National Science Foundation's Research Experience for Undergraduates are available. Millspaugh and Millenbah (2004) provided a comprehensive list of national programs that support undergraduate research. The equipment costs for third-level projects can be kept reasonable if students are encouraged to use equipment already present in a laboratory or if equipment can be borrowed from other sources.

Not all third-level projects lead to peer-reviewed publications but a substantial proportion do, provided that mentors are willing to devote additional time to working with the students through the publication process. For example, the Fish Physiological Ecology Laboratory at CSU has supported 14 independent undergraduate research projects in the last decade; 6 of the projects have culminated in a peer-reviewed publication. Irrespective of the end products, each of the 14 undergraduate projects in the Fish Physiological Ecology Laboratory has been a positive experience for all, and eight of the participating students have since earned master's degrees in related fields.

APPARENT AND HIDDEN COSTS OF PROVIDING HANDS-ON EXPERIENCE

Providing students with hands-on and experiential learning and with undergraduate research opportunities is not without costs, as has been briefly mentioned above. For example, at CSU and FGCU, courses with intensive laboratory sections such as those above use different approaches to support the courses. At CSU, students are assessed a "special course fee" to help cover the costs of vehicle rental and the purchase of expendable materials and supplies. The equipment used in the laboratory exercises was purchased with startup funds provided to the professor specifically for teaching purposes or was purchased for a research project and, upon completion of the project, is also used in teaching. In contrast, at FGCU, the students are assessed a relatively minor fee for supplies, and the university covers the capital cost of purchasing the demonstration equipment (estimated at over $100,000; Table 1). Under an ideal scenario, these costs would be borne by the institution, but because discretionary and instructional budgets have been reduced, some of the costs are being passed along to the students. Not immediately apparent are the costs borne by the instructors who elect to use their research equipment and supplies to supplement the teaching inventory. These costs, particularly for expensive items such as boats, swimming flumes, and acoustic Doppler velocimeters, can run into tens of thousands of dollars.

A related challenge is that of providing students with a low student-to-instructor ratio. As shown in Table 1, the courses at CSU and FGCU enjoy relatively low enrollments. These low student numbers allow greater interactions among students and with course staff and are also manageable in terms of logistics. In courses with larger enrollments (i.e., anything over 30 students), additional laboratory sections that break the course into smaller groups would be required. Adding laboratory sections would also require either more course staff in the form of graduate and undergraduate teaching assistants or an understanding between the instructor and the administration that the added teaching load would necessarily result in a reduction in research productivity. If the institutional funding situation precludes the hiring of additional graduate teaching assistants, offering undergraduate teaching assistants credit hours for the time spent working with their peers is one possible alternative.

TABLE 1. Average enrollment and current student course fees for courses at Colorado State University and Florida Gulf Coast University that provide intensive hands-on laboratory sections. The course fee allocations include cost of vehicle rental (travel); expendable supplies such PVC pipe, fish feed, and reagents; and services such as boat and equipment maintenance.

Institution	Course name and number	Average enrollment (no. of years)	Current student course fee ($US)	Course fee allocation (%)		
				Travel	Supplies	Services
CSU	Introduction to Fishery Biology	17 (11)	65	22	63	15
	Fish Culture	12 (11)	55	15	69	16
	Fish Physiology	18 (5)	35	—	88	12
FGCU	Fluid Mechanics	28 (6)	10	—	100	—
	Hydrology/ Hydraulics	27 (5)	None	—	—	—
	Water Resources Design	24 (5)	10	—	100	—

A final cost, to the instructors, is a professional one. Currently, the dominant paradigm for tenure and advancement in research-oriented universities is an emphasis on research productivity, which may be measured in the amount of funding secured and number of publications. Faculty in such institutions may find it challenging and perhaps counterproductive to increase their emphasis on undergraduate research and experiential learning because it could limit their research productivity and thus their chances for advancement. However, if interested faculty can initiate a paradigm shift by successfully arguing for an emphasis on enhanced undergraduate training while maintaining some base level of research productivity, then the field as a whole would benefit.

CONCLUSIONS

Faculty at institutions of higher education continue to be challenged with the need to deliver high-quality instruction to cohorts of undergraduates who are bearing a greater tuition cost at the same time that resources for teaching traditional courses are being reduced. Rather than trying to include ever more information into traditional lecture courses, we suggest that a greater emphasis on activities that provide undergraduate students with more practical experiences, particularly those that give students some degree of autonomy, will pay the greatest dividends for the students and, ultimately, for the profession. Doing so does require faculty to sacrifice some of the time allocated to traditional roles of instructor, researcher, and graduate advisor and does require greater administrative support (Millenbah and Millspaugh 2003). Nevertheless, the rewards in terms of more effective undergraduate training and mentoring do, in our opinion, make these sacrifices worthwhile.

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REFERENCES

American Association for the Advancement of Science. 2011. Vision and change in undergraduate biology education: a call to action. American Association for the Advancement of Science, Washington, D.C.

Aud, S., W. Hussar, F. Johnson, G. Kena, E. Roth, E. Manning, X. Wang, and J. Zhang. 2012. The condition of education 2012. U.S. Department of Education, NCES 2012-045, Washington, D.C.

Brandt, M. M., J. P. Holloway, C. A. Myrick, and M. C. Kondratieff. 2005. Effects of waterfall dimensions and light intensity on age-0 brook trout jumping performance. Transactions of the American Fisheries Society 134(2):496–502.

Dillner, D. K., R. F. Ferrante, J. P. Fitzgerald, and M. J. Schroeder. 2011. Integrated laboratories: laying the foundation for undergraduate research experiences. Journal of Chemical Education 88(12):1623–1629.

Dunkel, N. W., and J. H. Schuh. 1998. Advising student groups and organizations. Jossey-Bass, San Francisco, California.

Fechheimer, M., K. Webber, and P. B. Kleiber. 2011. How well do undergraduate research programs promote engagement and success of students? CBE-Life Sciences Education 10(2):156–163.

Ficke, A. D., C. A. Myrick, and N. Jud. 2011. The swimming and jumping ability of three small Great Plains fishes: implications for fishway design. Transactions of the American Fisheries Society 140(6):1521–1531.

Gabelhouse, D. W., Jr. 2010. Needs and proficiencies of fisheries hires by state agencies. Fisheries 35(9):445–448.

Howe, N., and W. Strauss. 2000. Millenials rising: the next great generation. Vintage Press, New York.

Hubert, W. A. 2011. President's hook: New fronteirs in fisheries management and ecology: leadership in recruitment of fisheries professionals. Fisheries 36(3):109–147.

Jackson, D. C., S. R. Chipps, and M. L. Brown. 2010. Fisheries education in the 21st century: challenges and approaches to training the next generation of fisheries scientists. Fisheries 35(6):264, 301–302.

Kelderman, E. 2008. Tuition rises as spending on instruction slows. Chronicle of Higher Education 14, May 9, 2008.

Leslie, L. L., C. E. Velez, and S. A. Bonar. 2004. Utilizing volunteers on fisheries projects: benefits, challenges, and management techniques. Fisheries 29(10):10–14.

Locks, A. M., and S. R. Gregerman. 2008. Undergraduate research as an institutional retention strategy: the University of Michigan model. Pages 11–32 *in* R. Taraban and R. L. Blanton, editors. Creating effective undergraduate research programs in science. Teachers College Press, New York.

Louv, R. 2005. Last child in the woods: saving our children from nature-deficit disorder. Algonquin Books of Chapel Hill, Chapel Hill, North Carolina.

Millenbah, K. F., and J. J. Millspaugh. 2003. Using experiential learning in wildlife courses to improve retention, problem solving, and decision-making. Wildlife Society Bulletin 31(1):127–137.

Millenbah, K. F., B. H. K. Wolter, and W. W. Taylor. 2011. Education in the era of the millennials and implications for future fisheries professionals and conservation. Fisheries 36(6):300–304.

Millspaugh, J. J., and K. F. Millenbah. 2004. Value and structure of research experiences for undergraduate wildlife students. Wildlife Society Bulletin 32(4):1185–1194.

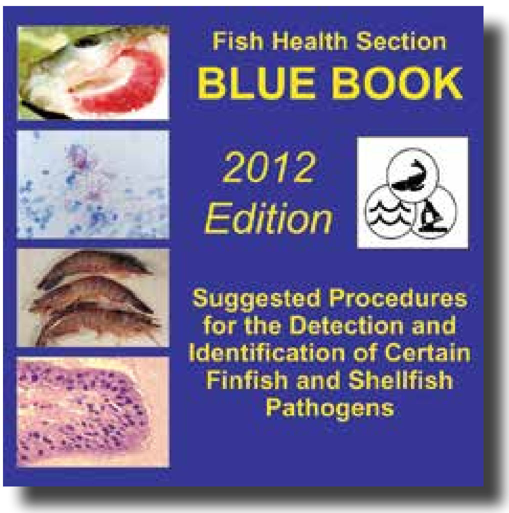
Pate, W. M., W. L. Stacy, E. I. Gardunio, and J. M. Lepak. 2011. Collaborative research between current and future fisheries professionals: facilitating AFS Subunit participation. Fisheries 36(9):458–460.

Smialek, J. 2011. Undergraduate research on the rise. The Daily Tar Heel. April 11, 2011.

Trosset, C., D. Lopatto, and S. Elgin. 2008. Implementation and assessment of course-embedded undergraduate research experiences: some explorations. Pages 33–49 *in* R. Taraban and R. L. Blanton, editors. Creatting effective undergraduate research programs in science. Teachers College Press, New York.

University of California–Office of the President. 2002. 2003–2004 Budget for current operations. University of California, Oakland.

Wei, C. A., and T. Woodin. 2011. Undergraduate research experiences in biology: alternatives to the apprenticeship model. CBE-Life Sciences Education 10(2):123–131.



The Importance of Hands-On Experience for Students in Fisheries Biology and Water Engineering

As a young man I often asked myself, “How does this work?” and proceeded to answer that question by reducing the item of curiosity into its elementary parts through deconstruction, much to the dismay of my parents. I also spent countless afternoons building Lego communities in my backyard sandbox. The most eventful and exciting part of those afternoons was creating miniature lakes and river systems throughout these communities with the garden hose, which often flooded the backyard. My curiosity about the “way water worked” eventually led me to pursue a Ph.D. in water engineering and an M.S. degree in fisheries biology, both at CSU.

During my time as a student at CSU I found that laboratory exercises, hands-on research, and student projects were crucial to my understanding of biology and engineering and furthered my passion and curiosity. Initially, I struggled as a first-year student when classes consisted of only lecture and did not include any hands-on active-learning components. Understanding the theory was difficult and sitting in lecture taking notes was mundane and I often questioned my choice of majors during that time. As I progressed in my studies, I was exposed to laboratory classes in both water engineering and fisheries biology that allowed me to gain hands-on experience. These types of classes appealed to my visual learning style (many engineers and biologist can be classified as visual learners) and answered and elucidated the aspects of the theory that were difficult to comprehend. In addition to reinforcing ideas presented in lecture, the lab experiences provided valuable professional training such as river surveying, fish and aquatic insect sampling, flow measurement techniques, pump and aeration system design, fish physiological limit testing, and aquaculture techniques. The laboratory exercises also provided crucial insight into what my future career might entail. Had the curriculum at CSU been lacking laboratory components, I most likely would have become lost in the theory and switched my major. Instead, the hands-on nature of the courses ignited a passion for biology and water engineering, a passion that I share with my students in the classroom on a daily basis.

