

FRESHWATER FISHERIES MANAGEMENT

Factors Associated with the Reduction of a Minimum Length Limit for Largemouth Bass in Lake Eufaula, Alabama-Georgia

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The current 406 mm minimum length limit for largemouth bass was increased from 305 mm at Lake Eufaula, Alabama-Georgia in July, 1992. We used a variety of data collected between 1987 and 1999 to evaluate the current length limit, two other minimum lengths (305 and 356 mm) and a protective slot limit (356 to 406 mm). Largemouth bass growth and size-structure decreased after 1992, as did angler catch rates. Exploitation was much lower during the late 1990s than the early part of the decade. Tournament metrics were markedly different between 1987-1991 and 1993-1999 with declines in angler success, number caught per day, and tournament participation and an increase in the time required to catch a trophy fish (≥ 2.27 kg). Simulation modeling suggested that the 406 mm length limit was appropriate under conditions of faster growth and moderate exploitation of the early 1990s, but was less effective as a management tool under the conditions of slower growth and lower exploitation of the late 1990s. A 356 to 406 mm protective slot limit would not result in a greater number of fish recruiting to 406 mm. Based on our evaluation, the length limit was decreased to 356 mm in November, 2000 by both Alabama and Georgia. This action will likely lead to an increase in tournament participation at Lake Eufaula.

Live fast, die young: can Puerto Rico largemouth bass be managed effectively?

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Sampling of juvenile and adult largemouth bass in Lucchetti Reservoir, Puerto Rico, has been conducted over the past 8 years. Annual population estimation has revealed that stock size varies about 3-fold annually. This variation is the result of the fishable stock being comprised almost entirely of age-1 and 2 bass, and marked annual variations in recruitment. Adequate forage for juveniles and adults results in rapid growth to maturity at age 1 and high condition of adults at all population levels. Puerto Rico largemouth bass, which are genetic intergrades, exhibit an extended spawning season and recruitment is related to water level conditions from January to June. High mortality rates of adult fish are due to unusually high natural mortality, which appears related to the extended spawning season. Bioenergetic studies are examining effects of the extended spawning season on growth, which typically slows after maturity.

Fishing mortality is exacerbated by high probabilities of post-release mortality. Management through liberalized harvest regulations, water level control during the spawning season, use of alternative genetic stocks, and supplemental stocking during years of poor reproduction, during late summer and fall, and with sterile triploids is being evaluated.

Changes in the Black Bass Population and Fishery with the Oligotrophication of West Point Reservoir, Georgia

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We examined the fishing tournament and population responses of largemouth bass *Micropterus salmoides* and spotted bass *M. punctulatus* to the oligotrophication of West Point Reservoir (10,467 ha). State-mandated reductions in point and non-point source phosphorus loadings resulted in nearly an order of magnitude decline in inflow total phosphorus concentrations (TP) entering the reservoir from the late 1980's to 1999. Concurrent with this decline in inflow TP, chlorophyll *a* concentrations at a mid-reservoir station declined from over 40 $\mu\text{g/L}$ in 1987-1988 to 9-17 $\mu\text{g/L}$ by 1997-1999. Largemouth bass and spotted bass recruitment decreased and increased about two-fold, respectively, and growth and relative weight of age-4 and older largemouth bass declined over time. This caused more than two-fold decline in electrofishing catch rates of largemouth bass greater than 304 and 406 mm (legal minimum length) long. The infusion of slower growing spotted bass (tournament 304 mm minimum length) into the black bass fishery resulted in a decline in average weight caught by tournament anglers, but increased the percent success of anglers processing at least one fish in a tournament with no change in catch-per-effort. The amount of tournament angling effort to catch a black bass over 2.27 kg increased from about 100-200 hours in the late 1980's to over 500 hours by the late 1990's. Simulation modeling predicted a 4-8 fold reduction in fish greater than 2.27 kg and 50 to 60% fewer largemouth bass greater than 406 mm in the population over time due to the reduction in growth and recruitment. Oligotrophication of West Point Reservoir improved water clarity, but resulted in the restructuring of the black bass population with fewer, smaller and less robust largemouth bass, but smaller and more abundant spotted bass in the fishery. When establishing water quality standards that result in reduced nutrient loading, fishery and water quality managers should collaborate to predict potential consequences and involve the public in these decisions. To improve tournament participation on West Point Reservoir, we recommend a reduction in the minimum length for largemouth bass to allow anglers to possess more fish and resolve the dilemma of having two different species-specific minimum length limits for tournaments.

Homing Behavior of Largemouth Bass in the tidal Chickahominy River, Virginia

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The tidal portions of the James River and its largest tidal tributary, the Chickahominy River, have provided outstanding recreational fishing for largemouth bass *Micropterus salmoides* for many years. Tournament fishing in these rivers has grown tremendously during recent decades. Many anglers competing in bass tournaments headquartered in the Chickahominy River actually spend time fishing in the James River because of its reputation for larger fish. At these tournament weigh-ins, all bass, including those imported from the James River, are released into the Chickahominy River. This may help explain the relatively high abundance and relatively low mean body condition and growth rate of this population. The primary objective of this project was to evaluate whether largemouth bass displaced from the James River to the tidal Chickahominy River would exhibit homing behavior. Ultrasonic transmitters were surgically implanted in 17 imported and 7 control largemouth bass during summer, 1997. Short-term mortality was high (63%), probably because of relatively high water temperatures (21.5 - 30.5°C) at the time of tagging. None of the surviving imported bass (n = 5) exhibited homing behavior for the James River. These results suggest that imported bass become part of the population in the Chickahominy River, which could impact population dynamics.

Effects of Bait Types and Hooking Location on Largemouth Bass Post-Release Mortality

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We compared post-release mortality of largemouth bass (*Micropterus salmoides*) caught with treble-hook lures, "Carolina-rigged" soft plastic worms, and live koi carp (*Cyprinus carpio*) fished two different styles (under a float and "Carolina-rigged"). Also, we evaluated the relationship of mortality to hooking site, bleeding occurrence, and fish total length (TL) for each bait type. Thirty fish were caught with each bait type during each of two angling events conducted at Lake Umphrey, Texas, during August 1995, tagged, and held for 72 h in a cage located in the lake. Mortality ranged from 13-33% across bait types and angling events and was not related to bait type for fish caught during either angling event ($P = 0.11$ and $P = 0.78$). However, anatomical hooking site was related to bait type ($P = 0.05$) and to mortality ($P = 0.02$). Fish hooked in the throat, gill, and mouth experienced 48%, 17%, and 20% mortality, respectively. Fish caught with plastic worms were most likely (18%) to be hooked in the throat. Bleeding occurrence was related to mortality ($P = 0.01$) but not to bait type ($P = 0.30$). Fifty percent of fish bleeding upon hook removal died, whereas 20% of fish not bleeding died. Bleeding was more frequent for fish hooked in the throat (48%) and gill (50%) than for fish hooked in the mouth (1%). A relationship existed between fish TL and mortality for fish caught with only one of the bait types. Probability of mortality of fish caught with treble hook lures (P) decreased as fish TL increased ($P = 1/1 + e^{-(9.002 - 0.025 * TL)}$, $R^2 = 0.11$, $P = 0.006$). Results of our study suggest that a bait type restriction would probably not result in an overall decrease in largemouth bass post-release mortality because differences in mortality were not significant across bait types.

