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IMPERILED FISHES AND AQUATIC COMMUNITIES ACROSS THE SOUTHERN LANDSCAPE: SPATIOTEMPORAL DATA BASES FOR THE 21ST CENTURY*

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The southern United States harbors the richest freshwater fauna of any similar-sized region in North America and supports a large portion of the endemic fishes and other aquatic organisms known on the continent. Concomitant with high diversity and endemicity is a growing list of imperiled aquatic organisms; 20 or more fish species are in need of conservation management in Alabama, Georgia, North Carolina, Virginia, and Tennessee. This diverse fauna and its setting within a rapidly changing landscape present numerous future and ongoing challenges to aquatic resource managers, especially those associated with conservation of individual species, aquatic communities, and flowing water habitats. Over the past century a vast body of knowledge has accumulated on the zoogeography, distribution, and biology of the southeastern fish fauna and to a lesser extent other aquatic organisms, but to date little of this information has been synthesized in an analyzable format capable of addressing long-term, site-specific changes (potential or realized) or affects across large spatial scales (reaches to watersheds to drainage basins). This information is paramount to formulation of sound management decisions and planning in both the long and short-term, especially as management inevitably moves from individual species to whole communities and watersheds. An important challenge facing researchers and managers in the southeast is to creatively use and expand this body of knowledge in a coordinated fashion for the benefit of fishes, aquatic communities, and habitats.

To address these needs, a symposium, jointly sponsored by the American Fisheries Society Endangered Species Committee and Southeastern Fishes Council, was organized and presented at the annual meeting of the American Fisheries Society, Tampa, Florida, 29 August 1995. The primary purpose of the symposium was to highlight the application of long-term or large-scale aquatic data sets and present creative approaches to illuminating factors at multiple spatial and temporal scales that interact to affect species diversity, ecological function of aquatic communities, and habitat in southern running waters. Specific objectives were to: (1) create a forum for scientists to share with managers the availability and potential applications of existing data and computationally intensive methods, including contemporary systematics, historical ecology, and GIS applications; (2) enhance communication between resource agencies and researchers concerning creation, maintenance, and use of large data bases for planning and management of endangered fishes, other imperiled aquatic fauna, aquatic communities, and sensitive aquatic habitats; and (3) focus on realized and potential problems attendant to the future of the southern aquatic fauna and germinate coordinated efforts at using the data in hand for betterment of the fisheries resource of the future.

We present in this issue of the SFC *PROCEEDINGS* brief summaries from the symposium presentations. We do so realizing that many members of SFC were unable to attend the AFS meeting and in an effort to share with members ongoing research on the great aquatic fauna of the southern United States.

STATUS OF FISH COLLECTIONS IN THE SOUTH: THEIR VALUE AND USES AS DOCUMENTATION CENTERS OF DIVERSITY

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Many biologists and resource managers are unaware that a wealth of data on fish communities, jeopardized species, and sites of aquatic diversity already exists in permanent fish collections located throughout the southern United States. Among the most significant in terms of size, historical data, and geographic coverage are the national centers at Tulane University and Florida State Museum and the regional centers at Northeast Louisiana University and University of Alabama.

*Editors Note: This introduction and the abstracts that follow are from a Symposium on Imperiled Fishes and Aquatic Communities Across the Southern Landscape: Spatiotemporal Data Bases for the 21st Century, held in Tampa, FL on 29 September 1995 as a joint effort of the American Fisheries Society Endangered Species Committee and the SFC. It was felt by the organizer, Mel Warren and concurred by the Editor that this information would be of interest to the membership of the SFC.

Together with more parochial collections these institutions are depositories of over 12 million fish specimens representing samples taken over the entire southern landscape. Most important to resource managers are the long-term data bases on stream-fish communities from several of the major southern drainages as well as preserved series of jeopardized species collected prior to their present threatened status. Most of these data have not been synthesized in any available format to allow convenient access. Crucial needs of fish collections include computerization, geo-referencing, adequate staffing, and space for growth. We recommend that a consortium of state agencies, universities, and private foundations be formed to provide the support and funding that will allow the historical aquatic resource information already available in collections to be utilized to its maximum level in the 21st Century.