One key aspect of my undergraduate experience that led to my success as a student was participation in student organizations such as the AFS and American Society of Civil Engineering. Becoming involved in these two student organizations had many benefits for me. These groups gave me contact to like-minded students, many of whom became my close friends. The upper level students in these clubs took underclassmen such as myself “under their wings” and gave me advice and guidance during the difficult first years of college. The feeling of belonging and having a place was instrumental in continuing my education. Being involved in these groups exposed me to fascinating student projects and allowed me to dive in and get my hands dirty. Through these groups I also developed professional habits such as attending conferences and seminars and grasped the importance of lifelong learning.

My experiences with laboratory activities and student organizations as a faculty member at FGCU have reinforced the importance of active learning and hands-on teaching. I have found that teaching using an integrated lecture/lab classroom setup with labs or demonstrations nearly every class period results in students grasping concepts in a shorter amount of time. In addition to making class time more valuable, the labs excite the students and kindle a fire for further study. I often have students asking me with excitement what we will learn in subsequent courses after completing an introductory water lab. In addition to developing an enthusiasm for water-based classes, the labs function to train the students by teaching them valuable professional skills. In my time at FGCU I have also seen the crucial role that student organizations have on student learning from the faculty perspective. I have seen the students gain research, leadership, teamwork, construction, and organization skills that will serve them well in their future careers. I have seen the benefit that student organizations have in student recruitment and retention as upper classmen help struggling freshmen to stay afloat and high school students get excited about coming to FGCU because of the student projects.

Overall, I believe that hands-on learning through laboratory exercises should be considered as the most important aspect of a curriculum. Students who asked themselves, “How does this work?” as children and proceeded to answer that question in a way similar to how I answered it may turn away from fisheries biology and water engineering if there are no active-learning components to excite them.

–Kristoph D. Kinzli

An Undergraduate's Perspective—
Sources and Benefits of Hands-On Experience

I began my undergraduate degree in fisheries biology without really knowing just what the major or the profession involved or whether it was in fact what I wanted my career to be. However, field trips and lab exercises early in my education hooked me on the field, and later hands-on experience gave me a head start toward my career goals. This hands-on education has come mainly through lab and field classes, the CSU student subunit of the AFS, independent undergraduate research, and the close relationship between CSU and local fisheries agencies, mainly CPW (formerly the Colorado Division of Wildlife).

Classes with a lab or field component are typically more enthralling and captivating than those without. The introductory fisheries class at CSU, FW204, has both lab and field exercises and often includes many non-majors. After a field trip during which we sampled a local lake and did population estimates on the lake's sport fish, I was told by one student who took the class because it "met a requirement" that she wanted to continue studying fish. That person and at least two other non-fisheries majors from that class are now fisheries students. Lab or field classes also provide a familiarity with methodologies and techniques that lecture classes cannot. Other CSU students whom I have talked to about this topic agree that the information on procedures and techniques was more easily retained when we were able to conduct the work ourselves compared to when we learned the information in a lecture setting. In addition, having actually done most of the methods and techniques used frequently in fisheries has dramatically strengthened my resumé and made finding employment and a graduate program relatively easy.

As an undergraduate, I also benefited from a highly active student subunit of AFS and several opportunities to conduct independent undergraduate research projects. The CSU student subunit of the AFS has conducted a string of research projects in recent years that have offered not only field experience but experience with experimental design, data analysis, and manuscript preparation. Additionally, both the Hughes Undergraduate Research Program and the Research Experience for Undergraduates Program provide undergraduates with funding to design and conduct research projects under the mentorship of faculty members in a manner that is similar to an M.S. thesis project. My involvement with these programs, from the initial planning phase through the publication of manuscripts, has given me confidence in my ability to successfully conduct future research through a graduate project.

Finally, learning, volunteering, and being introduced to job opportunities through local fisheries agencies, primarily CPW, also played a crucial role in the acquisition of technical experience during my undergraduate education. Biologists from CPW often volunteer their time to work with classes, seek student volunteers on local projects, and hire CSU students as seasonal interns or employees. The results of these types of interactions are that students are exposed to additional techniques and equipment and gain insight into what is expected of a professional fisheries biologist. The jobs I have had with CPW have also given me a much more in-depth familiarity with the skills and techniques specific to jobs such as fish sampling, identification, and tagging to the point that I am now able to teach those methods to others or lead others on similar projects.

Though I still have a great deal to learn about fisheries research and management, I was fortunate enough to complete my undergraduate degree with much more than a basic book and lecture-based education. Hands-on experiences have served to bolster my confidence in my abilities as a fisheries biologist and scientist and have provided me with the tools and knowledge I need to be a competitive candidate for a variety of fisheries-related positions and projects.

–Zachary E. Underwood

The 2012 Salary Survey of Public and Private Sector Fisheries Employers in the United States and Canada

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INTRODUCTION

The American Fisheries Society (AFS) has a long history of conducting salary surveys of fisheries professionals. The first survey was conducted in 1977 (Sullivan 1977) and surveys occurred about every 4 years until the most recent one in 1998 (Kendall 1999). These surveys provide a periodic measure of the salary ranges and compensation of fisheries biologists working in the United States and Canada. The results of these surveys are used to help determine salary ranges and plan for and implement salary adjustments of fisheries professionals.

Historically AFS staff, in consultation with AFS sections, has conducted the surveys. In 2005, members of the AFS Fisheries Administration Section attempted to conduct a salary survey, but persistent concerns from previous surveys and obstacles to timely completion prevented completion of the survey and led the AFS to seek a different approach. In 2012, the AFS contracted with Responsive Management, a natural resource survey research firm, to conduct the survey. A committee of AFS members (the authors) representing society committees and sections and leadership, including the executive director, was formed to review the project proposal, survey design, and report findings. Two surveys were conducted: (1) a web-based survey of United States public agencies, including state fish and wildlife agencies and federal agencies, tribal governments and organizations, and Canadian provinces, and (2) a web-based survey of private industry fisheries professionals, including environmental consulting firms, power and utility companies, aquaculture and private fish hatcheries, and nonprofit organizations. Follow-up contact was made with state agency fish chiefs to verify data provided in the initial survey.

The complete results of the survey are provided in a report from Responsive Management at http://fisheries.org/docs/policy_2012salarysurvey.pdf. The following is a summary of that report.

SURVEY DESIGN

Survey Instrument

A survey was designed to collect information on published salary ranges and the salary range of current employees (exclusive of benefits) at five professional levels, characterized by specific education requirements and duties and the number of professional biologists employed at each of these levels. Professional biologists were considered those employees holding at a minimum a bachelor's degree.

Level 1 includes entry-level fisheries biologists and/or fisheries biologists I. This level is a professional position holding at least a bachelor's degree. Duties and responsibilities may include assisting a more senior employee and performing assigned duties.

Level 2 includes field-level fisheries biologists or fisheries biologists II. This level is a professional position holding at least a bachelor's degree with previous experience. Duties and responsibilities may include fish culture and management, working independently, designing and/or conducting basic research projects or programs, and limited supervisory duties.

Level 3 includes supervisory fisheries biologists, district/region/area/team supervisors, or field supervisors but may also include specialists or experts in a particular area of fisheries or marine science research or management. This position is often a team leader or supervisor but also includes specialists. Employees at level 3 typically supervise field biologists and technicians within their work group only. Duties and responsibilities may include preparing status reports, preparing management and project plans, coordinating with other agencies or organizations, and providing technical advice or assistance to the public.

Level 4 includes assistant chiefs or program administrators in fisheries. Employees at this level direct and manage the activities of fisheries personnel, often through lower level supervisors. Duties and responsibilities are primarily managerial and administrative. This position typically reports to a chief, director, or administrator of fisheries (level 5).

Level 5 is a chief, director, or administrator of fisheries. Level 5 is the senior management position for the agency's or organization's fisheries program or division. Duties and responsibilities are all managerial and administrative.

Unlike the 1998 survey (Kendall 1999), respondents were asked to report the average salary for current employees at each level. The previous survey reported midpoint salaries. Averages were used in this survey because this was thought to be a more easily obtained calculation.

Additional information collected included length of service for employees and aspects related to salary incentives, bonuses, raises, and cost of living adjustments.

Once finalized, the survey of public agencies served as the template for the survey of private industry. This was the first time a salary survey of private industry has been conducted as a supplement to the survey of public agencies. Differences between the surveys for public agencies and private industries were minimal. Changes were made to the descriptions provided for each level/position to accommodate for differences between fisheries professionals and positions in the public and private sectors.

Survey Administration

The sample of state fish and wildlife agencies included 70 state fish and wildlife agencies, including inland and marine fisheries departments. Various U.S. government agencies (13), tribal governments/organizations (40), and Canadian provinces and territories (14) were contacted based on lists used in previous salary surveys (Kendall 1999).

For the survey of private industry, Responsive Management began with a sample of approximately 85 private industries provided by the AFS. Anticipating that private industries would be reluctant to complete the salary survey, Responsive Management supplemented the original database with its own research on private industries employing fisheries biologists. Approximately 1,000 industries nationwide that employ fisheries professionals were contacted.

The 2012 survey was administered as a web-based survey beginning in June 2012. All respondents had access to e-mail (for the delivery of the survey site web address and for reminders) and to the Internet for the survey site. Respondents were encouraged to complete the survey by a specific date. Shortly after distributing the initial survey, a trained, professional interviewer contacted each respondent to confirm that he or she received the survey and to encourage completion. The interviewer also monitored and maintained a log of contacts, which was updated with new information to ensure that the appropriate individuals were being contacted to complete the survey.

After a 2-week period, Responsive Management sent a second e-mail to thank those who completed the survey and to serve as a reminder to nonrespondents. The second e-mail was personalized and sent to an updated database to further ensure that the e-mail message was delivered to representatives most likely to have the information required to complete the survey. Again, recipients were given an invitation with specific information about the survey and an Internet link to the survey site. Additionally, a specific deadline was provided for survey completion, and the reminder highlighted the timeliness and importance of responding before the deadline. In the week following the second e-mail, a professional interviewer again contacted each respondent who received a survey, confirmed receipt, and encouraged survey completion.

Finally, a third wave of e-mails was sent to nonrespondents as a final reminder to complete the survey, followed by a personal telephone call by a professional interviewer. Throughout the project, survey responses and contacts with respondents were recorded in a database to ensure that all survey recipients received several notifications and personal telephone calls to encourage survey completion.

After developing a draft of the results, Responsive Management sent several tables and the notes to all fish and wildlife directors for final approval of the salary data. Final changes to the draft report were submitted by a deadline of January 11, 2013. All revisions submitted by state fish and wildlife directors were included in this final report.