Evaluation of a statewide volunteer angler diary program for use as a fishery assessment tool

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We implemented a statewide volunteer angler diary program for the 1995 fishing season to determine if angler diaries can provide data useful for fishery management purposes for the principal sport fishes in waters throughout Mississippi. Of 1,153 anglers volunteering to participate, 224 (19%) returned diaries with at least one trip entered into a diary and usable for data analysis. We found no significant ($P < 0.05$) correlations between angler diary catch per unit-effort (CPUE, fish per hour) and creel survey or electrofishing CPUE for black bass *Micropterus* spp. or crappie *Pomoxis* spp.. Length distributions of black bass reported by anglers and sampled by electrofishing were similar at five of seven reservoirs when black bass smaller than 250 mm were excluded from the comparisons. Length distributions of crappie differed between diary reports and electrofishing catch. Low participation by catfish (Ictaluridae) and sunfish *Lepomis* spp. anglers precluded similar analyses. The participating anglers differed from the general angling public in Mississippi, possibly biasing estimates of catch rate. Although angler diaries may have value for monitoring angler catch rate trends for diverse types of anglers and in numerous water bodies, our results show angler diary data should not be used to replace traditional fishery assessment data.

FRESHWATER FISHERIES ECOLOGY

Plant and Fish Communities in Enhanced Littoral Areas of Lake Kissimmee, Florida Following a Major Habitat Enhancement

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In 1995-96, a habitat enhancement project was conducted on Lake Kissimmee, Florida which included a major drawdown and organic sediment removal from about half of the lake's shoreline. In this study, we sampled fish and plant communities in two enhanced (scraped) areas of the lake during the summers of 1998 - 2000. The objectives of this study were to (1) assess how aquatic plant communities (i.e., abundance, biomass, diversity) in enhanced areas of Lake Kissimmee change over time and (2) evaluate how fish communities vary with aquatic plant communities in these areas. Plant diversity, macrophyte biomass, and macrophyte abundance were analyzed using repeated measures analysis. All variables differed significantly among years ($P < 0.05$). Stepwise multiple regression models assessed relationships between selected fish variables (diversity, biomass, percent composition of sportfish) and habitat

variables (e.g., water depth, macrophyte diversity, macrophyte biomass) within each sampling year and site. In general, percent area coverage of aquatic macrophytes (PAC), macrophyte biomass, macrophyte diversity, and water depth were positively related to fish variables.

Differences in Fish Communities between Two South Carolina Freshwater Tidal Wetlands as Determined by Electrofishing

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Due to an increase in the rate of plant succession in the Cooper River from a 1985 redirection of water flow, we wanted to compare the fish communities in two wetlands in different stages of plant succession. Dean Hall (DH) is a 63 ha wetland in a later stage of succession, while Bonneau Ferry (BF) is a 96 ha wetland in an earlier stage of succession. We electrofished permanent 200 m transects every other month from April through December 1999. We found 26 species in each wetland, but there were differences in numbers of individuals and species composition. A 2-way ANOVA showed that DH consistently contained more fish per meter than BF. Horn=s index of similarity of species composition was 0.794 and a canonical correspondence analysis (CCA) showed that sunfish were more common in DH and killifish more common in BF. We constructed species accumulation curves for each wetland, fit those curves with a log-model, and then compared those curves with ANCOVA. Intercepts and slopes differed between wetlands, with DH having a higher intercept and a greater slope. These differences between the two wetlands are probably related to the degree of channelization due to the stage of plant succession.

Prediction of stream fish microhabitat with complex hydraulic variables, an ecomorphological approach

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The ability to quantitatively predict fish habitat use greatly enhances habitat management especially community level assessments aimed at conserving biodiversity. Previous studies have found that habitat use relates to fish morphology and that morphology can be a tool for predicting habitat use. This study investigated relationships among 39 morphology traits and two hydraulic variables (Froude number, Specific energy) for four groups of fishes (darters, benthic and pelagic minnows, and suckers). Significant linear regressions (r^2 from 0.25 to 0.91) were inconsistent across groups sharing similar habitat such as darters and benthic minnows, suggesting relationships are only valid within families. For two sub-species of blacknose dace, we found that differences in morphology reflected differences in habitat use. In addition,

examination of the data found habitat use for 31 of 36 species from two rivers occurred in depths of 15-50 cm and water velocities of 20-60 cm/s. This range of habitat may represent core habitat for adult, rheophilic fishes during baseline flows. Future work with minnows will examine the relationship of swimming ability to morphology and habitat use based on relationships found here.

Seasonal habitat selection by adult striped bass in Lake Murray, South Carolina

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Adult striped bass *Morone saxatilis* (n=61, 597-914 mm total length) were captured by hook and line, and electrofishing in Lake Murray, South Carolina during November 1999 - May 2000. After capture striped bass were implanted with temperature-sensitive radio transmitters. Tracking efforts were conducted biweekly by boat during daylight hours throughout the reservoir. Striped bass were found in the upper sections of Lake Murray and throughout the upper Saluda River to Greenwood Dam during late November through early March. In March striped bass began to move down reservoir when reservoir surface temperatures reached 14 - 18 ° C. During summer months striped bass were distributed throughout the lower section of Lake Murray. Striped bass occupied depths of 10 - 32 m with water temperatures of 14 - 24 ° C and dissolved oxygen concentrations of 2.5 - 7 mg/L. Three striped bass remained in the Greenwood Dam tailrace through the summer months.

Spatial and temporal patterns of energy intake by lower Mississippi River catfishes

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Energy intake rates were determined for blue catfish *Ictalurus furcatus* and flathead catfish *Pylodictis olivaris* collected from different habitats in the lower Mississippi River in 1997-98. Diet composition of both species was ordered along a probable habitat gradient that generally corresponded with the caloric densities of the foods being consumed. Caloric densities of potential foods were greatest in floodplain lakes, least in the main river channel, and intermediate in secondary (side) river channels. The gradient was strong for blue catfish and weaker, though similar in direction, for flathead catfish. Patterns in energy intake for both species varied between years and among habitats. Compared to 1997, rates of energy intake were 34% greater for both species in 1998. For blue catfish, energy intake between April and June increased 54% in 1998 (during the spring 'flood pulse') with increases most evident in

floodplain lakes (151%). For flathead catfish, energy intake increases averaged 37% in 1998, but were 56% between April and June. Increased energy intake for catfishes in 1998 was attributed to the predominance of warmer water temperatures associated with spring flooding, which increased food consumption rates. Results may provide a template for floodplain management strategies used to enhance fisheries production in the LMR.

