Best Student Presentation/Poster Process
Best Practices for Managing Your Data
Computer-Facilitated Species Identification
Ecological Networks in Fisheries
The Gulf of Maine (GOM) is arguably one of the best studied marine ecosystems in the world. Interest in its physical environment, fisheries, and Canada/USA boundary have resulted in considerable research attention for more than a century. The GOM is also highly managed by two nations with a commitment to implementing an ecosystem approach to management.

The papers in this book review the management and policy tools and approaches required to implement integrated policy and management in the GOM; synthesize the current ecological and oceanographic understanding of the GOM, and the social, economic, and cultural interactions within the gulf; assess anthropogenic and external influences on the gulf ecosystem; and examine the science required to observe and predict changes in the GOM ecosystem, along with strategies to implement an ecosystem approach to management.
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DUES AND FEES FOR 2013 ARE: $80 in North America ($95 elsewhere) for regular members, $20 in North America ($30 elsewhere) for student members, and $40 ($50 elsewhere) for retired members. Fees include $19 for *Fisheries* subscription. Nonmember and library subscription rates are $174.
Think Globally, Act Globally

John Boreman, President

The 1993 American Fisheries Society (AFS) annual meeting was held in Portland, Oregon, and was the first AFS governing board meeting I attended as a member (I was president of the Marine Fisheries Section). Carlos Fetterolf, AFS president at the time, chaired the meeting. Every time someone in the meeting used the term “national” in reference to the society-wide level, Carlos demanded a 25-cent donation to the meeting kitty. His intent was to get people out of the habit of using the term and into the habit of recognizing that AFS members represent more nations than just the United States. Nowadays I rarely hear the term national used at AFS meetings and, when I do, I am tempted to ask for a quarter.

The AFS is indeed an international society. My latest count indicates that AFS membership now extends to 63 nations outside of the United States. We now have a Canadian Aquatic Resources Section and a Mexico chapter in the Western Division. We also have a very active International Fisheries Section that provides the AFS with a means of reaching out to our international members, keeping them informed of AFS activities, and making them feel welcome when they attend our meetings.

One of the major international roles that AFS plays is as a member of the World Council of Fisheries Societies (WCFS), which is composed of fisheries and aquatic science professional societies in North America, Asia, Europe, and Australia. Recently, the Mexican Fisheries Society and Canadian Aquatic Resources Section joined the World Council, representing fisheries professionals in their respective countries. Our executive director, Gus Rassam, serves as the World Council’s executive secretary, and AFS member Doug Beard is its current president. The mission of the WCFS is to promote international cooperation in fisheries science, conservation, and management. This past year, the WCFS sponsored the 6th World Fisheries Congress in Edinburgh, UK, which had a large number of AFS members in attendance; the 7th will be held in 2016 in Pusan, Korea.

Reasons for increasing AFS involvement in global fisheries science, management, and conservation issues, such as those being addressed through the World Council, should be obvious. Problems that our members are addressing in North America are common throughout the world. Prominent global fisheries issues include the role of aquaculture as a source of much-needed protein, especially in underdeveloped regions, and its impact on local ecosystems. Increased trade among nations has led to a concurrent increase in introductions of invasive aquatic species. Identification, treatment, and prevention of fish and shellfish diseases in aquaculture and sea farming operations, as well as in the wild, have become a global concern. Impacts of alternative modes of generating electricity, such as offshore wind farms, on aquatic ecosystems and fishing practices have also become an increasing cause for concern. Overharvest of fishery stocks is still occurring throughout the world, requiring closer international cooperation in development of stock assessment techniques, genetics-based methods of stock identification, economic analyses of import and export markets, and ecosystem-based approaches to fisheries management and conservation. Finally, global-scale environmental issues affecting fisheries resources (e.g., climate change, ocean acidification, eutrophication of inland and coastal waters, and chemical contamination) are drawing increased attention from our world leaders. With over 9,000 members representing 64 nations, the AFS is in an ideal position to address these global issues and, coordinating closely with the other members of the World Council, ensure that the best scientific and management approaches are being applied.

This is the message I intend to deliver at the annual meeting of the Japanese Society of Fisheries Science (JSFS) meeting in Tokyo next March and the Fisheries Society of the British Isles (FSBI) meeting in Glasgow in July 2013. Through the World Council, the AFS, JSFS, and FSBI have had an exchange program in which the societies’ leaders are invited to address each other’s annual meetings. At the AFS 2012 annual meeting in St. Paul, Shuichi Satoh, representing the JSFS, and Ian Winfield, representing the FSBI, spoke at our business meeting. In addition, the AFS, JSFS, and FSBI have had a tradition of co-sponsorship of symposia at their respective scientific meetings. However, the AFS and other members of the World Council need to do more than have their society officers deliver a few words of salutation at business meetings and co-sponsor symposia.

Ideally, cooperation among professional fisheries societies should involve exchange programs that accommodate visiting scientists and managers or student internships. The societies could assist in locating opportunities within their respective spheres of influence, screening candidates, and seeking financial assistance. Garnering financial assistance is most often the bottleneck for these opportunities and will likely not get easier in the current global economic climate. Short of co-sponsoring professional and student exchange programs with our fellow societies, increased sharing of information related to the science and management of fisheries can probably be undertaken with

Continued on page 94
How to Manage Data to Enhance Their Potential for Synthesis, Preservation, Sharing, and Reuse—A Great Lakes Case Study

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ABSTRACT: Proper data management (applying coordinated standards and structures to data collection, maintenance, retrieval, and documentation) is essential for complex projects to ensure data accuracy and accessibility. In this article, we used a recent project evaluating changes in Lake Whitefish (Coregonus clupeaformis) growth, condition, and recruitment in the Great Lakes as a case study to illustrate how thoughtful data management approaches can enhance and improve research. Data management best practices described include dedicating personnel to data curation, setting data standards, building a relational database, managing data updates, checking for and trapping errors, extracting data, documenting data sets, and coordinating with project collaborators. The data management actions taken ultimately resulted in a rich body of scientific publication and a robust database available for future studies.

Investing in data management allowed this project to serve as a model for taking the first steps toward a common goal of sharing, documenting, and preserving data that are collected and reported during the scientific research process.

CONTEMPORARY FISHERIES RESEARCH NEEDS THOUGHTFUL DATA MANAGEMENT PRACTICES

Data are the infrastructure of science, and modern scientific architecture has become increasingly complex. This trajectory can be partly explained by the preference of granting agencies toward projects that address broad-scale research questions; partly by advances in computing and communications technology that allow the scientific community to work with larger
data sets that transcend conventional spatial, temporal, and disciplinary boundaries (Lélé and Norgaard 2005; Wake 2008; Carpenter et al. 2009); and partly by advances in computing that have allowed data-intensive science (Newman et al. 2003) and modeling projects that rely on previously collected data to increase in frequency and magnitude (Kelling et al. 2009; Borgman 2010).

Any research project with multiple objectives or one that combines the expertise of multiple principal investigators—or even one that simply combines data from multiple institutions—will have the capacity to generate immense quantities of varied information, require the assimilation of previously acquired data, or both. This raises a variety of logistical complexities with regard to quality control, security, and accessibility of data and, as such, these projects can benefit greatly from formal data management strategies for entry, update, storage, validation, access, annotation, provenance (i.e., information regarding the origins, identification, ownership and structure of a data set), and archiving (McDonald et al. 2007; Brunt and Michener 2009; Kelling et al. 2009). Recognizing this, many funding agencies now require that all prospective grantees address data management as part of the project application (National Institutes of Health 2003; U.S. Fish and Wildlife Service 2006; National Oceanic and Atmospheric Administration [NOAA] 2010; National Science Foundation 2010).

Unfortunately, modern ecological data management practices have not evolved as quickly as their data sets (Katz et al. 2007; McDonald et al. 2007; Barnas and Katz 2010; Hook et al. 2010). Data management is an often underrecognized and underutilized tool (Michener and Jones 2011). The majority of scientists still manage data through spreadsheet entry, individualized post-entry error checking and manual grouping, or extraction of data for analysis (Porter and Ramsey 2002; Borgman et al. 2007; Nelson 2009). A recent survey of ecologists found that they felt that their own institutions lacked planning, technology, and funding for data management in the short term (during the project) and long term (post-project) and did not adequately provide training in data management (Tenopir et al. 2011). Heterogeneity in the practices and quality of data management limits data reuse, data sharing, and data integration and does not facilitate standardization of data collection methods or support economic efficiency given current fiscal climates.

A fundamental disconnect occurs between the broadly based, complex, interdisciplinary, and collaborative projects requiring data that are accessible, electronic, decipherable, error-free, and reusable and the heterogeneous and idiosyncratic data sets that are routinely being generated from the thousands of fisheries researchers collecting data in the course of their work. Fisheries managers and scientists must embrace the need to recognize data management as a critical step toward organizing their discipline and resolving this tension.

THE STATES OF FISHERIES DATA MANAGEMENT AND PEER-REVIEWED LITERATURE

Scientific data collection and compilation can occur at differing spatial scales, and the larger the scale, the more necessary it is to commit resources to data collection and management. Some examples of larger scale regional fisheries database efforts include FishMAP, a Great Lakes fish migration passage and knowledge database; GLATOS Web, a Great Lakes acoustic telemetry system; the Multistate Aquatic Resources Information System (MARIS); the National Fish Habitat Action Plan; the Pacific Northwest Salmon Habitat Restoration Project Tracking Database; StreamNet, which compiles and disseminates fish data from state, tribal, and federal agencies in the Pacific Northwest; and the Fisheries Information Networks (FINs), which are regional, cooperative, state, and federal data integration and management programs for the Pacific Region (PACFIN), the Atlantic Region (Atlantic Coastal Cooperative Statistics Program [ACCSP]), the Gulf of Mexico (GulfFIN), and Alaska (AKFIN; e.g., Beard et al. 1998; Katz et al. 2007; MARIS 2008; McLaughlin et al. 2010; Wang et al. 2011). In addition, there are regional fisheries databases housed at NOAA Fisheries Service Science Centers, which have long histories of managing data (NOAA 2011). At a smaller scale than these regional efforts, there are the data management endeavors of individual state agencies, coordinating groups of multi-affiliated fisheries researchers, university fisheries research teams, and the many individual projects that require the construction of databases during the course of their research (e.g., Watson and Kura 2006; Katz et al. 2007; Heidorn 2008; Frimpong and Angermeier 2009).

The current state of “how to manage fisheries-specific databases” in the peer-reviewed literature can be summarized as follows: the regional efforts listed above have multiple personnel dedicated to behind-the-scenes data management, using very sophisticated practices, but detailed descriptions of their specific efforts have not been documented in the peer-reviewed fisheries literature (e.g., K. Barnas, Pacific Northwest Salmon Habitat Restoration Project Tracking Database; D. Donaldson, GulfFIN; D. Infante, National Fish Habitat Action Plan; W. Kinney, StreamNet; C. Kruger, GLATOS Web; A. Loftus, MARIS; E. Martino, ACCSP; R. McLaughlin, FishMAP, personal communication). There are also countless textbooks on the structural mechanics of database design (Hernandez 2003; Pratt and Adamski 2007; Ling Liu and Özuş 2009), which tend to ignore the specialized needs of the scientific field. Finally, there are specific fisheries projects that required construction of a database for which the results of the findings have been published, but details of the data management plans have not (Watson and Kura 2006; Katz et al. 2007; Frimpong and Angermeier 2009; Whiteed et al. 2012). Very few generalized descriptions detailing both the technical and practical aspects of managing data generated by typical collaborative research projects are available to fisheries professionals to use as a resource (McLaughlin et al. 2001; Baker and Stocks 2007).
For individuals or teams of fisheries scientists collecting data independent from regional database efforts, formal data management guidance is not readily available as a resource, yet project-specific data management plans are increasingly required as a prerequisite for research grant applications. Therefore, the purpose of this article is to provide a synthesis of data management best practices for the typical fisheries investigator to serve as kind of a broad proxy for grant application and research plans while underscoring the added value that can be accrued by using these best practices. These best practices support data integrity throughout the project and position data to be reusable by future users by ensuring that they are accessible, electronic, decipherable, and error-free.

We used a recent collaboration among federal, state, and university fisheries researchers as a case study to highlight how data management works. Although data management practices are generally masked during the publication process, the authors feel that they are a fundamentally important part of scientific inquiry and communication and therefore should be subject to the same rigorous evaluations and discussions in the primary literature as other scientific methods. Not all fisheries projects will require all of the steps described subsequently, but we hope that this article serves as a guide for researchers asking themselves at the start of a new endeavor, “To what extent and how should data management be implemented for this project?”

LAKE WHITEFISH CASE STUDY

BACKGROUND

In 2004, two teams of scientists from Purdue University and Fisheries and Oceans–Canada independently submitted pre-proposals to the Great Lakes Fishery Trust requesting grant money to study Lake Whitefish (Coregonus clupeaformis) recruitment dynamics in the Great Lakes (Sutton et al. 2007). In a rare occurrence, the reviewers felt that the projects were similar enough to suggest that the two teams collaborate (M. Coscarelli, personal communication). Recognizing that choosing not to collaborate meant competing as two similar projects vying for a limited pool of money, the groups merged, submitted a full proposal for one project that addressed two different sets of potential Lake Whitefish recruitment impediments, and received funding for 3 years, where yearly funding depended on the success of the collaboration. The researchers convened as a group to discuss issues associated with data management (Table 1). The result of that discussion was agreement that the expanded project and conditional nature of the funding required implementing formal data management practices and a decision was made to allocate project resources to obtain a dedicated data curator as a permanent member of the research team.

DATA MANAGEMENT BEST PRACTICES

Selecting a Data Curator

A data curator is responsible for the technical and practical aspects of data management throughout a research project—although for large, complex projects, data curation is often done by a team of individuals, which may include subject-matter experts, data users, information technology staff, computer programmers, and a metadata librarian (Lord et al. 2004; Cragin et al. 2008; Akmon et al. 2011). A curator’s major responsibilities are to incorporate, organize, document, and retrieve data that they curate (Heidorn 2008; Witt 2009; Witt et al. 2009). The curator adds value to the research project by checking, verifying, and correcting data sets, as well as by providing software tools for data access, manipulation, and assimilation of any previously collected data, if required (Research Information Network [RIN] 2008; Cragin et al. 2010). Data curators apply rigorous procedures to ensure that the data sets they manage meet quality standards in relation to the structure and format of the data themselves (examples given in the following sections), ultimately contributing value by making data more discoverable and easier to access for potential reuse. A dedicated curator combines the benefits of expertise available to researchers in disciplines with centralized data repositories with the agility and advantages of localized data storage and management (RIN 2008). Though formal training in database design and management is ideal, a data curator need not be a professional database developer or computer programmer; he or she can simply be someone who has experience and is comfortable managing data. Our data curator was a postdoctoral researcher with experience managing modest-sized (<1 million records) databases obtained during past research projects.