Data Analysis

Respondent data were accepted at face value unless discrepancies in responses required revision. All costs were rounded to the nearest whole-dollar amount. Data analysis was performed using Statistical Package for the Social Sciences as well as proprietary software developed by Responsive Management. As in previous surveys, the American Chamber of Commerce Researchers Association (now known as C2ER) cost of living indices (COLI) were used to adjust only the U.S. state salaries for purchasing discrepancies (http://www.missourieconomy.org/indicators/cost_of_living/index.stm).The COLI factors from the second quarter of 2012 were used. Two states (West Virginia and Wyoming) were not covered by the C2ER report for that quarter. Indices for these two states were approximated by calculating an average based on surrounding states.

As with the previous survey, some staff classifications systems did not correspond directly with the five-level system used. Agencies with systems that differed markedly from the designated system had to make decisions on how to respond. Agencies were asked to provide explanatory notes on their results. These can be accessed at in the "Notes Regarding Survey Responses" at http://fisheries.org/docs/policy_2012salarysurvey.pdf.

If an agency had not authorized positions at one or more of the levels, their results were denoted by "NA" (not applicable) in the tables. An entry of 0 in the staff column meant that the salary level was authorized but did not currently contain any employees. Numerous tribal organizations and private companies requested that they not be specifically identified; therefore, in these two categories, respondents were identified to their primary state of operation or location.

SURVEY RESULTS

Response

Nearly all (68 of 69) of the state fish and wildlife agencies responded; only the Puerto Rico Department of Natural and Environmental Resources did not send data because their departmental organization is incompatible with the organization structure provided in the survey. Louisiana recently reorganized, resulting in the combining of its inland and marine divisions. Louisiana provided one response representing both divisions, which reduced the overall sample by one. Several coastal states indicated that their salary range for inland and marine divisions were the same but did not provide specific information on current employee salary ranges and employee numbers. Maine only provided data for its marine component.

Response from other agencies, organizations, and private industries were much lower than state agencies. Completed surveys received from these groups included the following: U.S. government agencies, 8 of 13; tribal governments, 8 of 40; provinces and territories, 4 of 14; and private industry, 52 of 985.

Unadjusted Salaries

The range of salaries and overall average salaries among the five levels were similar for both inland and marine state agencies (Table 1). The sample size was small for Canadian provinces and territories although salaries at all levels tended to be higher than U.S. agencies. Conversion rates between U.S. and Canadian dollars were within ±5% during 2012, which contrasts to previous surveys when the differential was up to 30% lower for Canadian dollars. Salaries for government agencies tended to be higher than state agencies at levels 3–5. Tribal government salaries fell within the salary ranges of state agencies.

Although an increased effort was made to collect salary data from the private sector, samples sizes were still too low to make meaningful comparisons with public sector agencies in most instances (Table 2).

Staffing

State inland agencies once again accounted for most of the fisheries positions (Table 3). Level 2 positions were most numerous for both types of state agencies, with government and tribal agencies more weighted toward level 3 and 4 positions.

The top end of the range for length of service for both types of state agencies reflected employee longevity (Table 4). None of the other public or private sector agencies or organizations demonstrated such length of service.

Adjusted State Salaries

Among inland agencies, Midwestern U.S. states occupied the four top spots in the rankings based on level 2 salaries (Table 5). No other regional patterns were noted. The top ranked marine agency at level 2 (Connecticut) was ranked eighth among inland agencies.

Salary Incentives, Bonuses, and Raises

Length of service and cost of living were the most common reasons employees received salary increases (Table 6). Most agencies and organizations have given raises to employees over the last 2 years (Table 7).

CONCLUSIONS

Although more state agencies provided data for this survey than in 1999 (68 vs. 58), staff totals were almost identical (3,716 and 3,709 for 2012 and 1999, respectively). This mirrors the trend over the last 30 years that saw employment in non-education positions in state and local governments remain around 30 positions per 1,000 resident population (Center on Budget and Policy Priorities 2012). The percentage of staff at level 2 was 44% in both surveys and the percentage at level 4 increased from 4% to 8%.

In 2012, the top salary for inland fisheries agencies for level 2 was $85,493, and the median salary was $51,999. When adjusted for inflation (Bureau of Labor Statistics 2013), comparably ranked salaries in 1998 were $82,138 and $52,559. For the higher level 4, the top salary for inland fisheries agencies was $105,574 and the median salary was $74,413. In 1998, top inflation-adjusted salary for inland fisheries agencies was $104,579 and the median inflation-adjusted salary was $71,063.

Somewhat surprisingly, length of service has changed little since 1998. Level 2 employees had an average of 13.3 years of service in 1998 and 13.6 in 2012. Median years of service were the same for both surveys at 14 years. Even at the higher level 4, the average years of service were 19.6 and 19.9 for 1998 and 2012, respectively. Median years of service were once again equal at 20.

Some agencies and organizations used AFS certification as criteria for salary increases. This is an improvement from the 1999 survey when AFS certification was not listed as a reason for increases by any agency or organization. Unfortunately, U.S. state agencies that employ the majority of the fisheries biologists accounted for in this survey rarely use professional certification as a reason for salary increases.

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REFERENCES

Bureau of Labor Statistics, U.S. Department of Labor. 2013. CPI inflation calculator. Available: http://www.bls.gov/data/inflation_calculator.htm. (January 2013).

Center on Budget and Policy Priorities. 2012. Some basic facts on state and local government workers. Available: http://www.cbpp.org/files/2-24-11sfp.pdf. (January 2013).

Kendall, R. L. 1999. The 1998 salary survey of fisheries agencies in the United States and Canada. Fisheries 24(9):6–14.

Sullivan, C. R. 1997. Salaries of fisheries biologists (June 1977) in the United States and Canada. Fisheries 2(5):2–4.

TABLE 1. Average salary (unadjusted for cost of living) of public sector fisheries agencies for five employment levels from entry (level 1) to senior administration (level 5) and the number of staff at each level. Salaries are given in U.S. dollars for U.S. agencies and in Canadian dollars for Canadian agencies.

Agency or organization	Level 1		Level 2		Level 3		Level 4		Level 5	
	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff
States, inland										
Alabama	NA		46,036	12	67,216	13	84,276	2	90,725	1
Alaska	48,336	68	62,684	103	78,117	116	102,354	19	119,832	2
Arizona	30,631	4	42,915	16	56,598	17	61,297	4	77,091	1
Arkansas	40,460	12	45,000	24	52,919	15	67,634	4	80,452	1
California	56,760	125	74,952	75	78,936	25	86,352	12	87,024	1
Colorado	56,664	29	65,520	2	88,008	5	85,236	2	105,216	1
Connecticut	66,781	5	82,613	10	93,599	4	NA		114,172	1
Delaware	40,356	2	51,272	3	56,046	5	72,721	2	79,341	1
District of Columbia	45,345	2	56,389	3	67,600	1	76,996	1	88,545	1
Florida	30,659	14	37,072	60	50,381	73	70,303	15	84,172	8
Georgia	44,079	10	51,627	11	59,593	8	66,517	2	77,848	1
Hawaii	54,750	0	54,500	12	75,000	2	74,000	2	90,500	0
Idaho	47,382	34	58,864	19	68,057	9	74,380	5	83,304	1
Illinois	48,768	5	67,836	21	80,508	14	79,116	13	93,168	1
Indiana	36,043	11	45,288	11	52,901	4	66,747	3	85,878	1
Iowa	66,000	30	75,000	5	82,000	2	94,000	1	92,000	1
Kansas	NA		45,808	26	49,683	8	53,721	4	61,838	1
Kentucky	ND	0	41,799	13	53,094	16	70,875	3	74,542	1
Louisiana	44,679	0	44,727	57	62,180	45	65,009	5	88,380	6
Maryland	42,271	13	51,419	17	65,475	13	77,715	10	92,914	1
Massachusetts	56,742	8	62,038	11	70,986	5	77,594	1	82,456	1
Michigan	62,754	9	64,000	20	78,145	13	89,731	6	103,473	1
Minnesota	46,834	64	54,789	92	66,962	44	85,608	7	97,196	3
Mississippi	27,780	1	31,463	4	34,734	2	43,977	5	45,185	3
Missouri	33,702	2	43,835	43	57,432	8	58,599	7	82,872	1
Montana	NA		46,459	35	53,888	10	67,895	11	85,426	1
Nebraska	33,355	16	43,572	23	57,221	22	69,111	4	88,593	1
Nevada	40,663	4	52,717	10	63,606	3	65,207	3	ND	0
New Hampshire	46,206	4	53,680	5	58,159	2	NA		72,582	1
New Jersey	51,046	0	61,253	0	82,565	4	NA		77,632	1
New Mexico	35,144	2	42,668	1	46,852	11	63,939	1	76,488	1
New York	62,215	30	80,540	13	92,974	3	NA		98,791	1
North Carolina	40,013	11	48,414	26	72,216	7	63,839	3	86,536	1
North Dakota	53,490	3	65,304	9	70,098	2	NA	0	89,736	1
Ohio	NA		52,594	25	65,376	7	73,600	2	69,555	1
Oklahoma	38,346	20	54,600	10	NA		66,480	1	66,712	1
Oregon	40,416	38	49,812	142	62,964	56	77,604	28	117,756	1
Pennsylvania	47,374	11	54,142	19	58,211	17	66,426	4	NA	
Rhode Island	45,027	0	48,169	0	63,488	14	78,443	2	81,951	1
South Carolina	29,160	7	38,201	14	45,636	26	54,708	16	92,720	6
South Dakota	35,693	4	43,534	13	47,590	3	52,011	2	58,981	1
Tennessee	50,988	17	58,980	14	71,712	4	71,904	1	85,752	1
Texas	40,894	12	53,421	33	64,561	30	85,306	12	107,637	1
Utah	40,924	0	40,248	24	54,850	7	67,226	8	88,733	1
Vermont	32,406	2	39,749	11	51,709	11	59,738	21	70,200	13
Virginia	48,545	4	54,308	10	64,296	4	72,891	4	94,653	2

TABLE 1. Continued.