Diel movement of largemouth bass in a South Carolina Stream

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Largemouth bass *Micropterus salmoides* (n=57; 279-692 mm TL) were captured by electrofishing during June 1999 and November/December 1999, in Steel Creek, South Carolina. Largemouth bass were surgically implanted with radio transmitters after capture. Individual bass (n = 8 - 12) were located every 2 h over a continuous 24-h period in August, November, February, and May and diel activity was evaluated. . In August, surface water temperatures varied between 24 - 30° C along the length of Steel Creek. Individual diel displacement was restricted to a maximum of <115 m (n=9; \bar{x} = 60 m). In November, surface water temperatures varied between 13 - 19° C along Steel Creek. Individual largemouth bass diel displacement increased to a maximum of 1800 m (n=8; \bar{x} = 575 m). In February, surface water temperatures in Steel Creek varied between 10 - 14° C. Individual diel displacement increased to a maximum of 2300 m (n=12; \bar{x} = 770 m). In May, surface water temperatures in ranged between 13 – 23° C. Individual diel displacement decreased to a maximum of 800 m (n=9; \bar{x} = 400 m). Activity in August and November was primarily nocturnal beginning at dusk and continuing through dawn. In February and May activity was primarily diurnal beginning at dawn and extending through dusk.

Habitat and Diet Comparison of Largemouth Bass and Shoal Bass in the Upper Chipola River, Florida

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The shoal bass *Micropterus cataractae* is a recently described species endemic to the Apalachicola, Chattahoochee and Flint River drainages of Alabama, Georgia and Florida. There is a paucity of habitat and trophic information on this species. The objectives of this study were to compare diet and micro-habitat associations of largemouth bass *M. salmoides* and shoal bass in the upper Chipola River, Florida. Electrofishing was used to sample fish in the summer (May-August) and fall (September-December) 1999 and 2000. Chi-square analyses revealed significant differences ($P < 0.001$) between the proportion of adults and age-0 of each species collected from pool, riffle and shoal habitat areas. Largemouth bass were collected in higher proportions in pool and riffle habitats than shoal bass, whereas shoal bass were collected in higher proportion in shoal areas than largemouth bass. These habitat trends were identical for both adult and age-0 fish. Stomach content analysis revealed that crayfish dominated the diets of large ≥ 300 mm total length (TL) largemouth bass whereas fish were the primary resource of largemouth bass < 300 mm TL and all sizes of adult shoal bass. Age-0 diet contents of both species were mainly insects and small fishes.

Movement of brown bullhead in the tidal Anacostia River, Washington D.C. USA

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We investigated the movement of the brown bullhead catfish in the Anacostia River. Our objective was to document that bullhead found with high liver and skin tumor prevalences, which have been linked to elevated PAH (polynuclear aromatic hydrocarbons) levels in Anacostia River sediments, are resident. During the Spring 2000, a method of transmitter attachment was evaluated by implanting dummy transmitters (7-scotchcaste® coated, 7-paraffin coated) into the peritoneal cavity of 14 fish. All 7 fish implanted with paraffin-coated transmitters retained their transmitters for the duration of the experiment (71 days) and relative weight gain (5.98-17.29 %) was not different from controls. On 20 July 2000, 10 brown bullheads (mean TL 265 mm, mean wt. 252.9) were caught via electrofishing near the CSX Railroad Bridge. The fish were internally fitted with paraffin-coated ultrasonic transmitters in the field and released. During the study, we tracked 10 individuals from 21 July through 13 Sept 2000. No fish were observed leaving the Anacostia River and fish remained within 1 mile of their release location. Based on the results, bullheads are resident in the Anacostia throughout the summer. Tracking will continue next spring and fall and the effect of temperature on tag retention will be investigated.

Habitat Utilization and Distribution of Striped Bass in J. Strom Thurmond Reservoir

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An 18-month radio telemetry study was conducted to record the summer and seasonal habitat use and distribution of adult striped bass *Morone saxatilis* in J. Strom Thurmond Reservoir, a 28,329-ha impoundment on the Savannah River. The objective was to determine the summer and seasonal habitat preference of adult striped bass in Thurmond Reservoir, and to relate actual habitat use to available habitat, as defined by the U.S. Fish and Wildlife Service habitat suitability indices for inland stocks of adult striped bass. This will provide a baseline index of available and utilized striped bass habitat prior to modification of the thermal and dissolved oxygen regimes of J. Strom Thurmond Reservoir. During spring and early summer of 1999 and 2000, a total of 48 adult striped bass (>3 kg) were surgically implanted with temperature-sensitive radio transmitters. A systematic roving search of Thurmond Reservoir was conducted at least monthly to locate transmitted fish and record reservoir water quality from June 1999 to December 2000. Results suggest that adult striped bass distribution and movement in J. Strom Thurmond Reservoir is influenced by changing temperature and dissolved oxygen levels. Striped bass occupied large tributaries and the lower main reservoir during the winter months. In the spring some fish moved up into tributary headwaters attempting to spawn. As tributary temperatures warmed and dissolved oxygen levels dropped, striped bass left the tributaries for the main reservoir. In early summer, striped bass were found throughout the main reservoir, but as the middle and lower reservoir warmed and became anoxic, striped bass movements directed toward the upper section of Thurmond Reservoir, which is influenced by releases of cool, oxygenated water for power generation. A significant proportion of transmitted fish occupied the upper section of Thurmond Reservoir until the reservoir started the turnover process from cooler surface temperatures. After the beginning of turnover, striped bass redistributed throughout the reservoir with several fish returning to the same tributary in which they were found the previous spring.

SETTING THE LIMITS: BAG AND SIZE REGULATIONS IN COASTAL MARINE FISHERIES

Bag and size limit analyses for the northern and southern regions of the Atlantic red drum.