BIODIVERSITY AND CONSERVATION OF FISHES IN THE SOUTH: LESSONS FROM HISTORICAL ECOLOGY

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The southeastern ichthyofauna is one of the most diverse faunas in North America. This region has suffered fewer dramatic paleoclimatic changes since the Cretaceous than other regions. Sampling by ichthyological parties have not only revealed a significant number of taxa with restricted distributions but have yielded substantial museum data to document temporal and spatial changes in the fauna. Recent advances into systematic (evolutionary) relationships within this fauna, using these museum data, have revealed numerous replicated and highly predictable historical patterns of diversification within the region. Historical Ecology incorporates systematic hypotheses of organisms into efforts to better understand the origins of not only their distributions but their ecologies, physiologies, behaviors, etc. This novel research program promises to enhance our abilities to accomplish objectives frequently outlined in management and conservation plans. Phylogenetic hypotheses are historical templates onto which distributions and biological attributes of organisms may be superimposed to reveal origins of traits important in conservation and management. For some taxa these traits are unique; for others they are historically constraining (inflexible) elements of imperiled faunas. Recent advances in this program also offer assistance to managers in the decision making process of prioritizing and targeting species and/or communities for protection.

A GIS DATABASE OF MISSISSIPPI FISHES: APPROACH, PROBLEMS, AND APPLICATION TO CONSERVATION ISSUES

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The ichthyofauna of the southeastern United States has been sampled for several hundred years but most intensively since the 1900's. To understand Mississippi's inland fish fauna, I first constructed a computer database of museum material and then used the information to identify regions requiring further collecting. Museum data are advantageous in offering both temporal and spatial coverage, and the potential for examination of specimens and original field records. Each locality was identified on USGS 1:100,000 maps using universal, transverse, Mercator Coordinates, and the coordinates were added to the database. Since 1986, over 30 fish museum collections in the eastern United States have been accessed, and the current database contains 89,000 records. Data for each species are plotted on State drainage maps using Atlas GIS. Overall, 282 species are recorded, with 202 native, freshwater, 10 non-native, and 70 estuarine/marine species. Most of the 10 drainages have 100 or more species, exceptions being the Lake Pontchartrain and Coastal Rivers. However, a GIS plot of taxon density indicates that centers of species richness are grouped across drainage patterns with a broad band running diagonally from the northeast to southwest corner of the state. Diversity is also high in coastal areas due to the influx of estuarine/marine species.

DUSTING OFF THE JARS: USING MUSEUM COLLECTIONS IN STUDIES OF FISH ECOLOGY AND FISHERIES MANAGEMENT

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Although the systematic importance of fish research collections is well understood, they are underused in ecological and fisheries research. Recent thesis projects undertaken by students at Northeast Louisiana University illustrate the application of research collection data to three different ecological and management problems. One project focused on the life history of the crystal darter, *Crystallaria asprella*, a species classified as "Of Special Concern" by AFS. Specimens used were collected over a two-decade period. The

use of museum specimens reduced the need to obtain large samples of an imperiled species. A second project described the reproductive cycle and life span of the cypress darter, *Etheostoma proeliare*. Although this species is common in the Ouachita River watershed, it is usually collected in small numbers. As in the crystal darter study, data were pooled by month across years to develop sufficient samples for analysis of annual trends. The objective of the third study was to design an IBI to assess impacts of timber management on relatively undisturbed headwater streams of the Ouachita Mountains. Historical fish collections from the region were used as reference data sets for constructing the IBI. Museum specimens provided a supplementary data set that was not otherwise available because of logistical limitations.