Agency or organization	Level 1		Level 2		Level 3		Level 4		Level 5	
	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff
States, inland										
Virgin Islands	27,386	1	40,137	1	65,490	0	68,804	0	85,000	1
Washington	30,996	4	48,000	200	50,000	50	55,000	20	70,000	12
West Virginia	32,028	5	47,916	1	50,105	7	NA		60,759	2
Wisconsin	46,823	0	50,708	47	61,158	35	75,660	9	91,782	1
Wyoming	45,768	14	56,067	38	67,295	26	84,871	7	109,493	1
Average	43,971	13	52,601	27	63,764	16	71,676	6	85,828	2
States, marine										
Alabama	ND	1	40,000	5	ND	0	58,000	2	ND	1
Connecticut	66,781	2	82,613	7	93,599	1	NA		114,172	1
Florida	31,068	3	37,537	8	49,695	4	56,218	3	73,640	5
Georgia	42,438	2	46,844	4	54,489	3	59,442	1	73,884	2
Maine	44,614	12	48,715	11	49,773	6	40,233	2	78,945	1
Massachusetts	47,791	6	57,705	24	70,617	7	79,734	10	97,300	3
Mississippi	28,949	3	31,277	11	44,808	0	40,279	17	51,939	7
New Hampshire	44,395	5	48,819	2	57,935	1	NA		66,000	1
New Jersey	52,000	4	63,350	0	82,500	4	93,800	1	100,800	2
New York	62,215	9	80,540	6	92,974	2	NA		ND	1
North Carolina	38,293	11	43,380	21	53,044	6	64,499	9	95,341	2
Rhode Island	43,483	0	48,169	0	62,000	2	79,000	2	87,000	1
South Carolina	28,971	32	35,319	22	44,878	19	57,875	5	92,720	6
Texas	46,261	10	55,800	44	64,840	19	86,809	8	107,637	1
Virginia	36,185	5	48,360	3	53,566	5	78,710	1	98,000	1
Average	43,817	7	51,229	11	62,480	5	66,217	4	87,491	2
Provinces/territories										
Nunavut	95,000	1	ND	0	ND	0	ND	2	120,000	1
Prince Edward Island	53,606	0	64,155	1	57,472	2	69,830	2	89,277	2
Saskatchewan	66,218	3	ND	4	91,742	2	ND	1	ND	1
Yukon	75,692	1	82,000	1	99,840	1	NA		NA	
Average	72,629	1	73,078	2	83,018	1	ID	2	104,639	1
Government (federal, state, local, or combination)										
Columbia River Estuary Study Task Force (Oregon)	NA		44,625	4	59,500	2	NA		NA	
Gulf of Mexico Fishery Management Council (Florida)	NA		47,000	1	90,000	6	145,000	1	147,000	1
International Pacific Halibut Commission (Washington)	52,000	8	64,124	1	100,000	9	153,719	1	NA	
North Pacific Fishery Management Council (Alaska)	48,000	2	72,000	4	115,000	6	140,000	2	NA	
Pacific Fishery Management Council (Oregon)	NA		NA		109,261	7	NA		NA	
Susquehanna River Basin Commission (Pennsylvania)	44,212	2	55,406	2	63,621	1	NA		NA	

TABLE 1. Continued.

Agency or organization	Level 1		Level 2		Level 3		Level 4		Level 5	
	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff
Government (federal, state, local, or combination)										
U.S. Geological Survey (Georgia)	32,500	2	68,809	1	68,809	1	130,796	0	ND	0
U.S. Department of Agriculture Forest Service (New Mexico)	32,359	25	50,611	114	80,276	129	106,358	1	ND	4
Average	41,814	8	57,511	18	85,808	20	135,175	1	147,000	2
Tribal governments (by primary state of operation)										
California	NA		55,737	3	73,202	2	111,010	1	115,690	1
Idaho	50,747	5	62,331	4	78,865	10	111,072	1	103,500	2
Oregon	40,000	4	45,000	2	65,000	1	65,000	1	75,000	1
Washington 1	38,220	ND	44,500	3	51,335	1	NA		NA	
Washington 2	50,336	3	58,006	4	47,008	1	70,906	3	110,000	1
Washington 3	43,017	1	44,937	3	53,302	4	54,538	1	84,215	1
Washington 4	51,147	10	68,016	19	74,984	33	78,998	4	86,392	2
Wisconsin	29,000	0	37,250	2	41,000	1	NA		NA	
Average	43,210	4	51,972	5	60,587	7	81,921	2	95,800	1

NA = not applicable; ND = no data available or reported; ID = incomplete data. Nonresponding agencies are omitted.

TABLE 2. Average salary (unadjusted for cost of living) for fisheries-related private sector organizations or companies for five employment levels from entry (level 1) to senior administration (level 5) and the number of staff at each level. Salaries are given in U.S. dollars for U.S. agencies and in Canadian dollars for Canadian agencies.

Resident state of organization	Level 1		Level 2		Level 3		Level 4		Level 5	
	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff
Nonprofit organizations										
Alabama	NA		55,000	2	87,000	1	NA		NA	
Alaska	32,500	6	41,712	1	47,316	1	49,368	4	60,408	2
Alaska	57,500	1	NA		68,500	1	NA		NA	
Alaska	NA		NA		33,600	1	85,000	1	NA	
Alaska	NA		47,734	3	64,421	2	63,240	1	82,460	1
California	35,360	1	72,800	1	NA		NA		NA	
Idaho	NA		41,000	1	60,000	1	NA		NA	
Massachusetts	32,000	4	40,069	14	62,306	10	NA		NA	
Pennsylvania	44,212	2	55,405	2	63,621	1	NA		NA	
Utah	43,420	2	31,200	2	37,440	2	NA		62,000	1
Washington	40,000	1	43,000	1	49,000	2	90,000	1	NA	
Washington	58,800	211	NA		72,900	2	NA		NA	
West Virginia	32,000	1	57,700	1	64,900	1	131,500	3	NA	
British Columbia	46,700	4	52,000	2	64,000	3	78,000	1	78,000	1
Ontario	NA		NA		61,800	1	NA		NA	
Average	42,249	23	48,875	3	59,772	2	82,851	2	70,717	1
Environmental consulting firms										
Alabama	NA		NA		40,000	1	NA		NA	
Alaska	34,000	115	45,000	115	55,000	115	NA		NA	
Alaska	32,000	1	64,152	1	NA		NA		NA	

TABLE 2. Continued.

Resident state of organization	Level 1		Level 2		Level 3		Level 4		Level 5	
	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff	Average salary ($)	Number of staff
Environmental consulting firms										
California	27,310	3	45,007	5	83,568	11	NA		NA	
Colorado	34,000	5	37,000	3	45,000	1	55,000	1	NA	
Colorado	33,280	1	37,440	1	46,800	2	NA		NA	
Florida	39,745	6	42,280	2	54,400	2	60,415	1	NA	
Idaho	NA		NA		75,000	1	112,000	1	NA	
Idaho	38,000	2	58,000	3	75,000	2	NA		NA	
Minnesota	30,000	1	NA		50,000	1	NA		NA	
Missouri	31,200	1	41,600	1	47,840	1	NA		NA	
Montana	40,000	1	NA		65,000	3	NA		NA	
New York	29,000	1	NA		ND	1	NA		NA	
New York	NA		34,000	1	51,000	4	120,000	5	125,000	2
Oregon	NA		NA		90,000	4	NA		NA	
Oregon	44,464	7	62,881	8	76,460	3	94,004	3	127,626	2
Tennessee	NA		50,000	2	90,000	2	NA		NA	
Washington	33,000	1	50,000	1	90,000	2	NA		NA	
Alberta	64,397	6	72,134	6	96,512	5	NA		NA	
Alberta	43,500	2	50,000	2	65,000	2	85,000	1	130,000	2
British Columbia	71,125	5	91,250	4	116,500	1	NA		NA	
British Columbia	NA		NA		80,000	2	NA		NA	
British Columbia	42,000	1	4,500	2	ND	1	NA		NA	
British Columbia	NA		NA		NA		ND	1	NA	
Manitoba	NA		NA		90,000	1	NA		NA	
Average	39,237	9	49,078	10	70,623	7	87,737	2	127,542	2
Animal aquaculture/fish hatcheries										
Massachusetts	28,600	11	NA		80,000	1	100,000	1	NA	
Minnesota	32,000	3	44,000	2	65,000	1	68,000	1	NA	
New Hampshire	27,000	3	35,000	1	49,000	2	54,000	1	NA	
Power and/or utility companies										
Washington	NA		NA		73,000	1	NA		NA	
Washington	64,022	1	70,283	2	88,180	5	98,058	3	131,893	1
Washington	NA		83,221	3	99,570	2	NA		NA	
Washington	51,278	1	69,954	1	92,206	1	101,302	1	NA	

NA = not applicable; ND = no data available or reported. Nonresponding agencies are omitted.

TABLE 3. Percentage distributions of staff for fisheries-related public and private sector organizations or companies among five salary levels from entry (level 1) to senior administration (level 5).

Agency or organization	Number reporting	Number of staff reported	Percentage of staff by employment level				
			Level 1 (%)	Level 2 (%)	Level 3 (%)	Level 4 (%)	Level 5 (%)
States, inland	52	3,268	20	43	25	9	3
States, marine	16	448	23	38	18	14	8
Government (federal, state, local, or combination)	8	337	12	38	48	1	1
Tribal governments	8	135	17	30	39	8	6

TABLE 3. Continued.

Agency or organization	Number reporting	Number of staff reported	Percentage of staff by employment level				
			Level 1 (%)	Level 2 (%)	Level 3 (%)	Level 4 (%)	Level 5 (%)
Provinces/territories	4	25	20	24	20	20	16
Nonprofit organizations	17	309	75	10	10	4	2
Environmental consulting firms	26	503	32	31	33	3	1
Animal aquaculture/fish hatcheries	3	27	63	11	15	11	0
Power and/or utilities companies	4	22	9	27	41	18	5

TABLE 4. Summary statistics for average length of service of fisheries employees at agencies and organizations among five salary levels from entry (level 1) to senior administration (level 5). Sample size (N) is the number of agencies or organizations reporting for that level.

Agency or organization	Average Length of service (years) for fisheries biologists at									
	Level 1		Level 2		Level 3		Level 4		Level 5	
	Range (N)	Mean, median	Range (N)	Mean, median	Range (N)	Mean, median	Range (N)	Mean, median	Range (N)	Mean, median
Nonprofit organizations										
States, inland	1–25 (39)	9.0, 8	0–37 (49)	13.6, 14	5–38 (46)	18.8, 9.5	5–39 (42)	19.9, 20	1–43 (49)	22.0. 22
States, marine	1–34 (15)	8.3, 6	0–24 (15)	10.1, 10	6–35 (14)	19.2, 8.5	3–33 (13)	18.6, 20	1–33 (16)	20.7, 20.5
Government (federal, state, local, or combination)	1–15 (4)	5.0, 2	1–5 (5)	2.2, 1	1–25 (6)	11.3, 7.5	14–18 (4)	15.5, 15	3–16 (2)	9.5, 9.5
Tribal governments	1–12 (6)	4.5, 4	5–15 (8)	8.8, 8	0–25 (8)	9.6, 10	6–28 (6)	15.5, 14	10–30 (6)	17.3, 13.5
Provinces/territories	3–10 (2)	6.5, 6.5	2–11 (2)	6.5, 6.5	4–5 (2)	4.5, 4.5	0–9 (2)	4.5, 4.5	12–14 (2)	13.0, 13
Nonprofit organizations	1–4 (10)	2.6, 2.5	3–15 (11)	7.1, 6	2–24 (14)	10.2, 8	1–13 (6)	8.0, 8.5	5–22 (4)	11.2, 9
Environmental consulting firms	1–8 (17)	2.5, 2	2–15 (16)	5.2, 4.5	2–27 (21)	7.9, 7	1–35 (7)	13.5, 10	ND	ND
Animal aquaculture/fish hatcheries	2–4 (3)	3.0, 3	5 (2)	5.0, 5	5–20 (3)	11.0, 8	1–5 (3)	2.3, 1	5–38 (3)	19.3. 15
Power and/or utilities companies	4–5 (2)	4.5, 4.5	1–35 (3)	13.6, 10	11–21 (4)	15.2, 14.5	4–10 (2)	7.0, 7	ND	ND

ND = no data available or reported.