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An assessment of the Atlantic red drum for the northern (North Carolina and north) and southern (South Carolina through east coast of Florida) regions along the Atlantic coast was recently completed. The joint Red Drum Technical Committee (SAFMC/ASMFC) selected the most appropriate catch matrix (incorporating an assumption on size of recreationally-released fish), virtual population analysis (FADAPT), and selectivity of age 3 relative to age 2. Given gear- and age-specific estimates of fishing mortality (F) for the 1992-1998 period, analyses were made of potential gains in escapement to age 5 and static spawning potential ratio (SPR) from further reductions in fishing mortality due to changes in slot and bag limits. Savings from bag limits were calculated given a particular slot size for the recreational fishery, with no savings for the commercial fisheries in the northern region due to its being managed through a quota. Length-frequency distributions were converted to age-frequency distributions using region-specific age-length keys. Relative changes in catch-at-age estimates were used to adjust age-specific F and hence calculated escapement to age 5 and static SPR. Adjustment was made with the recreational savings to account for release mortality (10%, as used in stock assessment). Alternate runs for the northern region considered 0% and 25% release mortality for lengths outside the slot (the latter reflects an L-25 for mesh size regulations), and 0% vs. 10% gain across legal sizes in F (the latter reflects shift in effort to make up slot limit). These results are summarized for ranges of bag limits with increasing minimum size limit (for fixed maximum size), and with decreasing maximum size limit (for fixed minimum size limit). All analysis are relative to the 1992-1998 time period.

Risk-Averse or Overreaction? Changing the harvest regulations for sheepshead in Georgia

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The sheepshead is a sparid of considerable importance in the recreational and commercial fisheries of the southeastern United States. In Georgia, this species is highly popular with marine recreational anglers, yet harvest regulations are liberal and may do little to protect the stock from overfishing. Sheepshead first reach

maturity during the fourth year of life at a length of 305-mm (12-in), however, the current minimum-size limit in state waters is 203-mm (8-in) fork length. Georgia DNR creel data show that 77% of the sheepshead landed by anglers are less than 305-mm. Adults aggregating on nearshore artificial reefs are particularly vulnerable to harvest by anglers equipped with inexpensive satellite-based navigation devices and fish-finding electronics. Adult sheepshead exhibit spawning site fidelity and these dense aggregations are afforded little protection by the 25 fish creel limit. Meanwhile, angling effort and effectiveness continues to increase. Managers must decide if these circumstances warrant action. If so, what actions are appropriate given the scope of scientific data available on which to base a decision? They must answer the question if proposing changes to size and creel limits would be risk-averse or merely an overreaction.

Evaluating the Effectiveness of Maximum Size Limits for Spotted Seatrout and Red Drum in Florida

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The fisheries for red drum and spotted seatrout in Florida have come under strict regulations since the mid to late 1980's. Maximum size limits were enacted as part of these regulations. Since March 1987, there has been no allowable harvest of red drum larger than 27" total length. Spotted seatrout are managed regionally in Florida with a maximum size limit on the Atlantic coast of 20" TL for anglers and 24" TL for commercial fishers since 1996. Anglers are allowed to harvest one spotted seatrout over the maximum size limit per day. The upper tail of the length composition of samples taken from the population of Gulf coast red drum and Atlantic coast spotted seatrout within Florida's estuarine waters has shown only minor changes since the maximum size regulations were enacted. However, the upper tail of the length frequency of fish sampled from angler creels has shifted to smaller sizes since maximum size limits were enacted, especially for red drum. Estimated fishing mortalities have declined substantially following regulation for Gulf coast red drum and less so for Atlantic coast female spotted seatrout who comprise most of the larger fish in the population. Thereby the supply of red drum eligible for protection by the maximum size limit has increased and this can be seen as an increase in the number of older red drum in samples of fish taken from nearshore schools of adults. The supply of spotted seatrout reaching the maximum size limit is increasing at a more moderate rate. Clearly maximum size limits are useful only if fishing mortalities on younger fish are reduced enough to allow these fish to survive to reach the maximum size limit. Likewise, if there is an allowable harvest of some fish over the maximum size limit, as for spotted seatrout, large fish must become numerous enough so that anglers are restricted by the allowable harvest limit.

Modeling the interaction between size limits and sex-ratios in snook, *Centropomus undecimalis*, a protandric hermaphrodite

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Creel surveys indicate that common snook are among the top three most highly targeted species in Florida. Snook change from males to females and the median age of females is 6 years (median length 864 mm) on the Atlantic coast and 5 years (median length 635 mm) on the Gulf coast. Sufficient numbers of fish are caught to reduce the female spawning biomass even though approximately 90% of the fish are released after capture and the release mortality rate is low at 2%. To examine how changing the size limits changes the sex-ratios in the harvest and in the population, I developed a hybrid Monte Carlo-bootstrap model. The model is initiated with the numbers of fish by age (ages 3 to 20) from the stock assessment that uses a separable, age-sequential model; current fishing and natural mortality rates; current and proposed size limits, estimated rate of increase in Florida's human population, and the rate of increase in the ratio of snook stamps to residential saltwater angling licenses. Each fish in the population is assigned a length by randomly selecting a fish from the observed data base of lengths by age and sex. A fish is caught based on the mortality rates but whether the fish is kept or released depends upon the size limits, bag limits, or other regulations. The possible fates of the fish are 1) to survive, 2) to die naturally, 3) to be caught and kept, 4) to be caught and released and survive, or 5) to be caught and then die after being released. The fate of a particular fish is determined by comparing the cumulative probabilities of the possible fates to a uniform random value. Tallies of the number of fish by each fate are produced for each year. At the end of the year, the sex ratio, female spawning biomass, and number of trophy fish are recorded before the survivors are moved to the next age, recruitment (average of the three recent years) is introduced to age-3, and the process repeats. On the Atlantic coast, adopting a 26-34 inch allowable harvest slot is expected to lower the harvest by 24%, lower the sex ratio in the harvest from 40% female to 34% female, and raise the static spawning potential ratio to 44%. The 26-34 inch slot is expected to lower the harvest by 36% on the Gulf coast but not affect the sex ratio.

MARINE FISHERIES ECOLOGY

The influence of nearest-neighbor dynamics on artificial reef fish-assemblages off coastal Alabama

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In recent decades the deployment of artificial reefs off coastal Alabama has enhanced fishing opportunities for anglers. However, it is debated whether the deployment of these reefs has helped to increase regional fishery production or served merely to attract fish from other habitats. In order to address the attraction versus production question we deployed 7 replicated

reefs of 2 designs off coastal Alabama. These reefs were deployed without consideration of the location and proximity of other reefs. Since February 1999, quarterly surveys have been conducted to assess reef fish demographics (abundance, biomass, etc.) at each experimental reef location. Our results indicate high variability in reef fish demographics due to both reef location and design. We hypothesized that the observed differences in reef fish demographics were related to the proximity and abundance of artificial and natural reefs surrounding each experimental reef. Using a side-scan sonar we measured the abundance, distribution, and volume of artificial and natural reefs surrounding each experimental reef. We then related our measures of reef fish demographics to the nearest-neighbor variables attained using side-scan sonar. Distance to natural reef, artificial reef abundance, reef design and season accounted for more than 60% of observed variability in reef fish demographics.