Establishing Data Requirements

Before any Lake Whitefish project data collection occurred, our curator’s job was to determine what data were going to be

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<th>TABLE 1. Discussion items that help identify the data management needs for a collaborative research project.</th>
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<tr>
<td>Given that we want to store all project data together, does a single member of the research team have the skill set and time to manage data for the entire project? Do we know someone reliable but outside of the research team who could curate the data?</td>
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<td>How much data will we be collecting? What is the maximum size of our data set?</td>
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<td>Once we have collected data, will housing them require multiple tables? Can we use “flat file” (single data table) organization or do we need a relational database?</td>
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<td>How complicated will data entry be? How many different people will be entering data, at how many different locations? The more complex data entry, the greater the probability of errors and the more dedicated error oversight required.</td>
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<td>If multiple PIs are working on separate parts of the project, how important is it that their data be able to interact? Do the PIs need to combine data to answer research questions? If so, properly defining relationships among data is critical.</td>
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<td>Does our grantor require data management or data sharing as part of our grant stipulations? Will our data be shared beyond the PIs?</td>
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<td>If we need to use a relational database, how much will it change over time? How many researchers will need to access identical data simultaneously but separately? Will version control be critical to ensure that everyone is accessing the same data?</td>
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<tr>
<td>Are our data unique and can they be reproduced? Will we want to draw from these data sets for future studies? Is it worth the investment to preserve our data?</td>
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collected and by whom and who would be responsible for post-collection processing of data (Hernandez 2003; Pratt and Adamski 2007; Ling Liu and Özsu 2009). Three universities, two U.S. natural resources agencies, one tribal resource agency, and various commercial fishing operators worked together to collect data at 13 sites across lakes Michigan, Superior, and Erie from 2004 to 2006 (Figure 1). Adult, juvenile, and larval Lake Whitefish were sampled using gill and trap nets, beach seines, and plankton nets, respectively. Sampling effort parameters (e.g., date and location) and environmental data (e.g., water temperature) were collected during each sampling event. Biological data (e.g., length and weight) were collected on each life stage of the Lake Whitefish and their prey. Subsequent laboratory analyses resulted in the generation of further biological and physiological data (e.g., food habits, proximate body composition, and fatty acid composition). These collections resulted in a data set with more than 250,000 records. To ensure that data collection was standardized, our curator held initial meetings with individual project collaborators and collective meetings with the research group. During the individual meetings, the curator asked the collaborators the following questions:

- How are data defined; what formats will these data take (e.g., numbers, pictures, acoustic records, physical specimens, etc.); what are the units of measurement associated with numerical data; which data are textual? What information about data collection will be archived (e.g., sampling effort data such as weather, collection gear, sampling crew names, etc.)? How many records will be generated seasonally and over the entire project?
- How will data be captured or created (e.g., research vessel, fish tagging, moored buoy, online surveys, etc.)?
- What are the spatial and temporal coverage of data collections?
- Once data are collected, will they be postprocessed? If so, where will they be sent and what processes will occur?
- What are the timelines for data collection and post-processing? Are data being collected all at once or throughout a season? Are data being generated and recorded continually or in batches?
- How soon after processing or collection will data be sent to the curator for input into a database and how soon after input will data be needed for analysis? Will data be transferred all at once or in batches?
- How do data relate to other data (e.g., will a sampling event be related to multiple fish caught during that event, or will multiple stomach contents be related back to an individual fish)?

An initial meeting with the entire research team allowed for the development and documentation of a predefined set of standards for coding categorical data, such as sampling locations and Linnaean names of fish and invertebrate species (we recommend using standard Integrated Taxonomic Information System codes) and to determine how spatial and environmental

Figure 1. Schematic of the complexity involved in collecting and processing data for a Great Lakes Fishery Trust–funded Lake Whitefish project (Sutton et al. 2007). Lines indicate data exchange between entities. Solid lines represent data exchange between collector and processor. Dashed lines represent data exchange between a collector or processor and the data curator. N.B., schematic organizes data collectors in rows for formatting reasons and does not imply any type of hierarchy.
data would be captured and classed. For example, collaborators agreed to standardize classification of all nets as trap, gill, seine, or plankton. These initial meetings helped the collaborators to improve their understanding about the scope of the project and facilitated standardizing field sampling methods. Although it seems intuitive that collaborative projects would function this way (i.e., with or without a dedicated curator), the lack of a dedicated person accountable for bringing data management issues to the group and forcing standardization at the onset of the project often results in a situation whereby issues, sometimes uncorrectable, are overlooked until much later in the research process, increasing the time required to identify and correct errors (McLaughlin et al. 2001; Wallis et al. 2008).

Creating and Populating the Database

After becoming familiar with project data and collaborators’ collection procedures, a data model was created. The data model and associated entity relationship diagrams identified all attributes (i.e., data elements) in each table and defined how tables related to each other through key fields. Our model called for seven primary data tables and 11 lookup tables (Figure 2, Table 2). After the data model was created, we developed a means for data storage (i.e., relational database) using Microsoft Office Access software. (Special note on spatial data: There are two options when working with spatial data: (1) using an aspatial, tabular, relational database where records have a unique identifier, which can be linked to geocoordinates in a second, separate spatial database; or (2) working exclusively within a single spatially enabled database [supports spatial data types]. In the second case, each individual record’s spatial geometry is stored as an attribute and the database is integrated with the spatial software. We used the first option and stored only the latitude and longitude of our sampling events, importing those spatial attributes into ArcGIS when we needed to make maps or wanted to do specialized spatial analyses.)

Although we used Microsoft Access to develop our database, many relational database management software programs (RDBMSs) are available to researchers (Table 3). When selecting an RDBMS, researchers should consider the advantages and disadvantages of the price, required operating system, compatibility with other software programs, user accessibility, level of technical expertise, anticipated upgrade costs (time and money), and constraints imposed by the quantity of data to be managed.

Most scientists use spreadsheet software to store their data (e.g., Excel), rather than an RDBMS (Borgman et al. 2006). Though both spreadsheets and RDBMSs organize data in rows (in data storage language these are called “records”) and columns (“fields”), spreadsheets store data in individual tables as “flat files,” meaning that tables are not linked, whereas RDBMSs store data across multiple, interrelated tables, with the expectation that the user will primarily want to work with data across multiple tables simultaneously. Storing data using linked tables is the foundation of the relational database.

If data can be stored in a single table, a relational database is not necessary. If multiple tables are required to store data, creating a relational database using an RDBMS is the best option, because relational databases have rules that maximize data integrity across tables (Hernandez 2003). Generally, data integrity rules include the following: (1) tables that are constructed properly and efficiently (i.e., each table represents a single entity, every column in each table is comprised of distinct fields, fields are not repeated within a table, and each record is identified with a unique value called a “primary key” used for linking data among tables); and (2) data integrity (validity) is imposed at the record, table, and relationship levels (i.e., every table has a column for the key field and keys are used to create relationships among tables).

An experienced curator is able to harness the strengths of the relational database model and
software by taking advantage of the built-in procedural logic that relates information among tables, allowing users to focus solely on using declarative logic to extract data; for instance, when combining data from multiple spreadsheets the user has to manually relate data among different tables, whereas in the relational database the user simply has to indicate data for extraction because relationships between tables are predefined. The chances are lessened that data will become useless if knowledge of those relationships is ever lost because the relationships among data are required to be declared explicitly. Using an RDBMS, data tables can adapt to changing sampling designs and protocols without necessitating structural changes so that new data can easily be incorporated in the future. RDBMSs also offer several advantages related to data integrity and quality compared to spreadsheets. Properties of atomicity, consistency, isolation, and durability (ACID) describe the various mechanisms that the underlying RDBMS software uses to ensure data integrity between transactions (Haerder and Reuter 1983). Though spreadsheets optimize flexibility and ease of use by pairing data storage with visualization, RDBMSs optimize data integrity through ACID principles (Haerder and Reuter 1983; Hernandez 2003).

One foundation of ACID principles is the key field (previously mentioned), which is defined as a unique identifier that links data across tables. Keys provide the quickest way to retrieve data when searching or sorting and make it easy to manage, and analyze data sets of considerably larger size. RDBMSs run so efficiently because they only retrieve data required through a user-specified query, whereas spreadsheets load the entire data set into memory when the spreadsheet file is opened. In addition, the ability to partition a database into multiple files across multiple hard disks can reduce disk contention (bottlenecks caused by multiple processes accessing the same location on disk at the same time), making large and complex databases easier to work with. Additionally, RDBMSs use indexing to speed up which query results are returned for large data sets by reducing the number of records that must be scanned to return the desired result (Ling Liu and Oszu 2009).

### Version Control

Sampling and postprocessing of samples collected for the Lake Whitefish project occurred over 3 years; therefore, the coordination of data submittal and updates to the database was done semiannually by the data curator. Every time new data were uploaded or existing data were corrected, a new version of the database was created.

It is critical that the curator exert control over the perpetuation of multiple versions of a single database. If version control is not implemented, different versions of files, related files at different locations, and information cross-referenced among files are all subject to the viral phenomenon of cascading replication, summarize data from multiple tables. Keys can assume multiple formats as long as they are unique. The simplest format for a key is an autonumber, where each new record is assigned a sequential number starting at 1. In the Lake Whitefish recruitment database, the key for identifying each individual Lake Whitefish was a concatenation of sampling date, sampling location, life stage, and fish ID (e.g., 05_06_2007_ElkRapids_AD_001); this allowed the key itself to convey meaning and to function as more than just a serial number.

<table>
<thead>
<tr>
<th>Sampling</th>
<th>Fish</th>
<th>Invertebrates</th>
<th>Lipidsabc</th>
<th>Ageabc</th>
<th>Stomachabc</th>
<th>Reproductionc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>Species</td>
<td>Species</td>
<td>Total lipids</td>
<td>Age</td>
<td>Stomach weight</td>
<td>Gonad weight</td>
</tr>
<tr>
<td>Time</td>
<td>Life stage</td>
<td>Length</td>
<td>Fatty acid type</td>
<td>Structure used to determine age</td>
<td>Prey species</td>
<td>Egg diameter</td>
</tr>
<tr>
<td>Location</td>
<td>Length</td>
<td>Weight</td>
<td>Fatty acid concentration</td>
<td>Prey frequency</td>
<td>Egg weight</td>
<td></td>
</tr>
<tr>
<td>Latitude</td>
<td>Weight</td>
<td>Sex</td>
<td>Prey weight</td>
<td>Sperm velocity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitude</td>
<td>Sex</td>
<td>Biomass</td>
<td>Sperm tail length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>Maturity</td>
<td>Density</td>
<td>Sperm cell volume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gear</td>
<td>Liver weight</td>
<td></td>
<td>Milt volume</td>
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<td></td>
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</tr>
<tr>
<td>Tow speed</td>
<td>Body condition</td>
<td></td>
<td>Mean spermatocrit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tow distance</td>
<td>VFIa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ambient conditions</td>
<td>Protein2</td>
<td></td>
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<td></td>
<td>Energy2</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moisture2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Visceral fat index; 2 in muscle tissue.  
Alphabetic superscripts delineate data collected for life stages or groups as follows:  
a larval Lake Whitefish.  
b age-0 juvenile Lake Whitefish.  
c adult Lake Whitefish.
Quality Control and Standardization

One of the most elegant advantages of using relational databases is that they can be programmed to be as self-documenting as the users require. “Self-documenting” refers to the process in which data transactions are logged along with their identifying features, such as who ordered the transaction, a time/date stamp identifying when the transaction occurred, and the nature of the specific transaction. We designed our database to be self-documenting in the sense that all changes to data were recorded in the database itself, so users could query which data were updated, by whom, and when. Each time the database went through major updates, a description of what occurred was provided to users along with the new version. We implemented versioning control using an FTP site, because the site offered security and ease of distribution with minimal upfront programming. At the end of the project, our curator ensured that each collaborator was provided with a final version of the database that contained not only verified data but also previous versions of the database with records of any updates that occurred during the course of the project. This allowed the collaborators to audit revision history and recover deleted information if necessary.

Data Extraction

Scientists may not have been comfortable extracting data from a relational database, yet they still needed to be able to...
easily extract data for analysis. One of the greatest benefits of having a data curator was that collaborators could simply send an e-mail or make a call and ask for data to be assembled and formatted in whatever way was needed and the curator could deliver those data quickly and efficiently. For more generalized data selections, the curator set up standardized forms in the database with checkboxes that allowed collaborators to select data without assistance. As an overseer of data extractions from the database, our curator could ensure that two collaborators accessing the same data were doing so identically, decreasing the likelihood that different conclusions might be reached because different data were selected for analysis.

Because most statistical software requires data in a flat format, it might seem counterintuitive to take the time to create a database only to extract and flatten data for analysis. However, having taken the time to standardize, assemble, and properly structure data, there is no end to the various combinations that the curator can provide to the collaborators, and extracting data in any flat format takes mere seconds. Multiple statistical software packages allow selection of data within a database via structured query language (SQL); for example, users of R (R Development Core Team 2011) have several CRAN packages available that retrieve the results from relational databases as entire data frames (R Development Core Team 2011).

Initially, most collaborators felt uneasy allowing a data curator to develop and manage a database because they thought that it might limit their influence over extraction and analysis processes, thereby increasing the distance between themselves and their data. Consequently, our curator ensured that all collaborators had open access to the database and served as teacher and advisor for those who wanted to learn how to extract their own data, while allowing those who were familiar with databases the freedom to extract on their own. In fact, most of the collaborators eventually ended up extracting their own data as the project matured and they became familiar with the database structure and operation.

Data Documentation and Archival

Ultimately, the value of data are enhanced, not exhausted, by their subsequent publication and use (RIN 2008; Whitlock 2011). If data are not properly documented, no one outside of the original collectors will be able to use them properly; and because memories fade, eventually even the data originator may have trouble recalling important information relevant to a data set (Akmon et al. 2011). Broadly, “documentation” (descriptive information about data sets, also called “metadata”) includes the following components: what data are; when they were collected; how they were collected; geographic scope of the project; contact information of collectors; directions for citation; any information relevant to interpretation (e.g., processing that occurred, confounding factors, how missing data were handled, quality assessment, projection information, etc.); and individual definitions for each data field (see Table 5 for an example of data documentation for a single table of the Lake Whitefish database).

Multiple standards provide models for data documentation; the most comprehensive and broadly applicable are the Federal Geographic Data Committee Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998) and the International Organization for Standardization standards (ISO 9001:2011). For the Lake Whitefish project, our curator used Federal Geographic Data Committee standards to create a formal data dictionary, which was provided to each collaborator at the conclusion of the project. An object linking and embedding reference to the data dictionary was embedded in the data set so that it can continue to be accessed and interpretable into the future. For broadest access, it is best to archive data using open-source formats rather than proprietary formats when possible.