TABLE 5. Adjusted average salaries of fisheries employees at state agencies in five levels from entry (level 1) to senior administration (level 5). Reported salaries were divided by the relevant COLI for these adjustments. States are comparatively ranked by the adjusted salary at each level (inland separately from marine agencies) and ordered by their rank at level 2, the most abundantly staffed level overall.

Agency	COLI	Level 1		Level 2		Level 3		Level 4		Level 5	
		Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank
States, inland											
Iowa	1.140	75,234	1	85,493	1	93,472	1	107,151	1	104,872	5
Illinois	1.101	53,681	7	74,670	2	88,618	3	87,086	8	102,553	9
Michigan	1.121	70,317	2	71,713	3	87,563	4	100,545	2	115,943	3
North Dakota	1.064	56,940	5	69,515	4	74,619	10	NA		95,523	19
Tennessee	1.169	59,624	3	68,970	5	83,859	6	84,083	10	100,277	13
Colorado	1.048	59,394	4	68,677	6	92,249	2	89,343	6	110,286	4
Idaho	1.152	54,590	6	67,818	7	78,410	8	85,695	9	95,976	18
Connecticut	0.794	53,003	9	65,568	8	74,287	12	NA		90,616	23
Oklahoma	1.163	44,589	22	63,489	9	NA		77,303	18	77,573	33

TABLE 5. Continued.

Agency	COLI	Level 1		Level 2		Level 3		Level 4		Level 5	
		Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank
States, inland											
New York	0.778	48,405	15	62,663	10	72,337	15	NA		76,863	34
Wyoming	1.099	50,299	11	61,618	11	73,957	13	93,273	5	120,827	2
Texas	1.153	47,166	16	61,615	12	74,463	11	98,390	3	124,147	1
California	0.816	46,344	19	61,198	13	64,451	25	70,506	29	71,054	36
Virginia	1.102	53,486	8	59,835	14	70,840	17	80,309	15	104,286	6
Ohio	1.130	NA		59,419	15	73,860	14	83,151	11	78,581	31
Nevada	1.119	45,501	21	58,989	16	71,173	16	72,965	23	NA	
Georgia	1.132	49,884	12	58,427	17	67,442	20	75,278	21	88,101	26
Minnesota	1.040	48,718	14	56,993	18	69,655	18	89,051	7	101,105	12
Pennsylvania	1.044	49,450	13	56,515	19	60,762	31	69,337	31	NA	
Wisconsin	1.084	50,745	10	54,955	20	66,280	21	81,997	13	99,469	14
North Carolina	1.111	44,443	23	53,774	21	80,211	7	70,907	28	96,117	17
West Virginia	1.110	35,551	35	53,187	22	55,617	38	NA		67,442	39
Kansas	1.149	NA		52,627	23	57,079	35	61,718	37	71,043	37
Alabama	1.135	NA		52,245	24	76,282	9	95,643	4	102,962	8
Indiana	1.150	41,435	24	52,063	25	60,815	30	76,733	20	98,726	15
Arkansas	1.156	46,753	17	51,999	26	61,150	29	78,153	17	92,965	22
Massachusetts	0.815	46,250	20	50,567	27	57,861	34	63,247	35	67,210	40
Delaware	0.980	39,543	26	50,240	28	54,918	39	71,257	27	77,743	32
Missouri	1.136	38,281	28	49,790	29	65,234	24	66,560	33	94,130	20
Nebraska	1.142	38,100	31	49,770	30	65,361	23	78,942	16	101,196	11
Alaska	0.785	37,955	32	49,221	31	61,339	28	80,370	14	94,095	21
Louisiana	1.099	NA		49,171	32	68,358	19	71,468	25	97,161	16
Washington	1.020	31,603	39	48,940	33	50,979	44	56,077	39	71,371	35
Montana	1.052	NA		48,897	34	56,716	36	71,458	26	89,909	24
Kentucky	1.163	ND		48,593	35	61,724	27	82,395	12	86,658	27
New Hampshire	0.889	41,075	25	47,719	36	51,700	42	NA		64,521	41
South Dakota	1.072	38,273	29	46,681	37	51,030	43	55,771	40	63,245	43
Oregon	0.932	37,686	33	46,447	38	58,710	32	72,361	24	NA	
New Mexico	1.085	38,135	30	46,299	39	50,839	45	69,380	30	82,997	28
Utah	1.142	46,740	18	45,969	40	62,646	26	76,781	19	101,345	10
Arizona	1.023	31,325	40	43,887	41	57,880	33	62,686	36	78,837	30
Maryland	0.851	35,960	34	43,742	42	55,699	37	66,112	34	79,042	29
South Carolina	1.108	32,324	38	42,346	43	50,587	46	60,643	38	102,780	8
Rhode Island	0.856	38,563	27	41,254	44	54,373	40	67,181	32	70,186	38
District of Columbia	0.724	32,839	36	40,836	45	48,955	47	55,760	41	64,124	42
Florida	1.066	32,696	37	39,535	46	53,728	41	74,973	22	89,763	25
Mississippi	1.126	31,288	41	35,436	47	39,120	50	49,530	43	50,890	46
Vermont	0.869	28,147	42	34,525	48	44,913	49	51,887	42	60,974	45
Hawaii	0.617	NA		33,621	49	46,267	48	45,650	44	NA	
New Jersey	0.800	NA		NA		66,027	22	NA		62,082	44
States, marine											
Connecticut	0.794	53,003	3	65,568	1	74,287	2	NA		90,616	5
Texas	1.153	53,357	2	64,359	2	74,785	1	100,124	1	124,147	1
New York	0.778	48,405	4	62,663	3	72,337	3	NA		NA	

TABLE 5. Continued.

Agency	COLI	Level 1		Level 2		Level 3		Level 4		Level 5	
		Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank	Adjusted average salary ($)	Rank
States, marine											
Georgia	1.132	48,027	5	53,014	5	61,666	5	67,271	5	83,615	6
North Carolina	1.111	42,533	6	48,183	6	58,917	7	71,640	3	105,897	3
Massachusetts	0.815	38,955	11	47,035	7	57,560	8	64,991	7	79,309	9
Maine	0.951	42,410	7	46,309	8	47,315	13	38,246	11	75,046	11
Alabama	1.135	57,879	1	45,395	9	NA		65,823	6	82,490	7
New Hampshire	0.889	39,465	10	43,397	10	51,501	11	NA		58,670	13
Florida	1.066	33,132	12	40,030	11	52,996	10	59,952	9	78,532	10
South Carolina	1.108	32,114	14	39,151	12	49,747	12	64,154	8	102,780	4
Mississippi	1.126	32,604	13	35,226	13	36,702	14	45,365	10	58,497	14
New Jersey	0.800	41,584	8	NA		65,975	4	75,012	2	80,610	8
Rhode Island	0.856	NA		NA		53,099	9	67,658	4	74,510	12

NA = not applicable; ND = no data available or reported.

TABLE 6. Award criteria and percentage of agencies and organizations that offer salary incentives and/or bonuses for fisheries employees.

Agency or organization	Percent of agencies or organizations that base salary incentives and/or bonuses on					
	Length of service	Continuing education	AFS certification	Certification (non-AFS)	Other	Cost of living
States, inland	48	17	6	0	10	56
States, marine	50	31	0	0	6	81
Government (federal, state, local, or combination)	67	17	17	17	67	83
Tribal governments	25	0	0	13	13	100
Provinces/territories	50	25	0	0	25	25
Nonprofit organizations	41	24	12	12	35	47
Environmental consulting firms	35	42	19	23	31	46
Animal aquaculture/fish hatcheries	0	67	0	33	0	67
Power and/or utilities companies	0	25	25	25	0	50
Other	0	0	0	0	100	50

TABLE 7. Award criteria and percentage of agencies and organizations that have given raises to fisheries employees since January 1, 2011.

Agency or organization	Percentage of agencies or organizations that award raises on		
	Merit	Market survey	Career ladder
States, inland	55	30	50
States, marine	57	14	71
Government (federal, state, local, or combination)	100	40	100
Tribal governments	100	40	60
Provinces/territories	75	50	50
Nonprofit organizations	83	67	75
Environmental consulting firms	93	57	93
Animal aquaculture/fish hatcheries	100	100	100
Power and/or utilities companies	100	100	50
Other	50	0	50

AFS & Social Media

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Social media. A decade ago, it did not exist. Today, it is everywhere. President Obama uses a Google+ Hangout to interact with the public, and also has over 27 million followers on Twitter (currently ranks 5th). Why? What is all this stuff, and what does it mean to AFS?

Social media grew with the Internet, but exploded in use as technological advances spawned the synergistic combination of cell phones with the Internet. Over 85% of Americans now have cell phones, over 85% use the Internet, and now, over 67% of Internet users also use social networking sites (pewinternet.org). Mobile devices are pervasive, making information access instant, portable, and location-aware. Social networks are powerful, and they provide information that is personalized and participatory.

What is the role of AFS in social media? Social media outlets provide a forum for amateur experts (and bait bucket biologists) to influence people far beyond the local coffee shop—their reach is global in scope, and immediate. Fisheries professionals need to grow with society. We cannot confine ourselves to academic journals. We need to engage people where they are—online or connected! We also need to bring them to where we are—on a boat, on a beach, in our waders, or in a hatchery! Most people don't get to these places, or they drive right by them without even realizing it. But in the right social media context (YouTube videos, tweets, Facebook posts, etc.), we can connect or reconnect them to what we do—and potentially reach hundreds, thousands, or millions of people in the process. Here are some great examples of what your colleagues are doing in the realm of social media. ***AFS members are indicated in bold italics.***

AFS ON FACEBOOK

facebook.com/groups/39804224812

And the Award Goes to... Bravo to *President John Boreman* for using social media to advance the American Fisheries Society (AFS)—and for doing it so well. Need we say more? Read this post to see why you should join the American Fisheries Society Facebook Group.

AFS ON TWITTER

twitter.com/AmFisheriesSoc

Every day there's something interesting to read. Make sure to follow us on Twitter to get your daily fix and to start up your own discussions.

IN BLOGS

The Fisheries Blog

thefisheriesblog.blogspot.com

facebook.com/TheFisheriesBlog

Steve Midway, Patrick Cooney, and Dr. Dana Sackett. Photo credit: The Fisheries blog.

The Fisheries Blog is a group of three fisheries scientists who write popular articles, paper reviews, and other short fisheries-related content. This blog was started in 2011 as an outlet to share short, topical fisheries stories with our colleagues and friends. Bloggers Dr. Dana Sackett, ***Patrick Cooney***, and ***Steve Midway*** have published in a variety of peer-reviewed journals, including *Transactions of the American Fisheries Society*, *Marine Ecology Progress Series*, *Estuarine, Coastal and Shelf Science*, *North American Journal of Fisheries Management*, *Hydrobiologia*, *Epidemiology*, *Ecotoxicology*, *Environmental Science and Technology*, *Journal of Freshwater Ecology*, *Fisheries*, *BioScience*, and *Biology and Philosophy*.