ECOLOGICAL AND TAXONOMIC APPROACHES TO RECOGNIZING THE DIVERSITY OF FISH ASSEMBLAGES IN VIRGINIA

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The majority of biological conservation focuses on imperiled populations or species. This strategy is not effective at protecting aquatic populations or biodiversity in general, which encompasses a wide range of organizational levels (e.g., genes, species, landscapes). Conservation can become more effective by expanding its focus to include preventive measures and large-scale ecological elements (i.e., assemblages). Species-specific approaches should be complemented by protection of assemblages, including guilds, communities, and landscapes. Before policy to protect assemblages can be established, ecologists must develop an objective framework for taking stock of the variability in assemblage composition and organization. Such a framework (or assemblage classification) is likely to be based on taxonomic and/or ecological attributes of the biota. We used fish collections from Virginia to assess the comparability of assemblage classifications based on taxonomic versus ecological and life-history attributes of component species. Classifications were developed through multi-variate clustering and ordination procedures. Drainage basin, physiography, and stream size distinguished assemblage "types" at coarse levels in hierarchies developed from both classification approaches. Assemblage types recognized at finer levels were inconsistent between approaches, and reflected patterns of endemism and human impacts (e.g., dams). Taxonomic and ecological information are complementary; both should be incorporated into assemblage classifications.

TEXAS FRESHWATER FISH ASSEMBLAGES FOLLOWING THREE DECADES OF ENVIRONMENTAL CHANGE

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In 1953, C. Hubbs and colleagues surveyed fishes from a large number of freshwater habitats throughout the state of Texas. Thirty-three years later, he replicated sampling at 129 sites within the Red, Sabine, Neches, Trinity, Brazos, Colorado, Guadalupe, San Antonio, Nueces, and Rio Grande drainages. Great care was taken to reproduce fishing effort, sampling times, and dates at each location. Relative proportional abundances of families showed numerous changes from 1953 to 1986 within the ten basins. Mantel tests comparing family abundances in early (1953) and recent (1986) datasets showed little overall change statewide. Sites in the eastern half of the state that excluded marine species showed less significant positive covariation between early and recent datasets than those in the western Texas. Rank plots of species diversity (H') for the two regions of the state showed a consistent trend of decreased diversity over time in eastern Texas. The analyses reveal reductions in diversity on a local scale but also reveal relative stability in the statewide and regional ichthyofaunas. Despite the encouraging large-scale trends, several Texas fishes have gone extinct and others are threatened as a result of disturbances, including alteration of instream flow, eutrophication, and exotic species introductions.

STREAM FISH ASSEMBLAGES IN ARKANSAS UPLANDS: QUANTIFYING VARIANCE IN SPACE AND TIME BY USE OF HISTORICAL COLLECTIONS

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Ichthyological collections made by the authors and others provide a robust data base of information on fish distributions and abundances at sites on streams throughout the Ozark and Ouachita mountains of Arkansas. Collections over time at multiple sites in Piney Creek, Izard County, indicate the magnitude of differences in fish assemblages within one well-studied watershed over space (12 locations), time (20+ years), and disturbances (100-year flood). Geographically broad collections throughout the uplands are used to identify centers of local diversity, to relate local diversity to regional diversity, and to suggest use of "hot spots" of biodiversity as a core for conservation of non-game fishes in the state.

CORRELATES OF DEMISE: CASE OF THE SOUTHERN APPALACHIA FISH FAUNA

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The southeastern United States has the greatest species richness of temperate freshwater fishes in North America, with about 61% of the estimated 800 continental species north of Mexico. Encompassing 70% of the southeastern fish fauna, the southern Appalachian highlands represents the center of this diversity. Serious environmental threats have lead to decline and imperilment of approximately 23% of the species within the region. Generalized patterns of faunal decline correspond to common, widespread forms of habitat degradation, but the ecological correlates of imperilment have not been adequately determined. We analyzed patterns of imperilment using 45 variables representing nine general distributional, habitat, and life history criteria: range size; habitat size; vertical orientation; trophic guilds; longevity; maximum body size; spawning guilds; spawning substrates; and reproductive output. Variables for each taxon were scored using published information, museum records, and unpublished data. The most significant correlates of imperilment were range size, body size, and benthic habitat association; the most jeopardized species were those with relict or endemic distributions, small body size (< 150 mm TL), and/or a strongly benthic spawning orientation. Refined analyses of ecological parameters combined with spatiotemporal data provide improved understanding of imperilment trends and will facilitate greater proactive management of the native southern Appalachian fish fauna.