Scientific Value-Added Aspects of Data Management

As is becoming more common in research, field and laboratory samples for the Lake Whitefish recruitment project were obtained by multiple collectors at sites separated by substantial geographic distances. In consultation with the data curator, researchers were able to efficiently merge field and laboratory data contained in the relational database and effectively extract them to investigate complex relationships and identify mechanisms related to the effects of declines in Lake Whitefish growth and condition on recruitment potential of populations across the Great Lakes.

For example, all sampling events were recorded in the sampling table where each event had its own unique ID. Then, fish caught during a sampling event were stored in their own fish table, where every fish had its own unique ID and the ID of its sampling event. When lipid analyses were done on an individual fish, lipid data were stored in their own lipid table along with the ID from the fish the lipids were extracted from. Thus, even though these pieces of information were being stored in separate tables, the relational database, which linked the IDs among tables, allowed analyses to be performed across all fields without the onerous manual linking required if spreadsheets were
and biotic factors, including adult stock size, abiotic conditions et al. (2010b) to relate larval fish densities to several abiotic between the sampling and fish tables were used by Claramunt Lake Whitefish recruitment potential. In addition, the linkages higher quality sperm, suggesting that males are not irrelevant to show that male fish in better condition tended to produce recruitment potential was explored by Blukacz et al. (2010) in influenced by early life growth rates.

The male contribution to Lake Whitefish reproduction and used. Using the links among the sampling, fish and lipids tables, Muir et al. (2010) found that female Lake Whitefish in poorer physiological condition had a tendency to produce age-0 juveniles with poorer body composition at some sites, but this pattern was not evident across all sites. In the same manner, using the linkages among three other tables (sampling, fish, and stomach), Claramunt et al. (2010a) were able to partially explain this spatial pattern of juvenile condition by showing that early life history survival was likely dependent on favorable growth early in development, which allows an earlier ontogenetic diet shift to emergent spring macro-invertebrates, demonstrating that the link between parental and juvenile physiological condition was influenced by early life growth rates.

The male contribution to Lake Whitefish reproduction and recruitment potential was explored by Blukacz et al. (2010) using linkages among the fish, reproduction, and lipids tables to show that male fish in better condition tended to produce higher quality sperm, suggesting that males are not irrelevant to Lake Whitefish recruitment potential. In addition, the linkages between the sampling and fish tables were used by Claramunt et al. (2010b) to relate larval fish densities to several abiotic and biotic factors, including adult stock size, abiotic conditions during incubation, and spring productivity. It was precisely the extracting and combining data using linked tables that enabled the research team to efficiently address more complex and related questions and provide a more thorough understanding of Lake Whitefish recruitment potential.

Follow-on components of the Lake Whitefish recruitment project were also able to benefit from efforts to create and curate the Lake Whitefish relational database. For example, some members of the Lake Whitefish recruitment project team secured additional funding to analyze stable isotopes from tissue samples archived during the original project sampling. The project database made it straightforward to match the stable isotope data to the original project data through the addition of a stable isotope table. Information queried from linkages among the fish, lipids, and new stable isotope tables was used to address questions about the connection between Lake Whitefish condition and prey quality (Fagan et al. 2012) and the use of C:N ratios to predict lipid content (Fagan et al. 2011).
motivating them to make explicit all of the nuances of their data (McLaughlin et al. 2001; Porter and Ramsey 2002; Birnholtz and Bietz 2003). Databases can serve as storage for unique or irreplaceable records that can only be properly preserved for reuse though effective documentation and management (Brunt 1994; Borgman et al. 2007; Heidorn 2008). Only well-managed and documented data allow for reproduction of research where checks and balances operate at the most fundamental level (Parr 2007; Heidorn 2008; Borgman 2010). Others believe that because most research is publicly funded, data belong to society at large, and best practices should be used when managing those data for preservation and reuse (Costello 2009; Guttmacher et al. 2009; Borgman 2010). Effectively managed data allow for repurposing, thereby saving money that might otherwise be used for redundant collections (Hale et al. 2003; Carlson and Anderson 2007; Heidorn 2008). Finally, properly documented and organized data have unlimited potential for reuse by providing archival material to address future problems, thereby advancing science in ways possibly unforeseen by the original collectors (Postel et al. 2002; Nelson 2009; Borgman 2010).

One contentious issue surrounding data reuse is reluctance by researchers to share data beyond the original collaborators or close colleagues. Secrecy in guarding research has been part of scientific culture throughout history, and recent articles exploring the data sharing attitudes find scientists overwhelmingly unwilling to freely share data within and among their own community (Blumenthal et al. 1997; Campbell et al. 2002; Blumenthal et al. 2006; Vogeli et al. 2006; Haas 2011; Tenopir et al. 2011), where willingness to share data is positively correlated with the ease of extraction and relationship to requestor (Witt et al. 2009; Cragin et al. 2010). In some sense, curators negate certain issues surrounding resistance to sharing that have to do with expending time and energy to prepare data, but addressing the underlying scientific-professional reward structure that does not reward sharing remains outside their scope of influence (McDade et al. 2011).

Issues surrounding ownership and security also determine the extent to which data are shared (Beard et al. 1998). When research projects are funded by federal government agencies, philanthropic organizations, or private industries, grantor-specific stipulations often influence how data will be retained and disseminated (Fishbein 1991) as well as being subject to the Freedom of Information Act (5 U.S.C. 552). One simple solution to data sharing and ownership issues is a data sharing agreement. Data sharing agreements should be specific to each project and should include intended level of exposure (e.g., within the group only, within the field only, publicly accessible), level of control applied to data outflow, whether an embargo period will be applied to data availability, and how data will be recognized when being used by others. In our case, our data sharing agreement stipulated that data would flow freely among principal investigators (PIs) and that each PI could decide to share or not share their portion of the data beyond the original collaborators at their discretion.

Building and managing databases can be challenging, especially if long-term data management is underfunded. Granting institutions may recognize the benefits of requiring data sets as deliverables but may also be loath to become their ultimate resting place. One field that is taking on the challenge of long-term digital curation is library science. University libraries are creating institutional repositories as part of a larger technology and service structure that can contribute resources and expertise in data curation (Cragin et al. 2010). Data centers (open-standard, interoperable, nonproprietary web services) are also becoming widely established (Baker and Bowker 2007; Costello 2009). The lure of data centers is that by providing open or semi-open access to data, they act as a dual facilitator for finding and storing data and, as of yet, no one repository has been established as the mainstay for fisheries data. Examples of established open-access ecological data repositories are the Long Term Ecological Research Network, DataONE, and MARIS (Baker et al. 2000; MARIS 2008; Michener et al. 2012). All three provide a framework for assimilation and management of disparate data sets with tools for data discovery and guidance on data management. The NOAA also has its own sophisticated internal data centers, whose services, as far as we were able to ascertain, are not available to non-NOAA researchers.

Not everyone is sold on the idea of depositing their data in open-access repositories though. Tenopir et al. (2011) found that only 15% of ecologists expressed a willingness to place their data into an open-access repository, and the majority expressed different conditions for doing so, including the following: opportunities to collaborate (80%), mandatory reprints provided (75%), coauthorship (65%), results of analyses not disseminated without data providers’ approval (46%), legal permissions obtained (40%), and monetary reimbursement (28%). Not included in the survey was an embargo period allowing PIs the first chance to publish on data, but we assume that would also be a consideration of data providers. To mitigate issues specifically related to recognition, formal and consistent citation of databases will need to become more common in our field (NOAA 2012).

The concept of depositing data in an open-access repository was so foreign to the Lake Whitefish project team that we never seriously considered using one for our data set. This decision resulted in data that can now only be obtained through communication with a PI personally. We realize that our decision not to use a repository undermines a key message of this article, which is that data will not remain accessible without a plan for their preservation (Uhlir 2010), but the decision also accurately depicts the state of existing data preservation practices of most scientists in our position and field. We believe that whatever the future of institutional repositories and open-access data centers, they will continue to stay underutilized if they cannot support existing data practices specific to each scientific field and adequately mitigate the cultural issues associated with data sharing and recognition.

Given the shift toward large collaborative projects, we predict that formalized data management will become a more
Organization is an emergent property for any complex system, and efforts like the Lake Whitefish database are necessary as first steps in developing greater information organization within the fisheries research community. Looking beyond the development of a single database ultimately probes at a number of underlying systemic issues relating to large-scale information leveraging, in particular, resistance to sharing data, how to preserve and use historical data sets, the general lack of methodological standardization, and assessing whether the creation of these large-scale data endeavors yields returns enough to justify their investment in resources. Ultimately, the fisheries community should continue to examine ways to improve efficiency (reduce fragmentation) in research, reduce the duplication of effort in data collection, and spearhead efforts to coordinate data standards at a national level in order to adequately transfer scientific information. This can only be accomplished if we take the first steps toward a common goal of sharing, documenting, and preserving data that are collected and reported.

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From the Archives

Our great opponents in this have been the net-fishermen at the mouth of the river. Above that, every man wants a closed time; but, time says, “Everyone is going in, and I will go in too;” and they do, and catch all they can.


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**SuperIDR: A Tool for Fish Identification and Information Retrieval**

**ABSTRACT:** Students, fisheries professionals, and the general public may value computer-facilitated assistance for fish identification and access to ecological and life history information. We developed SuperIDR, a software package supporting such applications, by utilizing the search and data retrieval capabilities of digital libraries, as well as key features of tablet PCs. We demonstrated SuperIDR utilizing a database with information on 207 freshwater fishes of Virginia. A user may annotate fish images and identify fishes by using a dichotomous key; searching for key words, similar images, subimages, or annotations on images; or combinations of these approaches. Students using the software demonstrated enhanced ability to correctly identify specimens. Their comments led to improvements, including the addition of new features. The PC-based system for identifying freshwater fishes of Virginia may be downloaded and modified. SuperIDR is a prototype for PC-based species identification applications—the system architecture and the open-source software that we developed are applicable to other fish faunas and to a broader range of species identification tasks.

**INTRODUCTION**

Identification of freshwater fishes is critical to the study of fish ecology and management of fisheries and depends upon precise observation of external morphology, coloration, and internal characters. Learning to correctly identify freshwater fishes is challenging for fisheries students, who often find traditional dichotomous keys intimidating. Such keys are rigid in their approach and do not accommodate the range of learning...
styles actually utilized by students. In particular, dichotomous keys often do not focus upon diagnostic characters favored by many field ecologists and more user-friendly field guides (e.g., Page and Burr 2011). Many people in the general public would value ready access to knowledge about game and non-game fishes, including information on species identification, ecology, and life history. Such information generally is found in technical literature, which is not easily accessible to the general public.

A digital library (DL) is an information system with collections of documents/digital objects and their metadata and services to manage, organize, access, browse, index, and search through those collections to serve various user communities. Several DLs have been developed to present information on fish identification, ecology, and life history and aim to be widely accessible and understood by diverse users, including practicing fisheries professionals, students, and the general public. For example, FishBase (Froese and Pauly 2011) provides information on over 32,000 species of fish, catering to professionals such as research scientists, fisheries managers, and zoologists, as well as providing links to a variety of useful Internet resources. Fish identification tools include classical dichotomous keys, a picture matching-based key, and identification using morphometrics. Targeting a more general audience, EFish (Helfrich et al. 2001) provides ecological and life history information on freshwater fishes of Virginia within a taxonomic framework. EKey (da S. Torres et al. 2007) builds upon EFish by offering resources for identification of freshwater fishes of Virginia, including browsing by taxon, text-based search, and image recognition. A photo-based computer system (Lyons et al. 2006) provides traditional dichotomous keys, a multi-feature query tool, and a slide show for identifying Wisconsin fishes. The system also provides data on characteristics distinguishing species, illustrations of diagnostic characters, and an illustrated glossary. One commercial product is Reef Fish ID (ReefNet, Inc. 2012), which uses a search engine that operates with a few key characteristics and then narrows down the possible species. iPez (Guiñande et al. 2010), an automated system based on classification and regression trees and machine learning techniques, uses morphometric variation to identify fish taxa with input from either data files or interactive data entry by the user. Species identification using databases and automated systems has been developed for several biodiversity fields (reviewed by Gaston and O’Neill 2004). For example, EcoPod (Yu et al. 2006) is a PDA-based tool that uses a key-based approach, replacing traditional paper field guides with a mobile computing platform, in order to help semiskilled amateurs in identifying species (e.g., butterflies) in the field. EcoPod supports multiple ways of browsing through images and species information, including browsing of taxonomical classification and a key. In addition, it allows users to enter notes about an identified organism.

Recent developments in DL technology offer the opportunity to build upon the approaches used in existing Internet-based fish identification and information retrieval systems. In particular, recent advances in software development offer the opportunity to annotate and search annotations on images. One such notion is superimposed information (SI), or new information that is created to reference subdocuments (contextualized parts of documents) in existing information resources (e.g., annotation on part of an image). By integrating SI, a DL can provide enhanced support to tasks that involve working with subdocuments. As a result, annotations (and the subimages to which they refer) become separately accessible, searchable, and manageable within a DL. Because fish identification inherently involves distinguishing characters of fishes—that is, parts of a fish or its images—the task presents the opportunity to apply the concepts of SI and DLs. Against this background, the goals of this project were to

1. design and develop a DL, integrating capabilities to annotate, browse, and search for subimages and associated information; and
2. assess the use and usefulness of this DL in learning and identifying fish species and its support for working with subimages.

To address the first goal, we developed SuperIDR (Superimposed Image Description and Retrieval tool) for freshwater fish identification and for access to ecological and life history information. SuperIDR builds upon the features of earlier systems, enabling the user to add content (such as images, descriptions, subimages, and annotations) to the existing information base. It provides support for working with specific parts of images and performing text- and content-based image description and retrieval. In addition, it has pen-input capabilities, mimicking freehand drawing and writing on paper. Species information in SuperIDR was extracted from the EKey system (da S. Torres et al. 2007). Though we utilized a database for the freshwater fish fauna of Virginia for demonstration purposes, our tool may be adapted for use in other biodiversity fields, and its system architecture may be applied to a wide range of species identification tasks.