Southern Fried Science

southernfriedscience.com

facebook.com/pages/Southern-Fried-Science/411969035092

When ***Chuck Bangley*** joined **Southern Fried Science**, one of his first blog posts was titled "Shark DNA Used to Buff Up Aquacultured Fish":

Recently, farmed salmon genetically-modified to grow larger and faster than their wild conspecifics have been approved for human consumption by the FDA, though not without debate. This man-made subspecies was created by modifying the already-existing DNA of the fish, but what if it turned out that simply injecting DNA from a different species could improve the growth and protein output of farmed fish? And what if that foreign DNA came from sharks? This is exactly what researchers in the Middle East are trying out.

Chuck Bangley. Photo credit: Scientific American.

Ya Like Dags?

yalikedags.southernfriedscience.com

But wait—Chuck also has his own blog, **Ya Like Dags?**, which he's been running for almost 3 years (we're talking old school, content genius here):

While my "big-picture" posts on fisheries management and general-interest marine biology will go up at the parent blog, field work recaps and shorter, observational posts will continue to appear here. So really, if you want the full Dags experience you'll have to follow both blogs.

Ya Like Dags? offers up some tremendous posts, such as "Adventures in Acoustic Telemetry," "Spiny Dogfish Eco-tourism?," "Heartbreaking and Heartwarming Tales of Social Sharks," "Meet the New Dogfish, Same as the Old Dogfish," "Enjoying Seafood While Knowing Too Much," "Carcharhinus linkamanus," "Harpoon Fishing is Totally Badass," and more. But, wait, there's even more. Read an interview with Chuck Bangley that took place on one of Scientific American's blogs, "Rhythms of Life in Meatspace and Cyberland—A Blog around the Clock": blogs.scientificamerican.com/a-blog-around-the-clock/2012/03/27/scienceonline2012-interview-with-chuck-bangley/

Oceanographer's Choice

oceanographerschoice.com

Samuel Urmy. Photo credit: Samuel Urmy.

Samuel Urmy calls himself an eponymous oceanographer and, as he says in his blog, **Oceanographer's Choice:**

I . . . have been interested in the marine world for a long time. I got an undergrad degree in Earth Systems with an Oceans focus from the Leland Stanford Junior University in Palo Alto, California and a master's degree in the Fisheries Acoustics Lab at the University of Washington's School of Aquatic and Fisheries Sciences. I am currently in the Acoustical Laboratory for Ecological Studies (ALES) in the School of Marine and Atmospheric Sciences at Stony Brook University. That makes me a bioecoacoustical fisheries oceanographer, which should be good for at least 15 minutes of confused cocktail party explanation. This site is an ongoing log of the work in progress that is my own thinking, and all opinions expressed here are mine and mine alone. Please do not get mad at anyone else for them.

In one of his latest posts, "Getting a Clue on Population Variability," he writes:

The problem with this model, however, is that many fish populations display worryingly little resemblance to it. Large population swings are common in fisheries, and not always for reasons related to fishing. Lots of work has been done looking for, and in many cases finding, correlations between fish populations and oceanographic or climatic processes. Likewise, work has been done on indirect ecological effects, like trophic cascades. But it's rarely clear exactly how these links work, and we can't really predict beforehand how or if a particular stock will be affected by physical or biological factors outside of itself.

From Russia, With Ballast

blog.takemefishing.org/from-russia-with-ballast

Jim Long. Photo credit: Oklahoma Cooperative Fish and Wildlife Research Unit Cooperators.

Andy Whitcomb, who describes himself as "a columnist, outdoor humorist, and stressed-out Dad living in Oklahoma" also has his own website (justkeepreeling.com), and wrote for the blog "Take Me Fishing" about an unwelcome species and the always welcome, **Jim Long**.

During a recent fishing trip, my crappie jig snagged a small, striped shell. I placed it in an empty water bottle and sent a photo to ***Dr. Jim Long*** *at Oklahoma State University to confirm my suspicions.*

"This is significant," he stated as he verified it as a zebra mussel (Dreissena polymorpha). Native to the Caspian Sea, this tiny critter hitchhiked in the ballast of a ship. Well, not this particular mussel, but its ancestors did. And not that long ago. "Great, great grandpa zebra mussel" (life span may average about 6 years) disembarked from a freighter in the Great Lakes by about 1990. Since then, Oklahoma has listed 20 lakes as having zebra mussel populations. Now, thanks to a slow day of fishing and rather unorthodox bivalve sampling methods, Lake McMurtry is #21.

Biologists are concerned because zebra mussels can dramatically alter their environment with staggering numbers. These filter feeders can outcompete native mussels and larval fish for plankton. Plus, they clog pumping equipment for municipalities. Freshwater drum and channel catfish consume these mollusks, but cannot control the population.

To minimize the spread and effect of these and other invasive species, take these precautions such as cleaning and drying your boat between different bodies of water. Zebra mussels can live out of water for several days. And if they happen to be hitting minnow tipped crappie jigs in your lake, report it on the NAS Alert System. By gathering this biological data, hopefully we can learn how to control and manage these uninvited guests.

RESEARCH

Seismic Survey

dfo-mpo.gc.ca

Pete Cott. Photo credit: Fisheries and Oceans Canada.

Pete Cott, Ph.D. candidate, fisheries biologist at the Fisheries and Oceans Canada (DFO; Pêches et Océans Canada) is the DFO contact on a research project titled Potential Impacts of a Seismic Survey on the Behavior and Auditory Physiology of Fish in the Mackenzie River. The development of oil and gas reserves in the Northwest Territories requires seismic surveys to locate and delineate reserves. Hydrocarbon deposits can be found under land, seas, lakes, or rivers. The most common survey method for use in aquatic environments is based on the use of air guns. These instruments release into the water column a compressed air bubble, which collapses under water pressure to generate a high-level noise that is used as the seismic signal. This noise could potentially disturb or harm aquatic life. In 2002, a proposal was put forth to conduct a seismic survey along the entire length of the Mackenzie River and into the Liard River. The proposal did not include any relevant information relating to the impacts on fish from air gun–based seismic exploration in riverine environments. To support the environmental assessment of their project, the proponent was required to verify the predictions made in their project description. Results from their studies yielded some interesting and useful information. However, many questions remain unanswered. In 2004, the DFO will conduct further study on the potential impacts of air gun–based riverine seismic exploration, focusing on fish auditory physiology and behavior. The physiological component of the study will investigate hearing capabilities of fish after exposure to various levels of air gun–induced noise to determine whether certain northern fish species experience hearing loss and the duration or recovery of any hearing loss. The behavioral component will use hydroacoustics to monitor free swimming fish and their behavior in relation to noise generated from an approaching seismic vessel. For more information, visit www.dfo-mpo.gc.ca and search for "Cott."

Testing Regional Flow-Ecology Hypotheses

sifn.bse.vt.edu/sifnwiki/index.php/SIFN_Flow-Ecology_Hypotheses_Expert_Review

Shannon Brewer.
Photo credit: Oklahoma Cooperative Fish and Wildlife Research Unit Cooperators.

Shannon Brewer—assistant unit leader for fisheries at the Oklahoma Cooperative Fish and Wildlife Research Unit/Oklahoma State University is testing regional flow-ecology hypotheses. The first task is to develop the hydrologic and fish community data for the region. Gaging station data has been collected and analyzed for hydrological alterations, and fish community sampling data has been compiled into the MARIS (Multi-state Aquatic Resources Information System) template. Then, a review of hierarchical flow-ecology hypotheses developed by Mary Davis was undertaken. Next, the project will focus on filling in flow-ecology hypotheses where they are most important.

AFS VIDEOS

A River Loved: A Film about the Columbia River and the People Invested in Its Future

youtube.com/user/watsonjae

YouTube credit: watsonjae

"I'm Shuswap Indian, so basically being a Shuswap Indian, salmon is the basis and the backbone of our culture, it's akin I guess to Jesus Christ almost to the Catholics or something like that, right? Reverence for salmon is very, very high. Stories relate to how many the fish were based on the fact that the natives used to walk across their backs, it was that, it was that big of a run. There is no more salmon now in the headwaters of the Columbia or even anywhere in the Canadian side of the Columbia, and the fact that they're gone now for seventy years has had a very, very drastic impact on my people, being that seventy years of loss of salmon, has, along with that has gone our ceremonial uses and thinks like that that went with salmon, the ability to educate our children on processing techniques, capture techniques, first salmon ceremonies, things like that."

– Mark Thomas, Shuswap Indian Band

Water Is the Key to Life

youtube.com/watch?v=8DWLTaY6aQk

YouTube credit: troutheadwaters

Check out ***Mike Sprague,*** president of Trout Headwaters in his video about wetlands, rivers, and streams restoration.

Why Are Our Salt Marshes Falling Apart?

youtube.com/watch?v=eP3hRkX03Q8

YouTube credit: mblwoodshole

"If every individual could make the decision not to add nitrogen to their lawn, that would help the coastal areas a great deal."

– ***Linda Deegan***, senior scientist, The Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts

Channel Catfish Fishing Clinic

todaysthv.com/news/article/211325/143/Brighter-Side-Good-news-in-Arkansas

Video credit: THV

While Arkansas Game and Fish Commission biologist ***Ben Batten*** was in the process of putting together our very good *American Fisheries Society Invitation to the 143rd Annual Meeting in Little Rock, Arkansas* video (which can be seen here: youtube.com/watch?v=HNBacM3-JuE), CBS affiliate station THV's *Today Show* was taping Ben at the Fletcher Library as he taught participants (many of them children!) about gear, bait, rigging, fish handling, and Arkansas Game and Fish Commission pond locations. "It's just basics 101," Batten told THV. "We teach all about Channel Catfish, what they eat, a little biology background, what kind of equipment to use, what to bring on a trip."

In the Direction of Urban Aquaculture

youtube.com/watch?v=YXBFZhnGDrY

YouTube credit: UWASC

"We've gone more now in the direction of what we call Urban Aquaculture, which to some people may sound fussy and cute, you know, but it has a lot of potential … but perhaps the main things would be that it's going to create jobs. It will establish businesses and create jobs."

– ***Fred Binkowski***, Wisconsin Sea Grant Aquaculture Specialist

Fish Count! Beth Gardner is Restoring Fish Habitats

youtube.com/watch?v=zhfGy9hRcAY

YouTube credit: Montana Forests

"We've seen more Brook Trout, more nonnative Rainbow Trout and also Lake Trout are moving in and taking over. It's very discouraging. In my experience, Aquatic Restoration means conserving our native fish. Isolating them if we have to, from nonnative species moving in, and for Bull Trout, which cannot be isolated, still removing the nonnative fish, allowing the Cutthroat and Bull Trout to do what they've always done. Aquatic Restoration also means hanging onto good habitat, restoring past abuses, and making sure we can have both good fish habitat and also land management."