A Bioenergetics-Based Formalization of Habitat-Mediated Predator-Prey Interactions and Predator Growth Response on Coastal Reefs

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Importance of habitat in fish growth processes, population dynamics, and predator-prey interactions has long been accepted, but in most cases, such habitat relationships have not been known with sufficient mechanistic and quantitative detail to aid in the evaluation of proposed habitat-based management options. This is the case for gag grouper, one of the more valuable sports and commercial species in the SE United States. Past research on artificial reef systems has demonstrated that subadult gag prefer larger reefs to smaller reefs but they have higher growth rates and body condition on small reefs. This counter intuitive result prompted us to ask why. Is it a supply-demand issue (per capita prey availability) mediated by habitat or is it complicated by density-dependent interactions (e.g., interference, social behavior) that either decrease consumption rates (decrease foraging efficiency) or increase metabolic costs at high gag densities? We approach this question by considering the linkages between reef habitat, prey fish availability and gag grouper consumption, growth, and condition on large and small reefs (experimental and natural) in the context of an energy-balanced bioenergetics approach (growth = food ingested minus metabolic expenditures). Here we formalize the bioenergetics approach relative to reef habitat size.

Pelagic Fish Distributions on an Artificial Reef System in the Gulf of Mexico

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Pelagic planktivorous fishes aggregate at artificial reef structures and are known to be an important food resource for some species of piscivorous reef fishes. However, despite their importance little is known about the distribution and persistence of pelagic fishes at artificial reefs. The objective of this study was to collect data on the distribution of pelagic planktivorous fish and their association and persistence with reefs. We measured the distribution, density, and size-structure of fish using a BioSonics 120kHz DT6000 digital hydroacoustic system. Pelagic fish were sampled at two different spatial scales: at a large scale (km) to determine the association of pelagic fishes to reef structures and at a fine scale (m) to determine their persistence on the reefs. Initial analysis indicates that fish appear to have higher densities over the reefs when compared to the surrounding area. Fine scale sampling illustrates a dispersion and reaggregation process occurring from night to day, respectively. Reasons for the increased density and congregation on the reefs have not been determined, but two possible explanations are the reefs provide a common location for fish to find one another, and/or the reefs provide food due to upwelling of benthic organisms around the reefs.

Reefs of an uninhabited Caribbean island: fishes, benthic habitat, and opportunities to discern reef fishery impact.

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Navassa Island is a tiny (5 km²) uninhabited US protectorate located between Jamaica and Haiti. The shallow reefs of Navassa (<23m), have high live coral cover (range 20 - 26.1 %) and a high degree of architectural complexity which is particularly valuable as reef fish habitat. Despite its remoteness, an active artisanal fishery (primarily via traps and hook and line) carried out by Haitians is the primary mode of human impact on Navassa reefs. This fishery is unregulated. Even so, shallow reef fish communities exhibit high density (range 97 - 140 fish/60m²) and retain representation by large snapper, grouper, and herbivores which are largely lacking in nearby Caribbean locations with high fishing pressure. Given the apparently small impact that artisanal fisheries have yet had on Navassa reef communities, Navassa may

present a rather unique opportunity to study the ecological functioning of a trophically intact Caribbean reef. When/if fishing pressures increase, it may be possible to resolve at what levels of artisanal fishing intensity that adverse impacts on the reef community become evident, information that would be of utmost value to reef management.

Life-history of the knobbed porgy, *Calamus nodosus*, on the continental shelf of North Carolina and South Carolina

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The knobbed porgy, *Calamus nodosus* (Sparidae) ranges from North Carolina to Campeche Bank, Mexico. This research documents life-history characteristics of *C. nodosus* off the North Carolina and South Carolina coasts. Approximately 100 fish per month were sampled from fishery-independent and fishery-dependent sources. Sectioned sagittae were used to determine ages, with periodicity of growth increments validated by marginal increment analysis. Presumed ages ranged from 3 to 20. No bias in growth was evident between fishery-independent and fishery-dependent samples. The von Bertalanffy growth model fitted to observed lengths-at-age was $L_{age} = 324 [1 - e^{-0.2117 (t + 4.285)}]$. Sex and maturity stage were determined using histological preparations of gonad tissue. The sex ratio was exclusively female at sizes <275mm FL, and 89% male at sizes >351mm FL. Histological evidence of sex transition was seen in fish between 265mm and 351mm FL, and between ages 4 and 16. All fish greater than 297mm were mature. Spawning occurs in April through July. A thorough assessment of the life-history parameters of *C. nodosus* will enable the South Atlantic Fishery Management Council to more effectively manage this species.

Distribution, diversity and habitats of fishes on the continental shelf and upper slope of the South Atlantic Bight, USA

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Demersal fishes were sampled between Cape Hatteras and Cape Canaveral by trawl and trap in depths of 11-293 m from 1973 to 1999. I examined the data for long-term trends in biomass, abundance and diversity of economically valuable and ecologically dominant species occurring along the continental shelf and upper slope. Spatial distributions of these fish were mapped using GIS to visualize trends prior to statistical analyses. Mid-shelf depths (20-40m) were expected to have the highest levels of fish biomass, abundance and diversity due to increased productivity, thermal stability, and better reef development relative to shallower and deeper regions. This was true for the abundance of economically valuable species caught by traps directed at reef habitats (Kruskal Wallis, $p < 0.0001$); however, not the case for the abundance and biomass of those species caught by trawls directed at a variety of bottom types. Differences between mean catches were also analyzed by such parameters as year, location,

temperature, salinity and bottom type. Historical data and this type of long term trend analysis for fishes in the SAB have been lacking. Analysis of areas that have historically supported higher diversity and biomass of fishes might be useful in the development and management of marine protected areas.

The attraction of age-0 and age-1 red snapper, Lutjanus campechanus, to artificially placed shell plots.