The second goal of assessing the use and usefulness of SuperIDR was addressed by conducting multiple user studies in which we explored the use of subimages and evaluated the use of SuperIDR in fish species identification. In a controlled experiment, we found that students in an ichthyology class had a higher likelihood of correctly identifying an unknown fish specimen when they used SuperIDR than when they used traditional methods of fish identification, including a dichotomous key, fish identification web sites, and personal notes. In a follow-up qualitative user study, we investigated further how people worked with subimages in fish identification. Findings from the study suggest that working with subimages is an important, and sometimes necessary, part of fish species identification. The analysis of subimage/annotation content resulted in patterns of visual characteristics of parts of fishes (and their images) used in learning/identifying fishes, which can lead to improved ways of indexing and searching for subimages. The contexts and strategies of working with subimages in SuperIDR suggest new and enhanced support (i.e., DL) for scholarly tasks that involve working with subimages, including new ways of querying and searching for subimages and associated information.
METHODS

Software Development

We designed SuperIDR for archiving and interactively searching diverse interconnected data collections, including text, images, and annotations. Figure 1 outlines the software architecture of SuperIDR. Data collections consist of images, subimages (derived from images), textual descriptions, annotations, taxonomical classification data that might be used for browsing only (such as family- or genera-level images and information), and complex objects (including superimposed objects/documents) that might comprise the digital objects mentioned above.

Capabilities supported in SuperIDR include the following:

- Annotation: The annotation service enables a user to select subimages within images and to associate them with text annotations. In addition, a user can edit and delete annotations.

- Image management: A user can add images to and delete (user-added) images from a species database using the image management service.

- Text search: SuperIDR uses full-text or field-wise search to match keywords entered by the user against annotations, species descriptions, or both. Depending on the user’s selection, a separate ranked list of results is processed and displayed for species descriptions and annotations.

- Content-based image search: The content-based image search service inputs a query, which is either an image or a subimage. It then sends this query to the content-based image search component (CBISC; da S. Torres et al. 2006; Kozievitch et al. 2008), which in turn matches the visual content of this query image or subimage against the visual content of all images and subimages in the CBISC index. A ranked list of results is produced, which could contain images and/or subimages. Search results are displayed separately for images and subimages.

- Combined search: The purpose of including a combined search service is to give the user an idea of how image and text content might be combined in a search, especially focusing on subimages combined with text. We used this implementation of combined search as a starting point to understand a user’s expectations. Text and image content have been combined in various ways in information retrieval (Hong et al. 1998). However, there has been limited work done in combining text and images at the query level and in including subimages at the query level. We can consider this service to be a low-fidelity prototype for a combined search interface.

- Browsing: The browse service enables multiple ways of browsing through species images, descriptions, subimages, and annotations, including: images and description of a species; annotations and, for each image, the subimage in the context of its base image; taxonomical classification, including families, genera, and species of fishes using column-wise organization or tree-based organization; or a digital version of the identification key guide of freshwater fishes of Virginia (Jenkins and Burkhead 1994).

- Comparison: The comparison service is a special case of the browsing service. It enables a user to view two images side by side. A user is able to choose from images of the same or different species. While viewing the images side by side, a user can browse through annotations and view the associated subimages in the context of their base images. The goal of the comparison service is to enable the user to manually analyze two images side by side.

- Logging: The logging function is used to log all user interactions with the tool, a service that would prove useful to teachers or researchers as opposed to general users.

SuperIDR was implemented using the C# programming language in the Visual Studio .NET platform. The metadata and logs were stored in a MySQL database (Oracle 2011).
SuperIDR uses the CBISC (da S. Torres et al. 2006; Kozievitch et al. 2008) for indexing and retrieving the visual content of images and subimages. The Lucene (Apache 2011) component in SuperIDR is responsible for full-text and field-wise indexing and search of all text data in the SuperIDR collections, including textual description (of images) and annotations.

SuperIDR has been tested to run on Windows XP Professional, Windows 7, and Windows XP tablet PC versions. The SuperIDR source code, technical details, and a user manual are available in Murthy (2011). We developed SuperIDR to work with tablet PCs in order to take advantage of pen-based input in order to emulate the use of a pen on paper. In addition, pen-based input would make SuperIDR relatively portable and convenient, especially in field situations. We evaluated three different versions of SuperIDR in user studies. Existing functionality was improved and new functionality was added with each new version, taking into account feedback gathered in the user studies.

Much of the species-specific database, including formal color pictures, text, key, and geographic distributions, was drawn from Jenkins and Burkhead’s (1994) *Freshwater Fishes of Virginia*. The pictures of preserved specimens were original.

**Evaluation of SuperIDR**

We performed three studies to evaluate SuperIDR in order to determine the following: (1) Is SuperIDR useful for fish identification? (2) How does SuperIDR compare with traditional methods (e.g., dichotomous keys, personal notes, markings on images, fisheries websites, notecards, or combinations of these methods) for performing fish identification? (3) What are users’ perceptions about using SuperIDR for fish identification? and (4) How is SuperIDR employed to support the use of subimages in fish identification? We evaluated three different versions of SuperIDR in the respective user studies. Existing functionality was improved and new functionality was added with each new version, taking into account feedback gathered in the previous user studies. Procedures for data collection involving human subjects were approved by the Virginia Tech Office of Research Compliance Institutional Review Board under approval nos. 08-065, 08-066, and 10-692.

**Longitudinal Formative Evaluation**

We conducted a 2-month-long formative evaluation of SuperIDR with three fisheries students, one faculty member, and one researcher (Murthy et al. 2009). At the beginning of the study, all scholars were given a tablet PC with the SuperIDR application installed and configured. We conducted a group training session for all participants and asked them to use SuperIDR, as appropriate, in their daily activities, such as learning, research, analysis, and writing. Over the course of 2 months, we met biweekly with the participants as a group to receive feedback on the utility of SuperIDR. This formative evaluation helped identify significant improvements and led to the addition of new features to SuperIDR.

**In-Class Study**

To assess the effectiveness of SuperIDR, we conducted a study in spring 2008 with students in an undergraduate ichthyology course in the Department of Fish and Wildlife Conservation at Virginia Tech (Murthy et al. 2009). Students in this course learned about fishes and how to identify fish species; they practiced species identification throughout the semester; and they developed familiarity with species identification methods. In the study, we collected the following data:

- Species identification responses for 40 unknown specimens. For a specimen to be regarded as correctly identified, its family, genus, and scientific name had to be correctly listed. We tracked the number of correctly identified specimens for each session. Considering the binary property of the response (correct–incorrect) and the existence of multiple factors impacting the task outcome, we used the generalized linear model with a binomial (logit) link function to analyze the species identification responses.
- Demographic data and data about prior experience with species identification and software tools.
- Qualitative feedback on use of SuperIDR in an exit questionnaire.
- Log data of user interaction with SuperIDR.

**Qualitative Longitudinal Study**

In a follow-up qualitative user study, we further investigated how people worked with subimages in fish identification and how SuperIDR supported that use (Murthy et al. 2009). The rationale for the qualitative study design was to maximize the use of SuperIDR in various settings and to obtain rich data from multiple sources on use of SuperIDR. Hence, we recruited people with interest and experience in fish identification and whose ongoing study or work involved fish identification. We deployed SuperIDR for 3 weeks in the study or work contexts of six individuals from October 21 to November 18, 2010, in the Department of Fish and Wildlife Conservation at Virginia Tech. During this time, we recorded their use of the tool through interaction logs and diary entries. The diaries gave us a post-hoc means of observing situated behavior in contexts in which researchers were not present. We collected information on the participants’ background, fish identification materials and practices, and computer usage in a pre-study interview. In two separate sessions during the study, we had participants identify unknown specimens. In these sessions, we captured screen interactions with SuperIDR and conversations concerning SuperIDR. In a post-study interview, we asked participants about their use of subimages and about using SuperIDR in fish identification (using log and diary data to elicit information as required).
By analyzing logs, we were able to extract 940 subimages/annotations made by the participants. We analyzed them for recurring types or patterns of subimages/annotations. We used TagCrowd (Steinbock 2011), an online tag cloud generator, to obtain an overview of the words used in the participants’ annotations. TagCrowd considers a stop word list and other options, such as minimum frequency of keywords, maximum words to show, and whether to group similar words or not (such as memorize and memorizing) while generating a tag cloud. We preprocessed the annotation text to identify words that have the same meaning, such as “caudal” and “tail.” We entered this preprocessed text into TagCrowd, opting for a minimum occurrence frequency of 1, the default English stop word list, and grouping similar words, in order to generate a tag cloud of the 50 most frequently used annotation keywords. Our analysis of the qualitative data, including interviews, diary entries, screen captures, spoken thoughts, and images of materials used, was informed by the grounded theory approach. “Grounded theory” (Glaser and Strauss 1967; Glaser 1978; Strauss 1987) refers to a qualitative research method with the aim of developing a theory from data collected in the course of research.

RESULTS

SuperIDR Features and Scenario

Use of SuperIDR might best be described by means of a scenario illustrating how a student might use the tool to identify a fish specimen. Matt (a pseudonym), a fisheries science student, has some experience with species identification and uses a combination of methods to identify and learn about fish species. In the past, he has supplemented the use of dichotomous keys with personal notes, pictures from the Internet, a textbook, and other resources. The ichthyology instructor has decided to use a new software application in class, SuperIDR. Matt is comfortable with the use of technology and is enthusiastic about using SuperIDR, because it will likely help him with fish species identification. Matt explores the features of SuperIDR, beginning with a taxonomy browser, where fishes are organized according to families, genera, and species. He browses to Percina peltata (Shield Darter), the species being taught about in class (Figure 2). SuperIDR shows details of the species, including its physical description, habitat, and food habits (Figure 3). Matt can browse through the collection of images for a particular species. For each image, Matt may browse through annotations associated with parts of that image. Because the physical description does not have all of the distinguishing characteristics of the Shield Darter, the student adds more images and annotations to the species data. To annotate an image, the student marks the fish picture and associates the marked regions with text explanations, plus notes in his own words, making it easier to remember and learn about this species (Figure 4). The student often reviews the fishes about which
he is learning. He uses SuperIDR to browse through details of various species, using the browsing services of SuperIDR, including the taxonomical browser (Figure 5), the dichotomous key browser, and the species description interface (Figure 3). While reviewing Greenside Darter (Etheostomas blennioides) and Ashy Darter (E. cinereum), two very similar-looking species, the student uses the comparison feature in SuperIDR to analyze images from these species and study their similarities and differences (Figure 6). After 2 weeks, the student’s ichthyology instructor holds a practice specimen identification test. Some of the unknown specimens are in jars and some are in the form of images posted on the course web site. The student examines the fish specimens for specific characteristics and uses text search on annotations and species descriptions (Figures 7A and 7B). Browsing through the result list and occasionally clicking on a result for details, he is able to narrow down the options to the species of the unknown specimen. In some cases, the student uses the combined search to help identify the species of a specimen, provided as an image. He marks the mouth of the specimen’s image in the image part of the query and enters keywords describing characteristics of the mouth (Figures 7C and 7D). This narrows down the possibilities and he is able to identify the species.

**In-Class Study**

On entry questionnaires, 17 of the 18 students rated themselves as moderately or very familiar with computers, although 13 indicated that they had very low expertise with tablet PCs. Sixteen of the 18 students had previously taken a course on species identification, not necessarily fish species, so most were familiar with the task. Most students used annotations, marking, note-taking, and organization of some form on paper for learning, but most did not use digital applications to perform the same activities. All students were familiar with online search engines, with Google search and Google image search being the most popular responses.

In each of two sessions, pairs of students were presented with 20 specimens and asked to identify them (Table 1). In one session, students used traditional dichotomous keys; in the other they used SuperIDR. Half of the groups used paper keys first and then SuperIDR, and half used SuperIDR first. Each team worked with one specimen at a time. Table 2 summarizes the scores for teams using the respective methods across the two sessions. The team ($P = 0.015$) and the method ($P = 0.011$) had a significant impact on the outcome of the species identification task, whereas the session (hence, the nature of specimen) did not impact the outcome significantly. Using SuperIDR yielded a higher likelihood of identifying a specimen correctly than using traditional methods (Table 2) and with less than a week of use. However, the questionnaire responses indicated that students preferred using the identification key over SuperIDR. A reason for this could be insufficient use of SuperIDR and its subimage features (indicated by the log data). This, in turn, might have been due to the timing and short duration of the experiment. An indicator of student interest in SuperIDR...
is that 6 of 14 teams chose to keep SuperIDR for three more weeks until the end of the semester. Students said that they wanted to explore the tool further.

Qualitative Longitudinal Study

To tease out characteristics of a subimage and associated information, we considered participants’ fish identification materials, interview responses, and the subimages and annotations they made. It is clear from the tag cloud (Figure 8) that many of the keywords used in the annotations referred to parts of fishes, suggesting a reference to subimages (caudal, eye, mouth, etc.). We observed a variety of types of annotations and associated subimages (Figure 9). Some annotations directly described a visual characteristic of the subimage. Some annotations were about the morphological location of a body part. Some brought together multiple parts of the fish but used a single subimage/annotation to describe those parts. Some considered the image or the fish species as a whole or might have referred to information outside the image or the fish species. Finally, there were subimages or annotations that combined these types. This analysis of subimage or annotation types matched with the participants’ responses on the characteristics of subimages or annotations.

Using SuperIDR to identify an unknown specimen, participants followed a top-down approach to identifying fishes just as they did with traditional methods. In most cases, they were able to identify the family of the specimen within a minute of looking at the specimen (for both preserved specimens and images of specimens). Then, participants followed one of several paths to narrow down their choices, including (1) using the taxonomy (Figure 2), tree, or dichotomous key browsers (Figure 5); (2) using the text, image, or combined search (Figure 7); or (3) visually analyzing the specimen or image and identifying their choices. At the end of this step, they usually ended
up with two to three species from which to choose. Then, they would open the descriptions (Figure 3) of these chosen species and browse through the text, the images, and the annotations (if any) of the species. They would switch back and forth among species, analyzing and comparing the species’ information. Sometimes, they used the comparison feature (Figure 6) to analyze similarities and differences. Finally, they would select one species. The context of subimages, which might be described by the copresence of two or more subimages and associated information (including annotations and species description), was important. Manual analysis of subimages proved an important part of working with subimages, too. Even when SuperIDR returned the putatively correct species as the top result, participants often exhibited the need to confirm the species by analyzing all of its images and its distinguishing characteristics as well as other information after they had successfully identified the species of an unknown specimen.

We received positive feedback about the participants’ use of SuperIDR and observed and recorded interesting, new ways of working with subimages in fish identification. Participants felt that the bringing together of capabilities to work with subimages—that is, annotation, text-based search, content-based search, browser capability—was helpful. Searching on subimages and other information related to subimages was considered important, whether using SuperIDR or recalling information from one’s memory. To improve the search effectiveness, participants suggested additional capabilities to work with subimages, including (1) the use of faceted search to filter/view results based on subimages/annotations and other fields, (2) the ability to filter results considering the family or genus, and (3) the use of an ontology to suggest similar meaning terms for the annotation or query. Five of the six participants repeatedly made use of a combination of multiple subimages, associated annotations, and other species information as a query and expected the tool to match against species with images with similar subimages and annotations. Such a combination query might be considered as a complex object query.