– ***Beth Gardner,*** Swan Lake Fisheries Biologist on Forest Restoration in Montana

GULF OF MEXICO FISHERIES SYMPOSIUM—GULF SCIENTISTS SPEAK OUT

Six—count them—six AFS members were filmed at the first Gulf of Mexico Fisheries Symposium to give their assessment on the health of fisheries in the Gulf following the 2010 oil spill. Some of their early findings might surprise you!

youtube.com/watch?v=SfUAVgjHvDk (YouTube credit: DrGuyHarvey)

Dean Grubbs

Photo credit: Florida State University.

"Compared to when I was a kid as a recreation fisherman, I mean, red fishing is better now than it's ever been, at least in my lifetime." ***Dean Grubbs***, Coastal and Marine Lab, Florida State University

James Bohnsack

Photo credit: National Oceanic and Atmospheric Administration.

What have marine protected areas done for fishing? Watch what ***James Bohnsack***, Fisheries Science Center, National Marine Fisheries Service, has to say about it.

Jim Franks

Photo credit: The University of Southern Mississippi.

"I think we begin to reap some of the benefits of some of those management decisions." ***Jim Franks***, Gulf Coast Research Lab, University of Southern Mississippi

George Burgess

Photo credit: University of Florida.

"We want to be able to make livings, and have fun and the only way to do that is to be smart." ***George Burgess***, Director, Florida Program for Shark Research

Donald Kent

Photo credit: Hubbs-Seaworld Research Institute.

"It's a matter of being creative in our approach and utilizing resources." ***Donald Kent***, President, Hubbs-Sea World Research Institute

Jessica McCawley

Photo credit: Florida Fish and Wildlife.

"Tourists are coming back to the Gulf of Mexico and I think that people have a lot of confidence in eating Florida Seafood." ***Jessica McCawley***, Marine Fisheries Management

AFS 2013 Little Rock: Preparing for the Challenges Ahead

GRAND SOCIAL ON THE RIVERFRONT

The Riverfront area of downtown Little Rock will be the site of the Grand Social on Wednesday September 11. We will be offering you free libations (local beer, wine, soft drinks, and water) and feeding you some of the best Cajun food north of Louisiana. After some ice-breaking beverages on Wednesday afternoon, a regional restaurant will be serving a feast of fried catfish, fried and boiled shrimp, hush puppies, french fries, coleslaw, vegetable plates, beans, relishes, gumbo, crawdad tails, rolls, french bread, and of course bread pudding, banana pudding, and maybe a little pecan pie. While you are eating, you can take in the beautiful scenery. Then enjoy a walk along the 6th longest river in the U.S., perusing the Arkansas Game and Fish Commission's Witt Stephens, Jr. Central Arkansas Nature Center, and visit the wetland boardwalk along the river near the Clinton Library. We will have the entire riverfront from the River Market to the Clinton Library blocked off for the social. After more food than you can shake a Flathead Cat (*Pylodictus olivaris*) at, we will continue into the night with three local bands spread along the riverfront for your musical enjoyment.

Meeting details and registration information can be found at afs2013.com.

- The Arkansas River originates in the Rocky Mountains of Colorado and joins the Mississippi River, approximately 95 miles southeast of Little Rock.
- At the Central Arkansas Nature Center visitors can follow water through a series of exhibits of Arkansas' natural areas.
- The William E. "Bill" Clark Presidential Park Wetlands is 13 acres of restored wetlands adjacent to the Clinton Library.

New Seventh Edition of *Common and Scientific Names of Fishes*

Changes include capitalization of common names

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The seventh edition of *Common and Scientific Names of Fishes from the United States, Canada, and Mexico* (Page et al. 2013) continues the effort established by the six earlier editions to standardize the names of North American fishes, thereby improving communication among fisheries biologists, the popular press, and others with an interest in fishes. It provides the accepted common and scientific names for all fishes in the continental United States, Canada, and Mexico, including marine species inhabiting (as juveniles or adults) contiguous shore waters on or above the continental shelf to a bottom depth of 200 m. In the Atlantic Ocean, all shore fishes from Greenland and eastern Canada, the United States, and Mexico, including those from the Gulf of Mexico and Caribbean Sea south to the Mexico–Belize border, are included. In the Pacific Ocean, species occurring over the continental shelf from the Bering Strait to the Mexico–Guatemala border, including Guadalupe Island and Revillagigedo Archipelago, are included.

From 570 entries in the 1948 list (comprising primarily the better known sport, commercial, and forage fishes), coverage increased to 1,892 species in 1960 (the first attempt at a complete listing), 2,131 species in 1970, 2,268 in 1980, and 2,428 in 1991. The 2004 list (sixth edition), which added the Mexican fauna, increased the coverage to 3,694 fishes and added six cephalochordates. The present edition includes 3,875 native (indigenous) and established introduced species.

Major changes in the seventh edition include the capitalization of all common names in English, the addition of a common name in French for each Canadian species, and the recognition of occurrences in the Arctic Ocean as separate from those in the Atlantic and Pacific oceans. The southern boundary of the Arctic Ocean in North America is defined as extending from the northern tip of Labrador along latitude 61° N to Greenland in the Atlantic and from the western tip of the Seward Peninsula to the United States–Russia border in the Bering Strait in the Pacific.

The inclusion of a common name in French for all Canadian species (rather than only for those from Quebec, as in the sixth edition) provides a checklist for all Canadian species, just as the inclusion of common names in Spanish for all Mexican species provides a checklist for Mexico. The list does not provide a checklist of species for the United States, however, because all species, even if they occur only in Canada or Mexico, are given names in English (although all freshwater fishes from the United States are indicated as F:U in the column indicating where they occur). One goal for the eighth edition will be to create a means by which a checklist for all species occurring in the United States can be extracted.

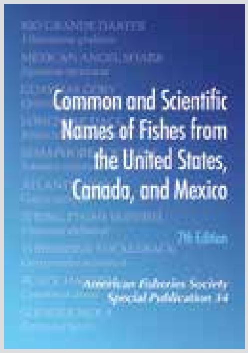
The capitalization of common names in English was a recommendation from an ad hoc committee of the American Society of Ichthyologists and Herpetologists, which concluded that capitalization helps to eliminate the ambiguity that accompanies names like blue catfish, lake trout, black brotula, and deepsea sole (Nelson et al. 2002) and that common names in English should be treated as proper nouns. This change moves the practice for North American fishes into agreement with that for several other vertebrate groups, where capitalization of English names is standard. The capitalization of the English names of fishes applies only to individual species such as the Bluebarred Pygmy Sunfish and Bumphead Parrotfish, not to groups of related species such as pygmy sunfishes, parrotfishes, and bony fishes. (See the accompanying sidebar for additional information on the capitalization of fish names in American Fisheries Society publications.)

The English common names (or portions thereof) of several species are derived directly from the Spanish names used in Mexico, which may include words with accent marks. The Committee on Names of Fishes was divided over whether to treat such words as "automatically anglicized"—and thus not to retain the accent marks—or to regard them as Spanish words included in English common names and to retain the accent marks. Following the National Geographic Society's *Atlas of the World*, we concluded that some geographic names have been so widely adopted into English that they can be considered anglicized (e.g., "Yucatan" as opposed to the Spanish "Yucatán" and Rio Grande as opposed to "Río Grande"), whereas others, which are generally not used in English, should retain their accent marks to assist in pronunciation (e.g., Cuatro Ciénegas Cichlid).

All additions to and changes in names and occurrences from those in the sixth edition are explained in an appendix, as has been done since the thirrd edition. Scientific names change with advancing knowledge of the phylogenetic relationships of species and in accordance with the views of taxonomists. Most of these changes are straightforward and without controversy (often because only a limited number of taxonomists work on those taxa). However, a few are not unambiguous due to conflicting conclusions among the scientists studying particular species or higher taxa. In those circumstances, the committee sought the opinions of experts and chose the name that seemed best supported. The committee did not adopt a proposed change in a species, genus, or family name if it had not been adopted by a majority of the scientists working on that taxon. The appendix also provides comments on names that remain unchanged from the sixth edition but for which new information warrants clarification.

Some higher taxa that are used by most scientists as well as in the seventh edition (Perciformes being a prime example) are undoubtedly paraphyletic. Even so, evaluating attempts to resolve relationships and improve classification is difficult because of conflicting conclusions and, often, the limited number of taxa sampled. Changes clearly are necessary to reflect evolutionary history, but making changes that are short-lived has the effect of confusing rather than improving names meant to communicate information about fishes. Our apologies to those who feel that their work has been given less credit than it deserves. Ultimately, the systematists who best understand particular groups of fishes will make the decisions about scientific names, but until such changes are accepted by the scientific community the committee will maintain a conservative approach.

Conservatism aside, the committee has discussed moving the process of reviewing and evaluating names to an online format that will allow all interested persons to contribute. This proposal will be discussed with members of the American Fisheries Society and the American Society of Ichthyologists and Herpetologists in the near future.



The seventh edition of *Common and Scientific Names* is scheduled for publication in April 2013.

Capitalization of Species Names in AFS Publications

In keeping with the capitalization of the English common names of fishes in the seventh edition of *Common and Scientific Names of Fishes from the United States, Canada, and Mexico*, the publications section of the American Fisheries Society (AFS) has revised some of its rules with respect to capitalization. In all submissions to AFS publications, authors should now

- Capitalize the English common names of all fish species, including those not in *Common and Scientific Names* and other AFS taxonomic publications
- Capitalize the common names of subspecies (e.g., Lahontan Cutthroat Trout)
- Not capitalize the names of life history variants (e.g., steelhead) and hybrids (e.g., saugeye)
- Not capitalize the common names of nonfish species, even if they appear in an AFS taxonomic publication
- Not capitalize common names that refer to groups of related species (e.g., Pacific salmon, darters)
- Not capitalize the common portions of names shared by two or more species when they are mentioned as a group (e.g., Gizzard and Threadfin shad; see section 2.12 of the AFS style guide)

Any questions about the capitalization of species names should be sent to the Journals Department (journals@fisheries.org).

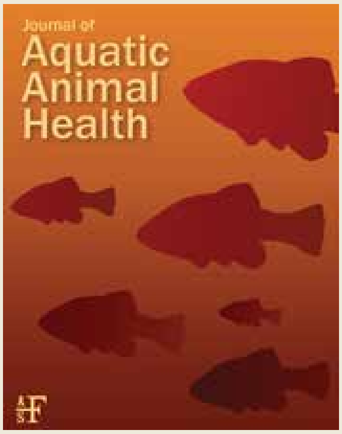
REFERENCES

Nelson, J. S., W. C. Starnes, and M. L. Warren. 2002. A capital case for common names of species of fishes: a white crappie or a White Crappie? Fisheries 27(7):31–33.

Page, L. M., H. Espinosa-Pérez, L. T. Findley, C. R. Gilbert, R. N. Lea, N. E. Mandrak, R. L. Mayden, and J. S. Nelson. 2013. Common and scientific names of fishes from the United States, Canada, and Mexico, 7th edition. American Fisheries Society, Special Publication 34, Bethesda, Maryland.