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In 1998 and 1999, we built 30 - 4 m² reefs of shell and 30 - 4 m² reefs of shell/concrete blocks at depths of 17 to 21 m, in the Gulf of Mexico, 14 to 25 km south of Dauphin Island, Alabama. For these years, there were 3 sites, 20 reefs each, placed at 20 m intervals. Sites 1 and 2 were centered around gas platforms, while site 3 was placed at least 500 m away from any other structure. Also, in 2000, we tested the effect of plot size on number of red snapper recruits. We built 10 - 4 m² and 10 - 9 m² shell plots. Mean counts for all red snapper, Lutjanus campechanus, were significantly different between reef types and years: 3.5 fish m² block, 4.8 fish m² shell in 1998; 5 fish m² block, 5.5 fish m² shell in 1999, 24 fish m² for both 2x2 and 3x3 m shell reefs in 2000 (P < 0.05). Separated into age-0 and age-1 year classes, few age-0 red snapper were observed in July, while age-1 were common. Age-0 red snapper reached counts up to 113 fish/reef in August 1998, and 216 fish/reef in August 1999, and 549 fish on a single 3x3 m reef in 2000. In 1998, age-0 fish were significantly more abundant on shell reefs, but in 1999 age-0 fish showed no significant differences between reef types. For all three years, age-1 fish were significantly more abundant on block reefs. In 1998, fish were significantly more abundant at site 1, but in 1999 fish were significantly more abundant at site 2. In 2000, we observed significantly more age-0 red snapper at site 3 (no gas platform) compared to sites 1 and 2 (with gas platforms). Also in 2000, we observed the same number of age-0 red snapper on the small sized 2x2 m reefs (24 fish m²) compared to large size 3x3 m reefs (24 fish m²). These results suggest that artificial shell reefs may attract young red snapper away from areas of intensive trawl fishing. Reef size did not effect the number of fish per m², thus scaling up may be possible. However, numbers were reduced around gas platforms, were predation may reduce there effectiveness as trawl mortality refuge.

Yield per recruit and spawning potential ratio: a simulation with red grouper

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In the southeastern United States, reef fisheries are managed by controlling the age of entry to the fishery in order to avoid growth and recruitment overfishing. Minimum sizes are selected to obtain a high yield per recruit and maintain the spawning potential ratio over a target level (usually 30%). In general standard YPR and SPR models do not take into consideration the complex life history traits present in most reef fish species. This paper details a YPR and SPR

model that includes sex change, growth spurts after sexual transition, age specific fishing and natural mortality, and recruitment failure due to sperm limitation or social disruption. The model also allows partial recruitment to the fishery, in addition to catch and release mortality. Stochastic components were added to the model parameters, and YPR and SPR for different combinations of fishing mortality and age of entry were estimated using Monte Carlo simulations. As an example, this model was run using updated information on the life history of the red grouper (*Epinephelus morio*). The results were compared with YPR and SPR estimations using standard models.

Population structure of red grouper, *Epinephelus morio*, and black grouper, *Mycteroperca bonaci* in the western Atlantic, as determined by microsatellite DNA analysis

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Red grouper, *Epinephelus morio*, and black grouper, *Mycteroperca bonaci*, are economically important species that, like other members of the Snapper-Grouper Complex in the southeastern U.S., are heavily exploited by commercial and recreational fishers. Life history characteristics such as slow growth, late maturity, and protogyny render them particularly sensitive to fishing pressure. The purpose of this study was to investigate the genetic population structure of red and black grouper using a particularly sensitive genetic marker. Results were expected to differ between the two species, based upon differences in life history traits.

Similar to other grouper population studies, these data indicate little genetic structuring among black or red grouper over broad geographic distances. Low overall genetic variation, larval dispersal, and inadequate time since separation may contribute to the genetic homogeneity within this region. Black grouper from Bermuda did show weak genetic differentiation, which may be a result of geographic distance or of past intensive harvests. Heavy fishing effort does not seem to have drastically modified catches or sex ratio in red grouper. The results from this study indicate that, although black grouper may be more sensitive to exploitation, population structure of both species have probably not yet been seriously altered by fishing pressure.

FISH ATTRACTION DEVICES (FADS): SCIENCE AND MANAGEMENT ISSUES

Deepwater Development Structures

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Deepwater leasing activities in the Gulf of Mexico have expanded rapidly in the last few years. Currently, the Gulf of Mexico has approximately 7,600 active leases – about 48 percent of these (about 3,650 leases) are in deepwater (1,000 ft or more of water depth). Only a portion of these deepwater leases will be drilled and explored. If commercial quantities of recoverable hydrocarbons are discovered through drilling activities, deepwater structures may be emplaced. These deepwater structures will reside on the OCS for the “production life” of the field – maybe 5 to 20 or more years. The deepwater structures may also serve as fish aggregating devices in the Gulf.

This paper will explain the current types and characteristic of the Gulf of Mexico's deepwater development structures including

- Bottom Supported and Vertically Moored Structures
- Fixed Platforms
- Compliant Towers
- Tension Leg Platforms
- Mini Tension Leg Platforms
- Floating Production and Subsea Systems
- Spar Platforms
- Floating Production Systems
- Floating Production, Storage, and Offloading Systems
- Subsea Systems
- Pipelines, both in-field and export/right-of-way, will be briefly discussed
- The concept of “host facilities” will be introduced. Graphics will depict the location of existing deepwater structures, proposed or projected deepwater structures, and subsea developments

Deepwater petroleum structures in the Gulf of Mexico – Assessment of their potential to function as fish aggregating devices (FADs)

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In view of recently accelerating deployment of petroleum structures in deep waters (>1,000 ft) in the northern Gulf of Mexico (GOM), the Minerals Management Service (MMS) recognized the potential for such structures to act as FADs. In order to allow assessment of this potential, we have researched and organized existing information and literature on FADs and on GOM highly migratory species (HMS) into an annotated, key worded, bibliographic database. This very large body of diffuse information has been reviewed and analyzed. It is being synthesized to provide MMS with a scientific basis for predicting and understanding potential impacts of deepwater structures on HMS. The existing body of information and literature clearly documents the importance and large impacts of FADs on fish and fisheries around the world. Extrapolation to the GOM from literature on FADs elsewhere indicates that yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*) and skipjack (*Euthynnus pelamis*) have high potential to be impacted. However, detailed predictions of FADs effects of GOM deepwater structures cannot be made from existing literature. It is likely that direct studies of fish aggregations around various types of deepwater petroleum structures will be needed.

The fishery for tunas associated with flotsam and FADs in the eastern Pacific Ocean

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Since its inception, the purse-seine fishery for tropical tunas in the eastern Pacific Ocean has obtained substantial portions of its catches from sets on flotsam and on fish-aggregating devices (FADs) placed by the fishers. Many other fisheries, both commercial and recreational, also utilize a variety of floating objects to find their target species. This paper describes the tuna fishery with respect to its evolution, the location, the techniques employed, and the catches and by-catches, and also the characteristics of the flotsam and FADs. This mode of fishing has increased considerably in recent years, and it is currently being regulated with temporal closures. Fishing on anchored FADs is not currently practiced in the EPO, but some coastal nations have plans to develop this type of fishery.

Questions about the association of tunas and other species with floating objects

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Several hypotheses have been offered to explain the association of tunas and other species with floating objects in the world oceans. These are reviewed, in an attempt to assess which ones best explain the association of tunas with floating objects. The emphasis is on experimental approaches that could shed light on the remaining alternatives. Besides the adaptive value of the association, it is also important to address other issues that should help in understanding the ecological and behavioral responses to the floating objects: How are the objects detected/found? Are all objects attractive? What is the residence time under an object? Are there diel changes in the association? Is there fidelity to individual objects? Why do some species or sizes associate with floating objects, while others do not?