NAVIGATION-RELATED CHANGES IN THE ALABAMA RIVER FISH COMMUNITY OVER A 20-YEAR INTERVAL

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In 1967, Royal D. Suttkus and the late Gerald E. Gunning initiated a survey to monitor the effects of effluents from a pulp and paper mill on the Alabama River fish community. Suttkus is continuing the survey to this day. Work on the second of two navigation "locks and dams" on the Alabama River was completed in 1970, impounding all but two of the survey sites and creating a narrow, 62-mile reservoir (Claiborne Lake). Completion of the dams resulted in a significant increase in daily flow variability within the impoundment as compared to the unimpounded river. Extensive dredging during construction and afterwards for channel maintenance is believed to have contributed to the heavy sediment accumulations that are now evident along the shore. All specimens and data from the Alabama River fishes survey are archived in the fish collection at the Tulane University Museum of Natural History, providing a unique opportunity to examine fish community changes in relation to navigation. The present study involves data from semiannual (winter and summer) collections made at 15 sites over the period 1968 to 1985. Collections were pooled in six, -yr blocks. Regression analysis was used to establish trends (increase or decrease) in species occurrence and sample-time-adjusted abundance across time blocks at individual collection sites. Binomial tests were used to assess overall trends in abundance across sites. Species abundance were adjusted for total sampling time within blocks. We hypothesized that: a) species richness would decline post-impoundment reflecting the change from lotic to more lentic habitat; b) diadromous and euryhaline species would decline in impounded portions of the river; and c) species classified in the literature as silt-intolerant or preferring gravel as spawning substrate would decline due to dredging activity. Richness declined at non-tributary sites, but showed little change at tributary sites, suggesting a refugium effect. Examined over all sites, richness decreased from 85 species in 1968 to 60 species in 1994. The strongest decline in average richness involved percids. Most diadromous/euryhaline species declined at impounded sites and showed little change at unimpounded sites; needlefish, however, tended to increase. Species classified as silt-intolerant or gravel spawners (e.g. speckled chub, crystal darter) declined over most sites, but persisted at sites midway between the dams, where the river most resembled preimpoundment conditions. Significant declines also were noted for silver chub, weed shiner, and moxostomine suckers. Species such as the silverband shiner, emerald shiner, weed shiner, and silvery minnow increased in abundance across sites. The results suggest that modification of streams for navigation-an activity that now effects virtually every major stream course in United States-can have dramatic consequences for fish community composition and structure. Museum collections such as the Tulane Fish Collection contain valuable historical (pre-navigation) data for assessing these impacts.

FISH COMMUNITY STRUCTURE AND LAND-USE IN AN ALABAMA WATERSHED (CHATTAHOOCHEE RIVER SYSTEM): METHODOLOGY AND RESULTS FROM HALAWAKEE CREEK

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We analyzed historical and present-day effects of land-use on fish community composition and present-day effects of land-use on in-stream habitat heterogeneity and sediment loading in the Halawakee Creek watershed, Alabama. Historical fish collection data (museum records) were arranged in five-year time intervals from 1966-1995 to represent historical trends in ichthyofaunal diversity and community structure. In 1995, 12 historical sampling localities were revisited by the first author to supplement the historical fish data and to measure sediment loading and in-stream habitat heterogeneity. At each locality, a 100-meter reach of stream was sampled; fish were captured by seine and back-pack

electroshocker. Historical and present-day land-use patterns (hardwood/pine forest, agriculture/pasture, pine monoculture, cleared pine, selective cut, and urban) were interpreted from aerial photographs and digitized into a Geographic Information System (GIS). Fish collection data, habitat data, and land-use information were incorporated into a GIS database for analysis. GIS technology was used to determine areas of coverage above each sample locality for each land-use category and to model fish species distributions along gradients of forest cover and stream size.