DISCUSSION

Considerable progress has been achieved in developing computer software (Lyons et al. 2006) and Internet resources (Helfrich et al. 2001; da S. Torres et al. 2007; Froese and Pauly 2011) to help identify fish and to access ecological and life history information. Recent developments in creation, maintenance, and active use of DLs provide opportunities to ease these tasks, enhancing learning and work. We developed a prototype DL system for fish identification and demonstrated its use in classroom and independent work contexts, demonstrating in particular the utility of working with parts of fish images. We developed the system for tablet PCs, which provide an intuitive interface emulating, as closely as possible, annotation of a paper document with a pen for selecting parts of images in documents and annotating those selections. The image description and retrieval tool will help users work with images and parts of images; associate them with multimedia information like text annotations derived from annotations made by an electronic pen on a tablet PC; and later retrieve information based on text- and content-based retrieval techniques. Information may be retrieved through searching or by browsing, browsing species based on taxonomy or a dichotomous key, retrieving annotations or species information based on keyword matching, or retrieving images and marks (parts of images) based on matching of content of images/marks (marks, which were created earlier).

Applications

We foresee several ways in which SuperIDR might be utilized by teachers and students, practicing fisheries professionals, and members of the general public.

A first set of uses and applications would be in fisheries education. We note that in this study, we developed and evaluated personal use of superimposed information in a DL; that is, the data in the DL were accessible and editable only

<table>
<thead>
<tr>
<th>TABLE 1. Species used in classroom evaluation of SuperIDR in evaluative sessions 1 and 2.</th>
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<tr>
<td><strong>Session 1</strong></td>
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<td>Alosa sapidissima</td>
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<td>Ambloplites rupestris</td>
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<td>Percina rex</td>
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<td>Cottus bairdi</td>
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<td>Etheostoma nigrum</td>
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<td>Percopsis omiscomaycus</td>
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<td>Micropterus salmoides</td>
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<td>Cottus caroliniae</td>
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<td>Percina notogramma</td>
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<td>Etheostoma flabellare</td>
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<td>Lepomis gibbosus</td>
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<td>Lepomis macrochirus</td>
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<td>Clinostomus funduloides</td>
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<td>Cyprinella galactura</td>
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<td>Micropterus dolomieu</td>
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<td>Notropis telcecopus</td>
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<td>Lepomis cyanellus</td>
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<tr>
<td>Percina aurantiaca</td>
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<td>Etheostoma ruflineatum</td>
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<td>Fundulus heteroclitus</td>
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by one person. However, DLs are well suited for sharing information accessible by multiple people. Thus, the development of a social or collaborative superimposed information DL is a natural next step, where multiple users—for example, instructors and students in a class—have access to and might create and edit content such as annotation of diagnostic characters on images of fish. The task of creating subimages or annotations on all of the fish in a regional fish fauna might be crowdsourced (Doan et al. 2011) by the class; that is, a single user would not be burdened with creating and adding all of content, and multiple users would benefit from all new content created. In addition, crowdsourcing would enable users to collaborate over shared content.

A second set of users would be practicing fisheries professionals for whom fish identification and information on ecology and life history are of day-to-day interest. SuperIDR may be used in a laboratory setting or in the field, because access to the Internet is not needed.

A third set of users would be the many people in the general public with an interest in fishes. Upon encountering a striking species, many people want access to information on the ecology and life history of the species. EFish (Helfrich et al. 2001) and EKey (da S. Torres et al. 2007) have proven popular for the purpose but do not offer a user-centered design that a web-based version of SuperIDR would offer. One major differentiation between SuperIDR and prior web-based systems is that SuperIDR offers ways for a user to extend the information base (including new images and annotations). This feature enables users to keep the SuperIDR content up to date as well as to incorporate new information and personal notes. Several interactive web-based fish identification resources that have been launched over the past few years were built using different architectures and offer different features for nontechnical users. For example, the WiscFish identification database (Hanson et al., no date) offers a taxonomic key and a keyword-based query system. The Discover Life website (Discover Life 2012), actually a compilation of resources, offers the user access to various approaches to identify different fish taxa. FishBase (Froese and Pauly 2011) offers dichotomous keys, picture matching, and morphometric identification. With the ability to annotate, search annotations, perform comparisons, and access other features of DL technology, we feel that SuperIDR offers features not available in other existing applications.

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Mean = 11.7

Mean = 14.7
SuperIDR as a Prototype

Though SuperIDR offers innovations over existing software and websites for fish identification and information retrieval, we recognize two ways in which it might be improved. First, knowing where a fish was collected, many users would find it simple and straightforward to use a key or resources concerning only those fishes occurring in that watershed. For example, an individual may want to search resources regarding cyprinids occurring in the James River Basin of Virginia. This feature may be offered wherever a reliable species list exists for given watersheds. Second, many users would value more complex Boolean searches than are currently offered. Such complex searches many involve a combination of a taxon, annotation, and location; for example, a search for a darter with dusky saddle marks living in the upper Tennessee River drainage.

We regard our system as a prototype demonstrating the potential of tablet PC-based data annotation, search, and retrieval by means of a case study involving freshwater fishes of Virginia. The system architecture is general—it may be applied to other fish faunas by adding or removing species-specific information to or from the database. This capability is supported by the existing software, which can support a change of the database using procedures described in the user’s manual. More fundamentally, the system architecture and coding may be applied in any case where external morphology provides the basis for distinguishing species; for example, it is being applied for identifying flies and butterflies (R. da S. Torres, unpublished). Features of the tablet PC platform and application—especially the ability to upload, annotate, and store images and then to search annotations—may prove useful to support fieldwork. We are extending our software to support identification of human parasites in Brazil (Kozievitch et al. 2010; Murthy et al. 2010), where field clinicians produce wet mounts of specimens but do not have access to a medical library or to the Internet and would value the ability to build and to access a searchable reference database.

ACKNOWLEDGMENTS

Development of the tablet PC software was supported by grants from Microsoft, the National Science Foundation (DUE-0435059), Coordination of Improvement of Personal Higher Education (CAPES), the Sao Paulo Research Foundation (FAPESP), and the National Council for Scientific and Technological Development (CNPq). We thank faculty, researchers, and students in the departments of Computer Science and Fish and Wildlife Conservation at Virginia Tech and at University of Campinas, whose help and valuable inputs proved key to improving various versions of this tool. We are grateful to the Department of Computer Science and College of Engineering for the loan of tablet PCs for evaluation by students. We thank Robert Jenkins, Noel Burkhead, and the American Fisheries Society for use of copyrighted materials on the freshwater fishes of Virginia. Tamar Hallerman photographed the preserved specimens.

REFERENCES


Blue Leaf has effectively used techniques ranging from presence/absence with PIT tags, to fine-scale three-dimensional tracking with acoustic tags, to fish movement and interactions with DIDSON sonar imaging. Call us for a free consultation and learn how our technical expertise in fisheries telemetry can help make your project successful.
The theme for the 142nd annual meeting of the American Fisheries Society (AFS) was “Fisheries Networks: Building Ecological, Social, and Professional Relationships,” and that provided me a hook to reflect on how studies of ecological networks have developed and how they can be used to inform fisheries research. Ecological networks, as we know them, date back to the pioneering studies of Raymond Lindeman around 1940 (Illustration 1). He studied Cedar Creek Bog in Minnesota and made a detailed model of nutrient cycling expressed as energy flows (Lindeman 1942). For this, he used thermodynamic principles to evaluate and understand ecosystem functioning, and through this he established the field of trophic dynamics. The study of energy flows and concepts he introduced, such as food chains, food webs, ecological transfer efficiency, and energy pyramids, now provide core elements of community and ecosystem ecology.

Lindeman was born in Redwood Falls, Minnesota, and educated at the University of Minnesota in the Twin Cities where AFS 2012 was hosted. He received a fellowship to work with G. Evelyn Hutchinson at Yale University, managed to publish his Ph.D. studies on Cedar Creek Bog though ill, but unfortunately he died soon after, at only 27 years old. He was a brilliant mind, and we can only guess how he would have shaped our research world had his days been more numerous.

Incidentally, this was also where I first participated in ecological research—as a first-year student joining the tail end of these studies, sampling fish in a lake in Denmark.

The IBP was mainly descriptive in its nature and had numerous modeling activities, including some dynamic ecosystem modeling—a topic to which we return later. A lasting legacy of the IBP was that it brought focus to ecosystem research. There were also numerous follow-up studies to the IBP. Methodologies had been developed and coordinated through the IBP, and many researchers had been introduced to the field. The time had come for ecosystem research.

Among the follow-up studies was an extensive 5-year study (around 1980) of the French Frigate Shoals in the northwestern Hawaiian Islands. Researchers quantified energy flows and biomass ranging from plankton through to marine mammals and over the 5 years gathered an impressive amount of data. Realizing the need to make sense of the mountain of data, the National Oceanic and Atmospheric Administration hired a newly graduated oceanographer, Jeff Polovina, to construct an ecosystem model of the French Frigate Shoals.

At this time there were two major activities on ecosystem modeling with a fisheries perspective. Taivo Laevastu and colleagues at the National Marine Fisheries Service’s Alaska Fisheries Science Center worked on a complex multispecies model of the Bering Sea (Laevastu and Larkins 1981) and K. P. Andersen and Erik Ursin (1977), at the Charlottenlund Castle, Danish Institute for Fisheries and Marine Research, were constructing an equally complex model of the North Sea. Polovina evaluated these modeling efforts and realized the impossibility of constructing species-based dynamic models for biologically diverse areas such as a tropical coral reef ecosystem. From the
Laevastu model, he adopted the principle of mass balance and used this to construct a simple ecological accounting system (Polovina 1984).

“Mass balance” here means that energy input has to balance energy output (including storage) for each species (or functional group) that is being modeled. If we can mass balance one species we can balance the whole ecosystem. For this, we use information about how much food predators require and compare this to how much production is available from their prey. It has to match. This adds constraints to the modeling. Adding constraints is fundamental for all modeling and is one reason that mass balance modeling has been shown to be successful. In 2009, this led to the modeling approach that Polovina developed, Ecopath (Illustration 3), being recognized by the National Oceanic and Atmospheric Administration as one of the 10 biggest scientific breakthroughs in the organization’s 200-year history.

I have been developing the Ecopath approach and software for more than two decades, starting off with Daniel Pauly in the Philippines (Christensen and Pauly 1992). Daniel had the idea of merging Polovina’s Ecopath model with ecological network analysis such as that developed by Robert Ulanowicz and others (Ulanowicz 1986). Finding out how and seeing it through became my Ph.D. work, which was focused on network analysis of trophic interactions based on meta-analysis of aquatic ecosystems.

From this work, let me highlight ecosystem development. One of the greatest ecologists of all times, E. P. Odum (Illustration 4), described a set of ecosystem attributes and how these would change as ecosystems develop (Odum 1969). I quantified most of Odum’s 24 attributes based on some 40 Ecopath models and ranked the models after maturity (Christensen 1995). It worked really well, and since then a number of colleagues have repeated the analysis with the same result. We can rank ecosystems.

The ranking is typical indicator work. You set a number of criteria, extract the numbers, and out comes a ranking. But what attributes and indicators should we use and how do we obtain the overall ranking? I was really fascinated by this during my Ph.D., the idea that one could extract a few indicators from food webs and use those to characterize the state of ecosystems.

There are, however, many indicators and properties in ecological network analysis—in order to be noticed, any ecologist doing research in the field must develop his or her own way of capturing the essence of ecosystems. This, combined with very few attempts at evaluating methods and approaches across studies, seems to characterize the field: consensus building has not been an integral part of the development. The big challenge after half a century of ecological network analysis is still to explain what the seemingly endless suite of indicators tells us.

Yet I do not intend to compare network analysis to the “Emperor’s New Clothes” (Illustration 5)—though it is a challenge to interpret the many concepts and indicators. I have worked enough with network analysis to see clear patterns, some of which are consistent and rather straightforward to explain, whereas others are much more elusive. As an example of where I have yet unfulfilled expectations of network analysis, let me point to the identification of critical species in ecosystems—the canaries in the coal mine.

I come to think of the Hitchhiker’s Guide to the Galaxy, especially the third of five volumes in the trilogy (Adams 1982). If you don’t remember it: our planet was really a giant supercomputer operated by mice. It tolled away for some millions years to answer the biggest, most fundamental question about life, the universe and everything. Eventually the answer came: 42; but by then no one remembered the question. I have often been in that situation with network analysis: It gives the answer, but what was the question? What do the indicators tell us? How do we interpret them? And, importantly, can we use this for making predictions?

Illustration 3. The basic Ecopath model creates a snapshot of an ecosystem at a given point in time: who eats who and how much? Mass balance links predator and prey: there has to be enough food for the predators.

Making predictions and evaluating “what if” questions remains elusive, however, as ecological network analysis has demonstrated very little predictive capabilities, such as we are craving for fisheries management. Rather, network analysis tends to be static, almost without exception—it is the study and interpretation of snapshots such as mentioned earlier.

Dynamic considerations have, however, entered from a different route. There was a productivity subgroup of IBP that focused on modeling, including dynamic modeling of ecosystems. For this, they created a new field in ecology, systems analysis, and recruited a cohort of bright, quantitative young scientists who used the emerging computers to make models and perform analyses never imagined before.

In essence, what they did was turn the snapshot from the static food web studies into the movie version. And somehow a movie is less open to interpretation than a photo: it adds constraints. But the modeling had problems. All predator–prey modeling is in essence built on Lotka-Volterra dynamics. This means that the consumption by predators is estimated from the number of predators times the number of prey times a search rate. More predators equals more consumption; more prey equals more consumption. Behind this is a thermodynamic principle called “mass action,” and this works absolutely fine when mixing reagents and wanting to predict the products. There are, however, problems when using it in ecology.

The systems analysts in the IBP found that their dynamic models were unstable and commonly experienced cycles and model self-simplification. Cycles are fine when modeling, for instance, snowshoe hare–lynx interactions in boreal systems (Krebs et al. 2001), but they are not a regular feature of more diverse ecosystems. What presented a bigger problem was self-simplification: Lotka-Volterra models are inherently unstable, and it is not possible to maintain ecologically similar groups in models with top-down, mass action control. The poorer competitors will die out. This was a problem that marred the modeling of ecosystems, and eventually most or all of the IBP modelers left the field to pursue other avenues.

One of the bright young fellows in the IBP was my colleague Carl Walters. He had struggled to make ecosystem models behave and had given up (Hilborn and Walters 1992). Then one day in the early 1990s he was out fishing on a lake in British Columbia with his 9-year-old son, Will. When you fish with Carl you don’t often catch anything, so Will got bored, looked over the side, and saw a lot of nice big Daphnia in the water (Illustration 6). He asked: “Why don’t the fish eat them all, Dad?”