JOURNAL HIGHLIGHTS

Journal of Aquatic Animal Health
Volume 25, Number 1, March 2013



Control of *Flavobacterium psychrophilum*: Tests of Erythromycin, Streptomycin, Osmotic and Thermal Shocks, and Rapid pH Change. *Randall W. Oplinger and Eric J. Wagner. 25: 1–8.*

Isolation of *Yersinia ruckeri* Strain H01 from Farm-Raised Amur Sturgeon *Acipenser schrencki* in China. *Li Shaowu, Wang Di, Liu Hongbai, and Lu Tongyan. 25: 9–14.*

Mortality of American Bullfrog Tadpoles *Lithobates catesbeianus* Infected by *Gyrodactylus jennyae* and Experimentally Exposed to *Batrachochytrium dendrobatidis*. *Linda J. Paetow, J. Daniel McLaughlin, Bruce D. Pauli, and David J. Marcogliese. 25: 15–26.*

Viral Surveillance of Cultured Rainbow Trout in the Eastern Black Sea, Turkey. *H. Ogut, C. Altuntas, and R. Parlak. 25: 27–35.*

[Communication] Experimental Infection of Koi Carp with Viral Hemorrhagic Septicemia Virus Type IVb. *Emily R. Cornwell, Sandra L. LaBuda, Geoffrey H. Groocock, Rodman G. Getchell, and Paul R. Bowser. 25: 36–41.*

[Communication] Mixed Metazoan and Bacterial Infection of the Gas Bladder of the Lined Seahorse—A Case Report. *Paul A. Anderson and Barbara D. Petty. 25: 42–52.*

Effects of Aquarium-Related Stressors on the Zebrafish: A Comparison of Behavioral, Physiological, and Biochemical Indicators. *David Gronquist and John A. Berges. 25: 53–65.*

Experimental Infection of Australian Freshwater Fish with Epizootic Haematopoietic Necrosis Virus (EHNV). *Joy A. Becker, Alison Tweedie, Dean Gilligan, Martin Asmus, and Richard J. Whittington. 25: 66–76.*

NEW AFS MEMBERS

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Ryan Battleson
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Benjamin Morris
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Caleb Zurstadt

CALENDAR
Fisheries Events

To submit upcoming events for inclusion on the AFS web site calendar, send event name, dates, city, state/province, web address, and contact information to sgilbertfox@fisheries.org.

(If space is available, events will also be printed in Fisheries magazine.)

More events listed at www.fisheries.org

DATE	EVENT	LOCATION	WEBSITE
April 15–18, 2013	Western Division Annual Meeting	Boise, ID	www.idahoafs.org/2013AnnualMeeting
April 22–24, 2013	Sustainable Ocean Summit (SOS) 2013 - World Ocean Council	Washington, DC	www.oceancouncil.org/site/summit_2013
April 25–26, 2013	NPAFC 3rd International Workshop on Migration and Survival Mechanisms of Juvenile Salmon and Steelhead in Ocean Ecosystems	Honolulu, HI	npafc.org/new/index.html
May 7–9, 2013	The 3rd Managing Our Nation's Fisheries Conference	Washington, DC	www.cvent.com/events/managing-our-nation-s-fisheries-3/event-summary-94ddf325198f-4501996ccc62aa396aa2.aspx
May 11–19, 2013	Fisheries Awareness Week	Ireland	www.faw.ie
May 20–24, 2013	AFS Piscicide Class - Planning and Executing Successful Rotenone and Antimycin Projects	Logan, UT	fisheriessociety.org/rotenone; Contact: Brian Finlayson at briankarefinlayson@att.net
May 30–31, 2013	Annual Meeting for the Louisiana Chapter of the American Fisheries Society	Baton Rouge, LA	http://sdafs.org/laafs/meetings/meeting-registration
June 25–27, 2013	2013 International Conference on Engineering & Ecohydrology for Fish Passage	Corvallis, OR	fishpassage.umass.edu Contact: Dr. Guillermo R. Giannico at giannico@oregonstate.edu
September 23–26, 2013	OCEANS '13 MTS/IEEE - The Largest Ocean Conference in U.S. History	San Diego, CA	www.oceans13mtsieeesandiego.org.
August 3–7, 2014	International Congress on the Biology of Fish	Edinburgh, United Kingdom	icbf2014.sls.hw.ac.uk


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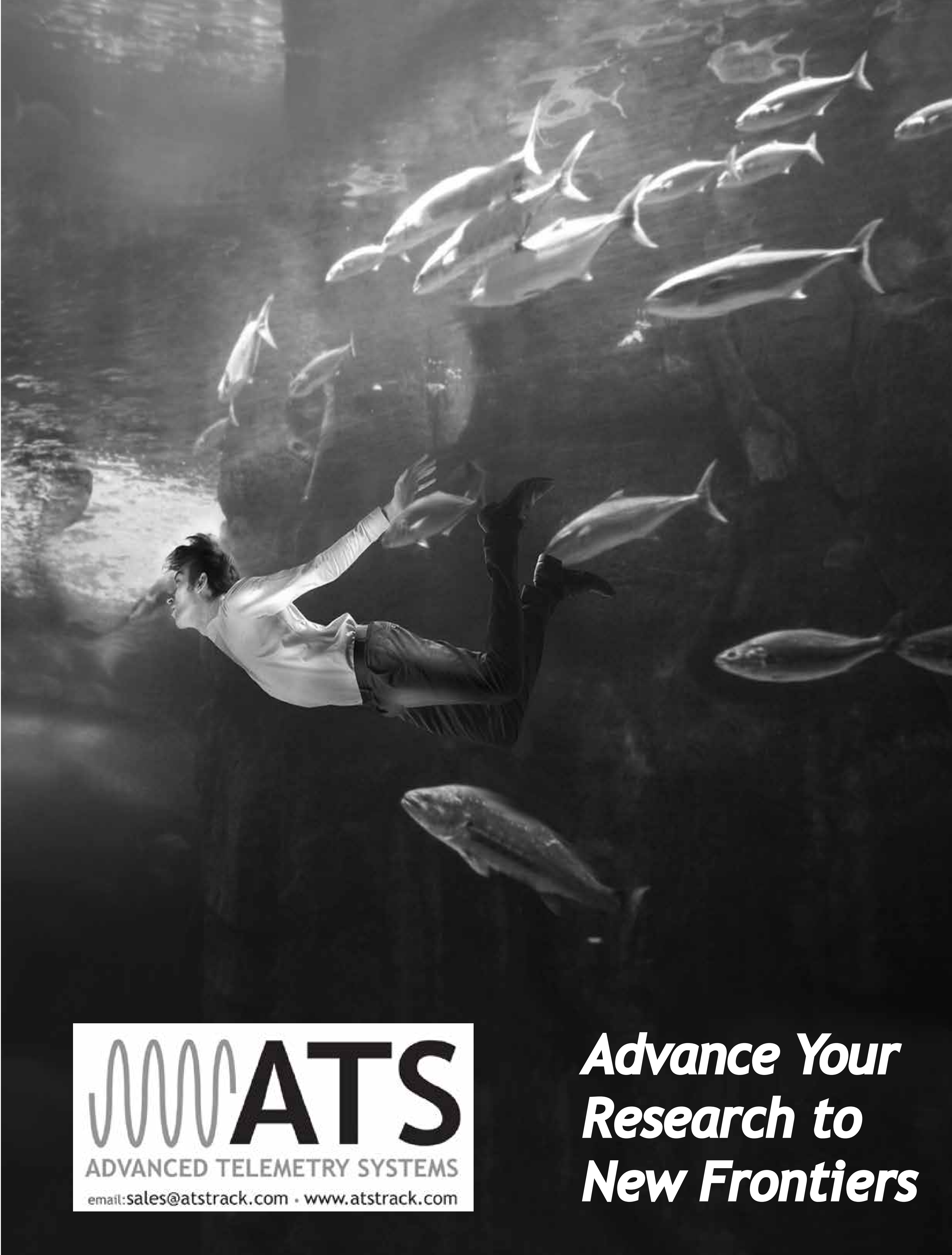
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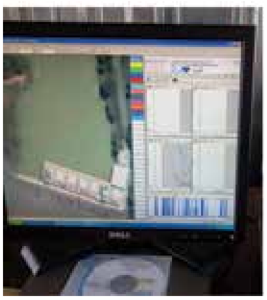


Tracking Acoustic Tags in Noisy Tailraces: Real-World Monitoring at Brazil's Três Marias Dam

An unprecedented fisheries research project is underway in Brazil's São Francisco River studying fine-scale fish behavior at a hydro-electric dam. Here, the Federal University of Lavras' Dept. of Biology (UFLA), the Companhia Energética de Minas Gerais (Cemig), one of Brazil's largest power generators and distributors, and HTI are all working together tracking fish to improve fisheries management downstream from the Três Marias Dam.

The Três Marias Dam is a 2,700 m (8,900 ft) long and 75 m (246 ft) high embankment with a reservoir surface area of 1,040 km2 (400 sq mi) and a capacity of 21 km3 (5.0 cu mi). This dam plays a central role in power production and flood control for the region.

HTI's Senior Scientists Sam Johnston and Colleen Sullivan worked with the team on-site to help with telemetry deployment and system testing. Around 200 curimba (*Prochilodus costatus*) and mandi (*Pimelodus maculatus*) were tagged with HTI *Model 795 Acoustic Tags*. The tag weights and tag life were ideal for study requirements, in addition to permitting numerous tags to be present at one time without any tag data collisions or false positives. To cover the tailrace area, 11 hydrophones were installed in fixed locations. Each hydrophone was attached to a simple fabricated housing on a metal rod and sub-mersed in a specific location. Tags were simultaneously detected and identified in real-time at a distance up to 100 m (328 ft) in the turbulent, white water of the dam's tailrace. Each fish was tracked in two dimensions (2D).

By the end of the project the group will have data with correlated animations (visualizations via HTI's *AcousticTag* data acquisition and analysis software) that will accurately illustrate how fish approach the plant. This vital information will significantly help managers improve the regulation of fish that accumulate near generat-ing units during various stages of operation. This work will also produce a PhD thesis for researcher and student, Fabio Suzuki.

According to biologist Dr. Luiz Gustavo Martins da Silva, "This technology will help us elucidate the behavior of fish below Três Marias Dam increasing our knowledge to develop management actions for conservation...our team (Fabio Suzuki, Paulo Pompeu and Carlos Alves) is very proud of that." HTI is pleased to contribute and support this study undertaken under the Peixe Vivo Program, a Cemig conservation initiative. To learn more about the equipment or methods used, contact Sam or Colleen at (206) 633-3383 or consulting@HTIsonar.com.

> **"This technology will help us to elucidate the behavior of fish below Três Marias Dam increasing our knowledge to develop management actions for conservation... our team (Fabio Suzuki, Paulo Pompeu and Carlos Alves) is very proud of that."**
>
> Dr. Luiz Gustavo Martins da Silva, Biologist - Federal University of São João Del Rei

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