Fish and FADs: A Review of the Influence of FADs on the Movement and Distribution of Pelagic Fishes.

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The state of knowledge of the influence of anchored FADs on the behavior and distribution of pelagic fishes (predominantly tuna) will be reviewed. Various techniques have been employed to investigate the influence of FADs on fish behavior. These methods include gut analyses, tag-and-recapture experiments and sonic tracking. Tag-and-recapture experiments are demonstrating that FADs can have a very strong influence on the movements of tuna (and on fishing effort) on a regional level. Sonic tracking has taken two forms; active tracking of animals equipped with transmitters and passive monitoring of fish movements by data loggers placed on the FADs. In the former case, tracking vessels are used to follow individual fish and continuously monitor their horizontal and vertical movements - both when they are near a FAD and when they move away. Passive monitoring can elucidate the long-term revisitation patterns of tuna and also possibly give indication of school cohesion and longevity. Current data will be discussed in terms of possible pertinence to Gulf of Mexico fisheries.

Tuna Fishing and Fish Aggregating Devices

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The international symposium "Tuna Fishing and Fish Aggregating Devices", October 1999, in Martinique, takes stock of the exploitation of large pelagic fish around FADs, based on regional

synthesis for the three oceans and the Mediterranean Sea. Main themes included technology, fishing methods, impact on resources, biology of fish aggregation, anthropology and economic aspects of FAD exploitation. These meeting gathered results from recent and ongoing studies on FADs in different oceans of the world, enhanced collaboration between scientists and managers involved in the development of FADs, promoted the emergence of scientific and technical research and formed a first network for cooperation on this topic. This communication resumes the main discussions and results of this worldwide consultation on FADs purposes.

Integrated Statistical Models of Tuna Movement in Relation to Fish Attractors.

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Integrated statistical models combine theoretical models of biological processes with statistical models of the observational errors in measuring the dependent variables in the process model. Three classes of integrated statistical models will be presented — compartment models, advection-diffusion-reaction models, and state space Kalman filter models. The data requirements, expected output and possible interpretations of each class of model will be presented with examples of application for the analysis of tuna tagging data. The applicability of these models to the study of the movement of pelagic fish in relation to deep water rigs.

Tuna in the Gulf of Mexico

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A general overview of tuna biology, ecology and fisheries in the Gulf of Mexico will be presented, with emphasis on yellowfin (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) tuna, species known to associate with fish aggregating devices (FADs). In the context of considering potential impacts on fish populations and fisheries by the presence of FADs, the current state of knowledge regarding various aspects of tuna biology and fisheries will be discussed, as well as some potentially important areas where more information is needed. Recent results from studies regarding yellowfin abundance trends and spawning in the Gulf of Mexico will be presented. The potential impact of FADs on stock assessments will also be discussed, with reference to recent Atlantic tuna assessments.

Petroleum Platforms in the Northern Gulf of Mexico: Deepwater Structures as Fish Attracting Devices (FAD) for Pelagic Fishes

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Petroleum platforms in the northern Gulf of Mexico (NGOM) comprise one of the largest FAD (fish aggregating device) arrays in the world, attracting surface and midwater pelagic fishes. Petroleum platforms influence pelagic fishery resources and are an important component of the northern Gulf's commercial and recreational fishing industries. Among the numerous pelagic fishes attracted to offshore NGOM platforms are *Rachycentron canadum*, *Seriola dumerili*, *Scomberomorus cavalla*, *Decapterus punctatus*, *Coryphaena hippurus*, *Acanthocybium solandri*, *Thunnus albacares*, and *Thunnus atlanticus*. The role of offshore NGOM platforms as FADs for pelagic fishes is examined, and possible mechanisms for the attraction of pelagic species to platforms are explored. Potential interactions/interrelationships between "deepwater" (300 - 1,550 m) platforms and pelagic fishes (predators and forage species) are discussed. Deepwater platforms provide new opportunities for the study of pelagic species to better understand their life history, ecology, behavior, and habitat requirements in the Gulf of Mexico.

Cold-core eddies, the Loop Current and larval tuna; a preferred spawning and nursery habitat?

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Bluefin tuna, *Thunnus thynnus* and other scombrids spawn in the Gulf of Mexico in late April, May, and into early June. The relationship between larval bluefin tuna and thermal fronts has been established through previous studies, while an assessment of eddies and their associated fronts as spawning and nursery habitat has not been undertaken. In 1995 we began a three year effort in the eastern Gulf of Mexico to examine the influence of these eddies and the Loop Current on the distribution of scombrid larvae. Preliminary results indicate that scombrid larvae were located in the upper 25 meters, and were most abundant near the cold-core ring - Loop Current interface. Understanding the dynamics of scombrid spawning habitat is difficult in view of the scale and variance in inter- annual and decadal circulation patterns in the Gulf of Mexico, and our efforts are far from complete. However, we are concerned that offshore oil structures acting as FADS could disrupt this spawning behavior by concentrating bluefin in non traditional spawning sites. This would not only increase their vulnerability to longline and recreational fishing gear, but could lead to greatly increased larval mortality as well.

Gulf of Mexico petroleum and gas rigs as FADs for sharks and rays

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Offshore petroleum and gas structures can function as attracting devices for a variety of marine species, including elasmobranchs (sharks, skates and rays). Sharks and rays may use these structures as refuges, as core areas for daily activities, and as sources of food, both natural and anthropogenic (bait, offal). In the shallow depths surrounding these structures in the Gulf of Mexico, sharks such as the silky shark (*Carcharhinus falciformis*), scalloped hammerhead (*Sphyrna lewini*) and whale shark (*Rhincodon typus*) and rays such as the spotted eagle ray (*Aetobatus narinari*) and the Atlantic manta (*Manta birostris*) are often observed. Some pelagic elasmobranch species, such as the silky shark, appear to use these structures as core areas for juvenile stages. In the deep waters surrounding the structures (>1000 ft), species of deepwater sharks such as sixgill sharks (*Hexanchus* spp.) and large deepwater dogfishes (*Centrophorus* spp.) have been observed by ROV-mounted video cameras deployed from the rigs. The implications of these various observations will be discussed in reference to the emerging trend of deeper petroleum and gas rigs in the Gulf of Mexico.