Carl went on to give the obvious explanation, one that any fish biologist could have given. “We are fishing for the big trout, they are out here in the open, deep part of the lake. The small trout are hiding along the shore where the big ones don’t come, and they are the ones eating the Daphnia. If the small trout come out here, they would immediately be eaten by the big ones.” A simple, straightforward explanation, and only afterwards did the profound implications of the reply dawn on him.

The fundamental aspect missing in predator–prey modeling was behavior. Organisms are not randomly moving particles as thermodynamics and mass action terms tell us. Think of a coral reef with its swarms of planktivores (Illustration 7). The small stay close to the safety of the reef; the larger stray a bit further away, but only a safe distance. The moment a roaming piscivore, such as a barracuda, comes patrolling by, they all take cover.
The implication of this is that the prey concentration the piscivores sees is different from the total planktivore abundance; similarly, the plankton concentration we may measure with nets around the reef is different from what the planktivores actually experience when their foraging is restricted to the immediate safe surroundings of the reef. It takes three to tango: the planktivore (dancer one) restricts its activities in response to the piscivore (dancer two), and this in turn restricts its own access to plankton (dancer three; Walters and Martell 2004).

From a modeling perspective, Walters developed an elegant way of adding behavior to predator–prey modeling through the foraging arena theory (Ahrens et al. 2012). Organisms change between two behavioral states, being available or unavailable for predation, and including this only calls for adding one additional parameter to the Lotka-Volterra equation, a behavioral exchange coefficient (that relates to carrying capacity).

One small step of logic but a giant step for modeling—suddenly the ecosystem models started behaving. Where it had been almost impossible to get models to maintain diversity, incorporation of the foraging arena considerations stabilized the models, which in turn made it possible to replicate population trends in ecosystems. This started in earnest a decade ago when fitting ecosystem modeling to time series data started proliferating, and we have since witnessed a virtual explosion of case studies to the effect that there are now more than 50 of the kind (Illustration 8).

The case studies are based on the Ecosim module of the Ecopath with Ecosim (EwE) approach and software (Christensen and Walters 2004a), and we have drawn a number of lessons from them (Christensen and Walters 2011). As a rule, to explain historic changes in ecosystems we have to consider (1) food web effects, (2) environmental change, and (3) human impacts (Illustration 9). An implication of this is that environmental productivity patterns can be identified throughout the food web. There are variable time delays linked to turnover rates and food web constellations, but we can see environmental signals propagate through the food web. We have also seen evidence that environmental productivity can be amplified through the food web. The biological explanation for this may be that more food results in excess beyond maintenance, freeing resources to be allocated to growth and reproduction.

Fit-wise, the models tend to work well for species or groups with strong fisheries impacts; that is, we generally find good agreement with single-species assessment models. Where there are divergences, they can often be explained from model assumptions related to food web effects. It is also clear that though trends for some species can be explained, there can be others for which the models are unable to offer insight—often because we have no reliable information about what the important drivers of change may be for such species. There is, however, nothing to indicate that such model failures have implications for the overall model fit—here one rotten apple does not spoil the bunch.

We see impacts of changes in predator abundance on forage species (prey release) and, in some cases, the opposite effect, where prey abundance impacts predators. In addition, there are cases where fisheries seemingly outcompete predators as increased fishing mortality on a forage species is accompanied by decline in predation mortality (Walters et al. 2008).

Where ecological networks currently have their greatest potential for contribution in fisheries is in evaluating trade-offs for management. We have reached the point where we can evaluate tradeoffs between alternative uses of fisheries resources with some authority; see, for example, Christensen and Walters (2004b).

Summing up, ecosystem models can now replicate historic changes in ecosystems and be used to evaluate the relative impact of fisheries, food web dynamics, and environmental change (Illustration 10), and notably use this to evaluate trade-offs. With models that behave well enough to replicate the past, we can start thinking of using them to predict the future, to ask what if questions.

This is the foundation for an initiative of the Nippon Foundation and the University of British Columbia (NF-UBC) called “Nereus—Predicting the Future Ocean,” which, with partners at Princeton, Duke, Cambridge, and Stockholm universities and at the United Nations Environment Programme’s World Conservation Monitoring Centre, has taken on the task of predicting how
the world’s supply of seafood may develop in a future that’s impacted by climate change. The key question we are asking is “Will there be seafood and healthy oceans for future generations to enjoy?” (Illustration 11). To answer the question we have to make predictions. There will be uncertainty and unexpected events, but we need to give guidelines for how to ensure that there will be seafood for future generations. What choices must we make for this?

Given that the seafood market is international, it is a global question, and we have to tackle the question through modeling scaled accordingly. There is, however, no tradition for global modeling in fisheries, and though the Intergovernmental Panel for Climate Change has done a tremendous job of predicting how our physical environment will be impacted by climate change, it is only now that the consequences of climate change on life on Earth are gaining attention.

The NF-UBC Nereus Program has taken on the task by developing a global ocean-modeling framework, which incorporates modeling of the physical environment, lower and higher trophic levels, and human activities including governance. It is a framework that incorporates alternative modeling components in order to consider uncertainty through an ensemble approach, inspired by how the Intergovernmental Panel for Climate Change has tackled global environmental modeling.

Uncertainty indeed has to be a major factor in making predictions. Though ecosystem models now offer some predictive capabilities for evaluating major human impacts and making predictions, we cannot make beautiful orchestrated symphonies or detailed predictions, and we will never be able to do that for complex ecosystems. There are two notable factors that prevent this. One is Walters’ “vampires in the basement” (Illustration 12); the other is incomplete knowledge of how systems will react to management interventions (Walters and Martell 2004).

We must expect the unexpected; there will be events that we cannot predict. Invasive species is a case in point and, more generally, behavioral responses in ecosystems are no more predictive than they are for human systems. Let me illustrate with an example: seals have been increasing in the Strait of Georgia since culling ceased in the 1970s. Until a few years ago, mammal-eating transient killer whales were not observed in the strait. Then one summer a small pod came in and found plenty of prey—the next summer the whale watching boats counted 100 transient killer whales coming in, and transients have been regular visitors since then. From a modeling perspective, such behavioral events are unpredictable, and they have repercussions throughout the ecosystems.

There is also considerable uncertainty about how ecosystems will react to many management interventions, especially where our knowledge about drivers and impact is very incomplete. Our best option wherever this is the case is represented by adaptive management with carefully planned monitoring, experimentation, and adaptation (Walters 1986). Modeling is an integral part of this and is needed to guide the entire process and limit the risk of making preventable mistakes.

Therefore, though we cannot make detailed predictions for how ecosystems will develop, we as a society need to carefully choose what direction to take and we need to avoid the preventable mistakes. For this, it is crucial that policy makers and managers set clear objectives for management and that scientists in turn define and evaluate alternative policy options (Illustration 14). We need to manage our ecosystems with a strong com-

Illustration 10. The butler did it: humans are the usual suspects when evaluating fish population trends, but ecosystem models can now be used to evaluate the relative contribution of food web, environmental, and human impact.

Illustration 11. Will there be seafood and healthy oceans for future generations to enjoy?

Illustration 12. When making predictions expect the unexpected, the vampire in the basement will bite you.
mitment to moving in a sustainable direction if there indeed is to be seafood and healthy oceans for future generations to enjoy.

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REFERENCES


Illustration 13. Monitor (left), experiment (center), and adapt (right). The fundamental aspects of adaptive management rely on modeling as the guiding factor.

Illustration 14. Alice: “Would you tell me, please, which way I ought to go from here?” Cheshire Cat: “That depends a good deal on where you want to get to.” Policy makers need to set clear objectives for management, and scientists need to evaluate alternative options for managers.
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AFS 2013 Little Rock: Preparing for the Challenges Ahead

Begin making plans to attend the AFS 143rd Annual Meeting, themed “Preparing for the Challenges Ahead,” in Little Rock, Arkansas on September 8–12, 2013. Conference attendees will have the opportunity to network with fisheries professionals and students, stay current on the latest in fisheries science, and enjoy the sights and scenes of central Arkansas.

The AFS Technical Program will be held primarily at the State House Convention Center in Little Rock’s River Market district while social events will be held at various venues in the River Market district. The River Market district is located in downtown Little Rock along President Clinton Avenue on the banks of the Arkansas River. President Clinton Avenue recently was designated one of “10 Great Streets for 2009” by the American Planning Association’s Great Places in America Program. The Convention Center is located near the Clinton Presidential Library; Heifer International, headquarters of an international non-profit humanitarian organization; and the Arkansas Game and Fish Commission Witt Stephens Jr. Central Arkansas Nature Center. All are accessible by walking or trolley. There are numerous other opportunities in and adjacent to the River Market district for diners, shoppers, and history buffs. Little Rock is located near the intersection of the Arkansas Valley, the Ouachita Mountains, the Ozarks, and the Arkansas Delta, and thus is a jumping-off point for visits to the diverse geography of Arkansas. Nearby national parks include Little Rock Central High School National Historic Site; Hot Springs National Park; and the nation’s first national river, Buffalo National River. Diverse fishing opportunities are offered by the state for a variety of species—stripers, largemouth bass, smallmouth bass, walleye, rainbow and brown trout, and catfish.

The 2013 AFS Annual Meeting will feature a broad range of topics associated with current and future challenges facing aquatic communities, biological scientists, managers, other professionals, and the general public. Topics will include assessments of status and trends of species and communities and their habitats; management challenges and methods; and the potential effects of changing social structures and ecological stresses such as increasing human population, increasing water demands, and a changing climate. Planned symposia topics include large river floodplains, fisheries training for students, roles of fisheries in native American culture, and ancient fishes.

Contributed paper and poster abstracts are due by March 15, 2013.

Details will be found at afs2013.com/call-for-papers.

Meeting details and registration will be found at afs2013.com.
Beyond Biology: Can We Reconcile the Land–Water–Humankind Interface?

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The definition book was thrown at Sandy. Coming and going with multiple characteristics, including hurricane, sub-, post-, extratropical cyclone/storm signs1, the eventual “Superstorm” title continued the validation of changing climate characteristics.

As a Federal Emergency Management Agency (FEMA) reservist, I assist public entities in navigating regulatory compliance of infrastructure projects and conduct damage surveys during response and recovery. My first thoughts on providing some insight to my non-hurricane-zone American Fisheries Society colleagues came from my central New Jersey shore ground-zero observations. Returning a stranded cracked-shell horseshoe crab back to the sea, noting marine fish mortalities in upland areas and freshwater species mortalities from inland lakes that were inundated by saltwater or killed by septic waters unleashed through communities region-wide from overwhelmed sewers, would be interesting to report. The aquatic observations turned to mortality of burrowing animals and altered shorebird habitats. These and some instances of oiled wildlife, stranded individuals, and temporarily affected migrations of southbound migratory birds suggest that impact levels varied among species. Effects on beach morphology varied as expected in dynamic and altered shorelines. Some beaches were built up, and others were eroded. Some rivers rose inland to unprecedented levels because of the wind-enhanced tidal surge. Southern area embayments and rivers were lowered because of the offshore winds. Perhaps the most damage related to fisheries was the fishing industry damage in New York and New Jersey, prompting a federally-declared fishery resource disaster. Amidst the protected inhabited shoreline areas, the news was the fishing industry damage in New York and New Jersey, prompting a federally-declared fishery resource disaster. Returning a stranded cracked-shell horseshoe crab back to the sea, noting marine fish mortalities in upland areas and freshwater species mortalities from inland lakes that were inundated by saltwater or killed by septic waters unleashed through communities region-wide from overwhelmed sewers, would be interesting to report. The aquatic observations turned to mortality of burrowing animals and altered shorebird habitats. These and some instances of oiled wildlife, stranded individuals, and temporarily affected migrations of southbound migratory birds suggest that impact levels varied among species. Effects on beach morphology varied as expected in dynamic and altered shorelines. Some beaches were built up, and others were eroded. Some rivers rose inland to unprecedented levels because of the wind-enhanced tidal surge. Southern area embayments and rivers were lowered because of the offshore winds. Perhaps the most damage related to fisheries was the fishing industry damage in New York and New Jersey, prompting a federally-declared fishery resource disaster. Amidst the protected inhabited shoreline areas, the news was the fishing industry damage in New York and New Jersey, prompting a federally-declared fishery resource disaster.

The damage reminded me of either the poorest developing nations I have visited or a postapocalyptic movie set. The waterlogged mattresses, stuffed animals, and board games piled curbside among the thousands of tons of debris quickly turned my thoughts to my children at home, and how I would feel with such loss. Amidst the volume of debris (which would eventually surpass double that of the Great Pyramid of Giza’s volume) were lifelong possessions and memories. This was an event of a lifetime. People’s lives are changed—many by tragedy. One town recorded a 500-year flood event, another recorded record 30-minute rainfall; how does one even plan for that? In one town hall I noted a 1920 photo on the wall showing damaged beach houses and eroded dunes. The caption: “How the ocean is wrecking cottages at Longport near Atlantic City, N.J.” How timeless is that? These early 20th-century places of grandeur were at risk then. Today, weeks removed from the disaster, contractors in these damaged areas are finishing out partially constructed custom homes that were being built prior to Sandy. There is something wrong with this image as the neighbors empty their homes of damaged possessions, drywall, and insulation. Do we reconcile our persistence on these disturbance-prone landscapes with the fact that we are willing to endure these events? Does the pioneering or bold spirit of landholding compel us to stay no matter the risk or cost?

In the evenings of this deployment I had the opportunity to reflect on my lifelong experiences of ocean, river, estuarine, and lake walks that have spanned Asian, African, Middle Eastern, European, tropical, and North American beaches. I have likely walked hundreds of miles of the land–water interface, taking mental notes of this area that has drawn humankind since our origins. In fact, one of my favorite things to do, probably like many of you, is to watch waves run up on the beach, crash against rocks, or peel across a reef. A wave is the expression of

1 As a biologist I know that I will be clarified by the weather experts in a follow-up technical article sometime soon. For technical explanations you can visit the National Oceanic and Atmospheric Administration’s Weather Service and Hurricane Center or affiliated regional university program web pages dedicated to Sandy. One metric stands out: integrated kinetic energy. When adding up all of the total energy contained in the expansive area of tropical storm–force winds and the area of hurricane-force winds, Sandy contained the most integrated kinetic energy of any storm in history—none contained more overall sheer power in recorded history. For energy metric junkies, Sandy’s peak wind energy was 329 TJ—2.7 times higher than Katrina’s peak energy and the equivalent to five Hiroshima-sized atomic bombs.
Clockwise from top left: Ancient yet practical design of a stilt home (right) stands next to utterly destroyed multi-million-dollar homes in Sandy’s wake on the New Jersey shore. Extreme designs in flood-prone areas of Bahamas (top right) and Louisiana (lower right) propagate the determination of man to live by water despite the cost. Storm-proofing/storm-resistant construction typically means building higher and stronger. FEMA funds assisted in bolstering structures on the Dauphin Islands in Alabama (lower left) in recent years, but ensuing hurricanes created further damage, prompting buy-out strategies and avoidance of rebuilding in highly vulnerable areas.