Stream size was an important predictor of fish species richness and fish community structure. Controlling for stream size, there was a significant decrease ($p<0.05$) in species richness (adjusted for sample size) with an increase in agriculture/pasture cover. Relative abundances of *Ericymba buccata*, the silverjaw minnow, and *Luxilus zonistius*, the bandfin shiner, were lower in tributaries draining deforested areas. Ordination analysis of sample sites based on fish species representation (all species $>1.0\%$ relative abundance) suggested that land cover (agriculture/pasture) is an important predictor of fish community structure.

Local habitat conditions (substrate complexity and structure availability) were lower in streams draining deforested watersheds. There was a significant positive relationship ($p<0.05$) between the percent of stream bottom covered in sediment and percent of the watershed in agriculture/pasture. Streams prone to high rates of sedimentation were of uniform depth and substrate.

There was no significant difference ($p>0.05$) in percent forest cover within the Halawakee Creek watershed between 1966 and 1995. Overall species richness and fish community structure in Halawakee Creek have not changed significantly over time. However, populations of *Notropis hypsilepis*, the highscale shiner, and *Notropis texanus*, the weed shiner, have undergone dramatic declines since 1966. The decline of these two cyprinids may be due to the increase in populations of *Notropis baileyi* following the introduction of this species to Halawakee Creek in 1960.

Our results suggest that watershed land-use practices affect species distributions and community structure within a watershed via alteration of in-stream habitat characteristics. Additional work by the authors on five neighboring watersheds will aid in the interpretation of results found for Halawakee Creek.

USE OF HISTORIC FRESHWATER MUSSEL DATA IN THE MANAGEMENT OF AQUATIC RESOURCES OF THE APALACHICOLA RIVER BASIN

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North America, north of Mexico, harbors the greatest freshwater mussel biodiversity in the world, and the southeastern United States has more freshwater mussel species than any other region of the country. However, results of a recent National Biological Service (NBS) freshwater mussel survey of a large drainage basin in the southeastern U.S. suggest a very imperiled fauna. Unfortunately, little is known about the biology and ecology of freshwater mussels. Even less is known about how landscape changes affect them. Because of this tremendous need for landscape-scale information, we conducted computer-based spatial analyses (using ARC/INFO GIS) of the data collected during the NBS freshwater mussel survey of the Apalachicola-Chattahoochee-Flint (ACF) basin. These data include more than 9,000 records from collections made from 1991-1993 and more than 2,000 historic records obtained from museum collections, literature records, and technical reports. Our goals were to: (1) illustrate the present and historic distribution of freshwater mussels in the ACF basin; (2) illuminate basin-wide mussel population trends; and (3) identify anthropogenic and natural factors that have impacted mussel populations and distribution. The resultant spatio-temporal databases and maps will help ACF aquatic resource managers proactively manage the basin's resources to protect its fauna.

TRACKING INTRODUCED FISHES IN THE SOUTHEASTERN UNITED STATES

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Since 1978, the Southeastern Biological Science Center (SBSC), National Biological Service, Gainesville, Florida, has monitored the status and distribution of nonindigenous fish species in open waters of the U.S. The SBSC database now contains over 12,000 records representing over 400 nonindigenous fish species. The SBSC database documents authorized and unauthorized introductions of over 160 nonindigenous fish species into inland waters of Alabama, Florida, Georgia, and South Carolina. Of these, at least 30 foreign fish species and more than 30 transplanted species have established, reproducing populations. Continued maintenance of the database is extremely important because of the dynamics associated with introduced fish populations and the potential impacts certain introduced species may have on native aquatic species and ecosystems. Many problem fishes introduced into U.S. waters transcend political or state boundaries. A national database contains information that is vital in providing policy-makers and resource managers a more comprehensive and factual view of introduced fishes. Because any database is only as good as the information that goes into it, we continue review of older records of introductions to verify past identifications and associated information. As part of this process, we are contacting U.S. museums to document previously unreported records and to determine if historical records are supported by voucher specimens.