People have endured flood zone living for millennia. In modern history, the priority adjustments appear to be in reducing loss of life. FEMA was planning to revise the flood elevation rules in coastal towns next year, but these recommendations will likely be made for rebuilding actions even now. Changes are occurring so fast that today’s requirements are essentially obsolete. Although predictions can be made regarding where extreme flooding can occur, such as in embayments and rivers where water impounds during surges, recent storm events with their additional tide and wave factors necessitate broad-scale adjustments. Flood levels that would seriously impact New York were presented over two decades ago, but other priorities kept major actions from being implemented. Is Sandy the scale of action that causes wholesale change at this land–water–human interface?

In 2004, the Banda Aceh, Indonesia, shoreline and beyond was destroyed by a tsunami, and today many areas of the town are being rebuilt but disaster preparation has focused more on comprehensive disaster programs and early warning systems than on structures or relocation that reduce or eliminate the risks from future events.
It seems that we may tend to scale down the disaster and likelihood of wholesale floodplain development changes because the death toll was astonishingly low and property damage is recoverable. Recall that the 2004 Indian Ocean tsunami death toll topped 280,000. How were you affected by that? I am not sure what it would take to prioritize our preparation and planning. Tsunamis may not give the same preparation and evacuation period that hurricanes do, but it is now near certain that as development in low-lying areas persists, a tsunami would cause an unimaginable death toll.

Finishing out the deployment, the circumstances reminded me of a famous shark movie filmed a little bit north of the Jersey Coast. In the evenings I had the opportunity to skim through the newspapers to keep in touch with the pulse of coastline management. Frankly, with some of the posturing of civic leaders I was reminded of a moment of face wincing because the salty fisherman Quint in *Jaws* scraped his nails on the chalkboard to silence the crowd. In this case, my wincing was caused by the shrill of adjectives that I am not used to hearing together: “… to rebuild stronger, higher, and more sustainable, …” “… stronger, smarter, alternative, more resilient, …” “We need our beaches back open and fully functional by next summer.” In a short while, Chief Brody gets his first look at the size of the beast and, deathly afraid, says, “You’re going to need a bigger boat.” We have caught a glimpse of the beast and certainly our bigger boat is new thinking and management decisions that can reconcile our long-term relationship with the sea. This means that we need to innovate in ways that we have not yet pondered. Images associated with this article show construction approaches, but natural processes and habitat functions of coastlands still remain threatened, and the human risks are only slightly reduced.

The Netherlands’s Flood Protection Act plans on a 1-m sea level rise by 2100 in addition to rigorous analysis and reporting requirements. Centuries-old practices of preparing designated areas as fail-safe flood zones for inundation are maintained. As needed, both physical and economical changes are incorporated in the Dutch safety policy. The United States is slowly turning to incorporate this type of thinking. With so many jurisdictional levels mixed with the general population’s coastline affinity, the changes are not sweeping and challenge any notion of reconciliation. Climate change remains at the forefront of discussion in the aftermath—but the most immediate climate change must occur with the policies and management actions that reconsider the wisdom of rebuilding human infrastructure on the barrier dunes.

Larry Dominguez is a consulting fish and aquatic ecologist and cofounder of Ecologists Without Borders (ecowb.org). The opinions expressed in this article are those of the author and do not reflect positions of FEMA, Ecologists Without Borders, EcoAssets, or the American Fisheries Society.

Longstanding boardwalks could not hold their ground during Sandy even with upgraded fasteners. Destroyed boardwalk will total miles. Sand that was washed into town streets and homes, as high as 4 ft. in some areas, was returned to the beach after inspection and some screening. Much of the material was placed in emergency fashion to prepare for the Nor’easter storm that followed within days. The volume of sand that moved into neighborhoods extensively damaging homes gives evidence of the historic and natural processes that would otherwise occur to replenish or build barrier islands.

Seaside Heights in typical years (left) and a few days after Sandy. Boardwalks were initiated as a pragmatic measure to keep sand from being tracked into beachside attractions, eateries, and accommodations. The New Jersey coast boardwalk evolved into an economic artery in nearly every coastal town, and its function and attraction will certainly be formulated into recovery.
The Montana State University Student Subunit of the American Fisheries Society (MSUAFS)

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The Montana State University Student Subunit of the American Fisheries Society (MSUAFS) continues to devote time to public outreach, educating members of the local community about the importance of fisheries conservation, and responsible resource use. Partnering with Montana Fish, Wildlife & Parks and the Children’s Museum of Bozeman, MSUAFS conducted its second annual Family Fishing Fun event in June 2012, where children and adults from the local community learned about the importance of fisheries conservation, and many were introduced to fishing for the first time. The event was a great success, and sixteen children ages 5–12 and their parents spent three weeks learning about fisheries and honing their newly acquired fishing skills on local ponds.

Participants took part in classroom activities that provided a firsthand look at fish ecology, life history, and conservation. The first week consisted of a hands-on encounter with macro-invertebrates collected from local streams and ponds. Children were encouraged to handle a myriad of aquatic invertebrates, including large salmonfly and dragonfly larvae, mayfly larvae, leeches, and snails. Children were taught the importance of these invertebrates as food sources for fish and other organisms, but also as a key piece of a healthy ecosystem. The second week, children learned about general fish biology and the advantages of different body forms in lentic and lotic environments. The final week, children participated in fish dissections and were thrilled with the chance to investigate the internal anatomy of a trout. Each week, children were also provided equipment and instruction (including a safety talk) on how to fish, and given the opportunity to catch fish at a local pond. Many children experienced fishing for the first time, and many had even caught their first fish! By providing the community with opportunities like these, MSUAFS continues to help educate and inform the public about fish ecology and conservation, while fostering the desire to protect the fisheries resource in children and adults alike.
Revisiting the Process for Qualifying for the AFS/Sea Grant Best Student Presentation and Poster Awards

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The American Fisheries Society (AFS)/Sea Grant Best Student Paper and Presentation awards are an important mechanism to highlight the students in our profession and the future leaders of AFS. In 2007, the process for selecting the AFS/Sea Grant Best Student Presentation and Poster awards was substantially revised (Sutton et al. 2007). Prior to the changes, all students were randomly assigned to a small group of judges. Accommodating the ever-increasing numbers of students giving oral or poster presentations at the AFS annual meeting required a large team of volunteer judges. However, it was not always assured that each student would receive evaluations from the same number of judges. Some students received reviews from three or more judges, whereas others did not receive any evaluations (Sutton et al. 2007). Further, the high levels of variability in scoring among judges created difficulty in determining winners in either the poster or presentation medium. During the AFS annual meeting in San Francisco (2007), a new process for selecting finalists and judging these prestigious awards was piloted with much success and positive feedback from both students and judges. This process has remained in place since that time with only a few minor changes.

Although the selection and evaluation process for this award has been in place for 6 years, the system still appears to be largely unknown to the society. For example, in 2012, only 22 applications for the Best Student Presentation award and six applications for the Best Student Poster Award were completed. This is far below expectations given the numbers of student members in the AFS and the number of students who attend the annual meeting. Here, we describe the application process for students to be considered for Best Student Presentation or Best Student Poster awards, the selection of finalists, and the judging that occurs during the AFS annual meeting. We also address questions that are frequently asked by students and advisors in an effort to enhance participation in the process.

THE BEST STUDENT PRESENTATION/POSTER AWARD PROCESS

How do students apply for consideration for either award?

Application for consideration for these awards is very similar to the standard abstract submission process for the AFS annual meeting but with two additional requirements: an extended abstract and letter of support from the student’s advisor (Figure 1). Students begin by uploading a standard abstract for one medium (i.e., poster or presentation) to the online abstract submission system as described in the Call for Papers in Fisheries. Once the standard abstract is uploaded, the system will ask the student whether he or she wishes to be considered for the Best Student Presentation or Best Student Poster award. If the student selects “no,” then the process is complete and the student is assigned to an appropriate alternative symposium by the Annual Meeting Program Committee (Figure 1). If the student selects “yes,” then the abstract submission system prompts the student to upload an extended abstract, which is no more than three pages in length and includes background, methods, results (including up to five tables or figures), discussion, and references. Examples of extended abstracts can be found online at http://www.fisheriessociety.org/education/BSP.htm. The student will also be reminded to request an electronic letter of support from his or her advisor that must be e-mailed to the organizers of the Best Student Presentation/Poster symposium. The letter must indicate that the student’s research is at a stage appropriate for award consideration. In other words, the research project or specific objective must be complete or nearly complete. Both the extended abstract and the advisor’s support letter must be provided by the same deadline as outlined in the Call for Papers in Fisheries for standard abstract submissions. Failure to receive all of the required components will prohibit the student’s application from further consideration (Figure 1).
Figure 1. Flowchart describing the process for selection of the Best Student Paper/Poster at the AFS annual meeting. This process has been followed since the 2007 meeting in San Francisco.

The required elements were provided by the student and advisor. What happens next?

The next step in the process involves evaluation of the extended abstracts submitted by those students who completed the application process. The full list of applicants is reduced to a maximum of 20 finalists in each medium (though the total number of poster submissions has never exceeded 10 since 2007). From 2007 to 2011, the organizers of the Best Student Presentation/Poster symposium evaluated all of the extended abstracts for both mediums and selected the finalists. In 2012, a new system was piloted that assigned abstracts to division representatives from the Education Section and the Student Subsection who evaluated and scored each of the assigned abstracts based on a rubric (see the Extended Abstract Evaluation Form at http://www.fisherisociety.org/education/BSP.htm). This system will likely continue into the future. The evaluators’ scores are tallied and the distributions of scores are examined by the symposium organizers to select the list of finalists. All student applicants are notified whether or not they have been selected as a finalist very soon after the abstract submission deadline (Figure 1). Those students not selected as finalists are placed into appropriate alternative symposia by the AFS Annual Meeting Program Committee. Finalists in both mediums are assigned to the Best Student Presentation/Poster symposium and compete for the awards at the AFS Annual Meeting (Figure 1).

For those who are selected as finalists, what happens during the AFS annual meeting?

The final phase of the competition for these awards takes place during the AFS annual meeting; student finalists present their oral presentation or poster early in the week. The Best Student Presentation symposium typically takes place on Monday afternoon and Tuesday morning each year. The finalists for Best Student Poster stand next to their work during the Monday night poster and trade show social. Students must adhere to the guidelines for poster dimensions and presentation criteria as described on the AFS annual meeting website for all presenters in any symposium. The Best Student Presentation/Poster co-organizers assemble a team of volunteers to evaluate the finalists within each medium—five judges for presentations and three for posters. Each judge scores and provides comments to all students within each medium category based on established evaluation guidelines (see the Best Student Presentation and Poster Judging Sheets at http://www.fisherisociety.org/education/BSP.htm). At the conclusion of the Best Student Presentation symposium on Tuesday, all of the presentation and poster judges meet to examine the distributions of scores for all finalists within each medium, discuss any potential ties, and decide on the winners and honorable mentions in each category. The overall winners and honorable mentions for
the Best Student Presentation/Poster awards are then announced during the AFS business meeting on Tuesday afternoon. The overall winners in each category receive their plaques and prize money ($450 for each award) during the Education Section’s business meeting the following year. All student finalists receive scores and comments from the judges by mail from the Best Student Presentation/Poster co-organizers within a few weeks of the AFS Annual Meeting (Figure 1).

FREQUENTLY ASKED QUESTIONS

Question #1: Why are the extended abstracts and advisor letter required as part of the application for the Best Student Presentation/Poster awards?

Both requirements provide support that the student’s overall research project or at least one of the objectives is at or near completion. Results and tables and/or figures as required in the extended abstract indicate that data have already been collected and analyzed. The advisor’s letter lends further evidence that the student’s work is at the appropriate stage for consideration for these awards. Students will often present proposal or preliminary data at the AFS annual meeting to gain audience feedback or practice in scientific presentations, both of which are laudable goals. However, such presentations are not competitive and do not fit the goals of the awards described here. Completed projects represent the best of the best of what AFS students can produce.

Question #2: I was a student at [insert name of university or college here] and recently completed my master’s or Ph.D. program. I am currently working as a fisheries professional. The presentation I am planning for the AFS annual meeting is from my recently completed thesis or dissertation. Am I still eligible to apply for this award?

In short, the answer to this question is yes. If the research that the recently graduated student will be presenting was completed during the time spent in undergraduate or graduate study and all of the required application materials are received by the deadline listed in the Call for Papers in Fisheries, the student will be considered for either the Best Student Presentation or Poster award, depending on the medium he or she selected.

Question #3: Can I [a student] give the same presentation in both the Best Student Presentation symposium and in a second symposium that is related to my research topic?

The answer to this question is a simple no. Difficulties are often faced by the AFS Annual Meeting Program Committee to accommodate all of the presentation requests received. By submitting the same presentation in two separate time slots, students are potentially affecting someone else’s opportunity to present his or her work. A student may decide that presenting in a topic-specific symposium will be a better opportunity to share information with colleagues and network with potential collaborators and employers and that this will benefit him or her more than possibly winning the Best Student Presentation award.

Question #4: Did you mention that there was prize money associated with the Best Student Presentation/Poster awards?

The overall winners in both categories each receive a US$450 cash prize and a plaque during the Education Section business meeting the following year. Honorable mentions receive a plaque but no cash prize.

CONCLUSION

The criteria for applying and evaluating students for the AFS/Sea Grant Best Student Presentation and Poster Awards since 2007 is more rigorous compared to the previous system, but final evaluations and feedback from student finalists and judges indicate that they system is greatly improved. Collective confidence in selecting deserving winners and recognizing honorable mentions has increased since implementation of the new system. We hope that the number of students applying for consideration for these awards will continue to increase for 2013 and into the future. If there are any other questions that were not addressed in this article, we encourage the reader to contact the Best Student Presentation/Poster co-organizers or the Education Section officers (see http://www.fisheriesociety.org/education/officers.htm for contact information). Best of luck to all who apply! We look forward to seeing the products of your hard work.

ACKNOWLEDGMENTS

We thank Trent Sutton, Donna Parish, and James Jackson for initiating the changes to the selection process for the AFS/Sea Grant Best Student Presentation and Poster awards. Previous drafts of this article were improved with comments from Mike Quist and Craig Paukert. We appreciate the symposium organizers who served on the Best Student Presentation/Poster committee and all of the judges who have volunteered since 2007. Finally, we thank the AFS annual meeting program committee and their chairs as well as AFS staff who have aided in the success of the awards symposia from 2007 through 2012.

REFERENCE

Small Impoundment Management in North America

Edited by J. Wesley Neal and David W. Willis

420 pages, index, hardcover
List price: $79.00
AFS Member price: $55.30
Item Number: 550.69C
Published November 2012

To order:
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This book is an in-depth overview of biota, habitat, and human management in small water bodies up to approximately 40 ha in surface area. Authors were selected to cover the wide geographic diversity of ponds and pond management throughout North America.

The first section (Introduction and History) defines small impoundments, provides a concise history of pond management, overviews pond resources in the USA and world, and discusses the importance of small impoundments. Section Two (Pond Environment) addresses proper construction considerations, explores the physical and chemical characteristics of these waters, discusses productivity, and examines methods to manipulate environmental conditions in small waters. Section Three (Fish Management) describes current stocking practices and species selection, addresses the importance of proper harvest and assessment, and explores mechanisms involved in population dynamics and the occurrence of crowded predator or prey populations. Section Four (Problem Troubleshooting) addresses problems that can arise in small impoundments and provides solutions. Section Five (Opportunities) provides a platform for topics that previously had received limited treatment in the educational literature. Thorough discussions of fee fishing and community fishing opportunities for small impoundments are provided, as is an overview of careers in private sector pond management and extension/outreach. Finally, the technical aspects of managing small impoundments for wildlife are described in detail.

A primary use for this book will be university classes on pond or small impoundment management for advanced undergraduate or graduate students. Practicing fisheries professionals should also find substantial value in the depth of information provided by the book. Finally, private pond owners will find the book to be useful as they seek to learn more about ponds and pond management.
### JOURNAL HIGHLIGHTS

**Transactions of the American Fisheries Society**

**Volume 142, Number 1, January 2013**

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**Evaluating the Effects of Electricity on Fish Embryos as a Potential Strategy for Controlling Invasive Cyprinids.**


**Persistent Organic Pollutants in Juvenile Chinook Salmon in the Columbia River Basin: Implications for Stock Recovery.**


**Development and Evaluation of a Bioenergetics Model for Bull Trout.**

Matthew G. Mesa, Lisa K. Weiland, Helena E. Christiansen, Sally T. Sauter, and David A. Beauchamp. 142: 41–49.

**Connections between Campeche Bank and Red Snapper Populations in the Gulf of Mexico via Modeled Larval Transport.**

Donald R. Johnson, Harriet M. Perry, and Joanne Lyczkowski-Shultz. 142: 50–58.


**Response of Wild Trout to Stream Restoration over Two Decades in the Blackfoot River Basin, Montana.**


**Validating Back-Calculation Models Using Population Data.**


**[Note] Swordfish Vertical Distribution and Habitat Use in Relation to Diel and Lunar Cycles in the Western North Atlantic.**


**Trends and Synchrony in Black Bass and Crappie Recruitment in Missouri Reservoirs.**

Paul H. Michaletz and Michael J. Siepker. 142: 105–118.

**Exploring the Influence of Stock–Recruitment Relationships and Environmental Variables on Black Bass and Crappie Recruitment Dynamics in Missouri Reservoirs.**


**Assessing Juvenile Chinook Salmon Behavior and Entrainment Risk near Unscreened Water Diversions: Large Flume Simulations.**


**Relationships between the Abundance of Pacific Lamprey in the Columbia River and Their Common Hosts in the Marine Environment.**


**[Forum] Issues Regarding the Use of Sedatives in Fisheries and the Need for Immediate–Release Options.**


**Estimating Spatial and Temporal Components of Variation for Fisheries Count Data Using Negative Binomial Mixed Models.**

Brian J. Irwin, Tyler Wagner, James R. Bence, Megan V. Kepler, Weihai Liu, and Daniel B. Hayes. 142: 171–183.

**Longitudinal Length Back-Calculations from Otoliths and Scales Differ Systematically in Haddock.**


**Quantifying the Effects of Aging Bias in Atlantic Striped Bass Stock Assessment.**


**Potential Effects of Changes in Temperature and Food Resources on Life History Trajectories of Juvenile Oncorhynchus mykiss.**


**Spatial Segregation of Spawning Habitat Limits Hybridization between Sympatric Native Steelhead and Coastal Cutthroat Trout.**


**Evaluation of Sample Design and Estimation Methods for Great Lakes Angler Surveys.**


**Evaluation of Electrofishing Catch per Unit Effort for Indexing Fish Abundance in Florida Lakes.**


**Temporal Variation in the Physiological Responses in Largemouth Bass following Small Club Angling Tournaments.**


**Modeling Prey Consumption by Native and Nonnative Piscivorous Fishes: Implications for Competition and Impacts on Shared Prey in an Ultraoligotrophic Lake in Patagonia.**


**Reproductive Biology of the Tiger Grouper in the Southern Gulf of Mexico.**


**Environmental Constraints on Piscivory: Insights from Linking Ultrasonic Telemetry to a Visual Foraging Model for Cutthroat Trout.**

Adam G. Hansen, David A. Beauchamp, and Casey M. Baldwin. 142: 300–316.
little additional burden on financial and human resources. Our society has taken a step in this direction through our contract with Taylor & Francis for publishing our journals and publicizing them worldwide; our publications staff has seen an increase in manuscript submissions from other continents since the Taylor & Francis contract went into effect. I have also directed the AFS Publications Overview Committee to evaluate alternatives for increasing international visibility of our journals, including name changes that could make them more attractive to a global readership.

Thinking back to that governing board meeting in 1993, our society has made significant progress in recognizing that we are part of a much larger network addressing fisheries science, management, and conservation issues on a global scale. The ability to communicate at the speed of light has strengthened the network considerably, but there is still much more we can do. Perhaps Carlos should have handed out quarters to governing board members who referred to the society-wide level of the AFS organization as “the international”—something to ponder for future meetings.

Continued from page 51

**Continued from page 51**

**AFS Seeks Chief Science Editor for Fisheries Magazine**

The American Fisheries Society (AFS) seeks a scientist with a broad perspective on fisheries to oversee the science content of *Fisheries*. Editor must be committed to fast-paced deadlines, and would be appointed for a five-year renewable term which begins in 2013.

- Assign an appropriate science editor for each scientific paper submitted to *Fisheries*.
- Make final publication decisions based on peer reviews orchestrated by science editors.
- Ensure the veracity of each issue’s total scientific content.
- Help recruit and retain science editors, as well as providing mentoring and guidance.
- Solicit cutting-edge submissions as well as ensuring broad coverage.
- Work with Fisheries Managing Editor and AFS Publications Director on the content, themes, and direction of the scientific aspects of *Fisheries*

To be considered, send current curriculum vitae along with a letter of interest explaining why you want to be the Chief Science Editor by e-mail to alerner@fisheries.org.

Note: The Chief Science Editor receives an honorarium, and support to attend the AFS Annual Meeting.

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## 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

<table>
<thead>
<tr>
<th>DATE</th>
<th>EVENT</th>
<th>LOCATION</th>
<th>WEBSITE</th>
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<tbody>
<tr>
<td>February 21–25, 2013</td>
<td>Fish Culture Section Mid-Year Business Meeting</td>
<td>Nashville, TN</td>
<td>was.org/WasMeetings/meetings/Default.aspx?code=AQ2013</td>
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<tr>
<td>February 26–27, 2013</td>
<td>2013 AFS North Carolina Chapter Annual Meeting</td>
<td>Burlington, NC</td>
<td>sdafs.org/ncafs Contact: Greg Cope at <a href="mailto:greg_cope@ncsu.edu">greg_cope@ncsu.edu</a></td>
</tr>
<tr>
<td>April 8–12, 2013</td>
<td>7th International Fisheries Observer and Monitoring Conference (7th IFOMC)</td>
<td>Viña del Mar, Chile</td>
<td>IFOMC.com</td>
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<tr>
<td>May 20–24, 2013</td>
<td>AFS Piscicide Class - Planning and Executing Successful Rotenone and Antimycin Projects</td>
<td>Logan, UT</td>
<td>fisheriessociety.org/rotenone Contact: Brian Finlayson at <a href="mailto:briankarefinlayson@att.net">briankarefinlayson@att.net</a></td>
</tr>
<tr>
<td>June 25–27, 2013</td>
<td>2013 International Conference on Engineering &amp; Ecohydrology for Fish Passage</td>
<td>Corvallis, OR</td>
<td>fishpassage.umass.edu Contact: Dr. Guillermo R. Giannico at <a href="mailto:giannico@oregonstate.edu">giannico@oregonstate.edu</a></td>
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<tr>
<td>August 3–7, 2014</td>
<td>International Congress on the Biology of Fish</td>
<td>Edinburgh, United Kingdom</td>
<td>icbf2014.sls.hw.ac.uk</td>
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### From the Archives

The relations of the temperature of the water to tile movements of the menhaden schools having been studied, a new question is at once suggested. When the schools disappear from our coast, driven by falling temperatures, where do they go? The answer must be in the form of a theory, for no one has seen them during their winter absence - at least no one has been able to identify the New England and Middle States fishes after their departure in the autumn.


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**Announcements**

**February 2013 Jobs**

**Graduate Research Asst—Ph.D.**  
WV Univ – Wildlife & Fisheries Resources Program Student  
Salary: $19,848 annual stipend, plus full tuition waiver  
Closing: Until filled  
Responsibilities: Successful applicant will conduct genetic research on juvenile lake sturgeon in Lake Superior, with the primary goal of assigning individuals to their spawning population of origin. Opportunity for additional research questions related to juvenile lake sturgeon ecology/genetics.  
Qualifications: Highly motivated student with interest in fish genetic research. Requires a M.S. in fisheries science, ecology, genetics, or related field. Experience in genetics preferred. Submit letter of interest, CV, & unofficial transcript and GRE scores to Amy. welsh@mail.wvu.edu.  
Contact: Dr. Amy Welsh, at below email.  
Email: Amy.Welsh@mail.wvu.edu  
Link: wildlife.wvu.edu

**Aquatic Invasive Species (AIS) Tech**  
WY Game and Fish Dept  
Temporary  
Salary: $13.00 per hour  
Closing: 3/1  
Responsibilities: Aquatic Invasive Species (AIS) Technician (up to 41 positions) will inspect watercraft at key locations around the state in an effort to prevent the introduction and spread of aquatic invasive species. Participates in outreach and education efforts to inform the general public about the impacts of aquatic invasive species. Duties may include conducting physical watercraft inspections and decontaminations. Boater interviews at watercraft check stations. Provide outreach information and assistance to the boating public. Water quality and invasive species sampling, data entry, and equipment maintenance.  
Qualifications: Must be able to work well independently with minimal supervision and also able to work well with others on a crew. Experienced in the operation of watercraft, 4wd vehicles, and pulling trailers. Requires effective communication and public relations skills in daily interactions with the public. Weekend and holiday work will be required. Position may require extended days (4 days) in campers. Must have a valid driver’s license.  
Contact: Preference will be given to those who submit a cover letter to Beth Bear, AIS Coordinator, 528 S. Adams, Laramie, WY 82070 or below email, in addition to submitting the state application. The cover letter should include career plans, suitability for the job, and preferences for work locations as well as dates of availability (starting and ending dates are particularly important).  
Email: beth.bear@wyo.gov  
Link: statejobs.state.wy.us/JobSearch.aspx

**Fisheries Biologist**  
Private sector / Southeastern Pond Management, Birmingham, AL  
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Salary: DOE/DQ  
Closing: Until filled  
Responsibilities: Performing pond evaluations using electrofishing equipment, using the acquired data to create pond management plans, customer follow up / customer relations  
Qualifications: B. S. degree in Fisheries biology or related field is required, Masters degree in Fisheries biology is preferred. Preference may be given to applicants with boating and electrofishing experience.  
Contact: Scott Cherones, at below email.  
Email: scherones@sepond.com  
Link: sepond.com

**Staff Fishery Economist /Senior Fishery Economist**  
North Pacific Fishery Management Council  
Permanent  
Salary: GS-11/12/13 equivalent — (Salary range 68,000–98,000 DOE). Exceptional applicants may be considered for placement at the Senior economist level, (salary range 90,000–120,000 DOE).  
Closing: Until filled  
Responsibilities: The Department of Biology at Coastal Carolina University invites applications for a full-time tenure-track position at the Assistant Professor beginning Fall 2013. Responsible for teaching Ichthyology, Principles of Ecology, and will have the opportunity to teach other advanced courses in their area of specialization. Successful candidates will be expected to emerge as exemplars of teaching, contribute to both introductory and graduate courses and develop potentially fundable research programs in fish ecology involving undergraduate and graduate students. Candidates whose research interests include freshwater systems are encouraged to apply.  
Qualifications: PhD  
Email: cwilliam@coastal.edu  
Link: jobs.coastal.edu
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Monitoring Survival: Steps Toward Evaluating Predation Using Acoustic Tags

In waterways around the world, smolt survival continues to be a problem despite efforts to reverse these trends. Predation has been identified as one of the causes of the decline. Acoustic telemetry is commonly used to track downstream migration of salmonids and has recently been used to identify predatory behavior in other species.

Over the past decade, fine-scale fish tracks have illustrated migration behavior and survival in river systems throughout the world. New questions have emerged in recent years as more data becomes available from various species via fine-scale 2D/3D telemetry. A river system example is California’s Bay-Delta region. One of the principal questions of great importance in this region is: Can we determine whether or not an acoustically-tagged fish has been eaten by a predator? A critical assumption of survival estimation for tagged migrating species is that the detected tag signals are from distinctly unconsumed and freely migrating fish. With that, protocols for determining predatory-like movement have been objectively defined for use in analyzing telemetry data.

Sound pulses from acoustic tags easily pass through the body wall of a fish, even if a smaller fish is consumed by a larger fish. To correctly interpret tag data it is important to recognize a predation event in order to correctly classify a tagged fish for survival studies. If the acoustic tags have short, precisely controlled transmission intervals, detection & ID ranges that are the same, and are detected on multiple hydrophones at once, then accurate tracks of individual fish can be generated (Ehrenberg and Steig 2009). Two tagged smolts whose tracks overlap in space and time (appear to swim together) may indicate a predator has consumed two tagged smolts. Another possibility is that the tagged smolts are exhibiting schooling behavior. A likely predation event (shown left) shows two tags have continuously overlapping tracks for over three days and one of the tags became completely stationary (likely defecated) within the array. That tag remained stationary and slowly sunk into the substrate for several more days until the end of the tag battery life.

Understanding predator behavior and distinguishing it from migrating smolt behavior is key to correctly interpreting acoustic tag results (Vogel 2010). If fine scale 2D or 3D track data is available, then sudden behavioral changes or characteristic, quantifiable behavioral patterns can be used to infer predation events. However, behavior results should be interpreted in context with concurrent environmental factors, including simple sinuosity and average speed over ground for known tagged predators, tagged smolts, high tide (low water velocity) and low tide (high water velocity).

As acoustic telemetry advances, find out more about how scientists currently track fish behavior and determine predation events by contacting the fisheries scientists at support@HTIsonar.com.