Now It Can Be Told: 5 Long Years of Deepwater Surveys Around the Oil Platforms of Southern California

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Beginning in 1995, we have been conducting surveys, using an untethered research submersible, of the fish assemblages of seven oil and gas production platforms and numerous natural reefs in southern California. Thirty-five species of rockfishes (*Sebastes* spp.) form the dominant taxa over both artificial and natural structures; they comprise over 90% of all fishes by both number and biomass. There are three distinct fish assemblages around platforms: 1) midwater, 2) near-platform benthic and 3) the shell mound surrounding the platform. Young-of-the-year (YOY) rockfishes predominate in the midwater, subadult and adult rockfishes are found near the bottom and a separate suite of YOY rockfishes live on the shell mound. Because the midwater assemblage depends on YOY rockfish recruitment strength, it exhibits strong annual variability, depending on ocean conditions. The near-platform benthic assemblage appears to be more stable. There is some evidence that platforms both produce and aggregate fishes, depending on species.

Potential interactions between pelagic longline fishing and deepwater oil gas structures in the Gulf of Mexico.

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The fishing and offshore energy industries have coexisted and developed amicably for many years in shelf waters of the northern Gulf of Mexico. Recently, the offshore energy industry in the Gulf has shifted its interest beyond the shelf and into deep waters (>200 m). Currently there are over 3,500 active leases and 48 development/production facilities in water depths greater than 200 m. Deepwater oil and gas structures include fixed platforms, sub-sea completions, moored floating structures, and dynamically positioned ships. These surface-piercing structures represent obstacles to passively drifting longlines. The longline fishery targets yellowfin tuna and swordfish. From 1994 to 1998 permitted longline vessels made over 4,000 sets per year with an average length 37 miles of main line per set. Spatial distribution of longline sets and catches of major species for 1994 to 1998 period were plotted. These plots were compared with the location of current and future oil and gas structures to identify potential problem areas. Field observations around deepwater structures indicate that tuna, dolphin, and wahoo are attracted to deepwater structures.

ASSESSMENT OF ECOLOGICAL HEALTH

A rapid bioassessment technique for warmwater streams impacted by acid mine drainage in north Alabama

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Over 587 km of north Alabama streams in the Warrior coal field (Warrior and Cahaba river basins) have been degraded by acid mine drainage (AMD) released from abandoned, unreclaimed mines over the last 100 years. Restoration is ongoing at several sites. Our long-

term research at one restoration site (> 4 years) is addressing recovery of aquatic fauna (i.e., after implementation of restoration) in an AMD impacted stream (Black Branch) and in the toxic mixing zone that is present at and below the confluence of Black Branch and a pH neutral stream (Cane Creek). Our long-term macroinvertebrate community and water quality data at these sites characterize various levels of AMD impact and are therefore being used to develop a rapid bioassessment technique (RBAT) to locate, identify, and characterize other streams in the Warrior and Cahaba watersheds that may be impacted by AMD. Metrics used in our RBAT include; pH, alkalinity, conductivity, sulfate and concentrations of Al and Fe. Other metrics are taxa richness, diversity, and the percent of the community comprised by various taxa (e.g., % *Corbicula*). Our RBAT will be used to prioritize sites for reclamation and is the first for warmwater AMD impacted streams.

A Preliminary Assessment of the Ecological Health of Three West Georgia Piedmont Streams Using Fish Assemblages

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Carroll County is a rural county of approximately 83,000 people located 45 miles west of Atlanta and 90 miles east of Birmingham Alabama. Carroll is the heart of west Georgia and forms the western boundary of metropolitan Atlanta. The waters in the county flow either into the Tallapoosa / Coosa or the Chattahoochee / Apalachicola River Basins. In light of the ever increasing demand for water due to the urbanization of this region, current drought conditions and on going water negotiations by the tristate region, it is imperative that the biological diversity and ecological health of these streams be assessed before any further degradation can occur. Consequently, three streams were selected based on their potential for future degradation. Whooping Creek and Snake Creek, tributaries of the Chattahoochee River are targeted for reservoir construction. Buck Creek, a tributary of the Little Tallapoosa River is currently the recipient of waste water treatment and emergency water withdrawal. All three creeks were sampled during July/August 2000 and again during October/November 2000 using standard electrofishing techniques. Biodiversity, fish distributions, index of biotic integrity scores and an overall assessment for these three systems will be presented.

Detecting Agricultural Animal Waste in Stream Food Webs using Stable Isotope Techniques

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Carbon, nitrogen, and sulfur stable isotope ratios of stream water, sediments, and riparian and aquatic biota were compared to those of swine and poultry waste to evaluate the potential application of stable isotopes to detect agricultural animal waste entry into stream food webs. Water, sediment, plants, invertebrates, and fishes were collected during June and October, 1997, from two small Arkansas Ozark streams that were similar in all respects, except that agricultural land use (pasture) over one watershed was approximately double that of the other.

Water quality assessment confirmed that water ionic content, nutrient and bacterial concentrations, and nutrient and other material loadings were substantially higher in the more agricultural stream. A stable isotope ratio could be a functional tracer of elements derived from animal waste if two criteria were met: (1) isotopic compositions of water, sediment, or biota were distinct between streams; and (2) the difference could be explained by incorporation of isotopes from animal waste. Nitrogen and sulfur isotope ratios met the first criterion, but the nitrogen isotope ratio was the only one examined that met both criteria, and thus offers the best potential as a functional tracer of agricultural animal waste into stream food webs and ecosystems.

Hierarchical models for ecological inference at multiple spatial scales

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Natural resource management requires an understanding of both large and small-scale ecological processes. Consequently, fish biologists are increasingly relying upon models to predict the distribution or abundance of fish populations and to examine the effect of environmental or anthropogenic impacts on those populations at multiple spatial scales. The accuracy of these predictions depends, in part, on the development of rigorous statistical models using data that are often hierarchically structured, such as stream reaches nested within watersheds. In these instances, the use of traditional modeling techniques is usually inappropriate. Using data from the Pacific Northwest, we compared different approaches to predicting the distribution and abundance of two stream-dwelling salmonids using landscape- (watershed) and reach-level (study reaches) information. Watersheds (mean = 7800 ha) were characterized using a set of covariates describing physiography, vegetation, and current land-use. Stream reaches (mean = 85 m long) were characterized using covariates describing stream size, longitudinal position, and physical habitat. The models included simple linear and logistic regression with sample units treated as independent observations and 2-level hierarchical linear and logistic models in which study reaches were nested within watersheds. The accuracy of model predictions was assessed via leave-one-out cross-validation. In general, the simple linear and logistic regression model coefficients were biased to varying degrees and their precision was misestimated, which resulted in an overestimation of the statistical significance of landscape and reach-level characteristics. In contrast, the hierarchical models proved to be more accurate and provided ecological insight through partitioning the variance and covariance components among levels.

Characterizing Fish Assemblage Composition at Large Spatial Scales: How Much Sampling is Enough?

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Increasing knowledge and concern for fish movement, regional (large-scale) influences on communities and large-scale shifts in distribution and abundance of valued and invasive species, promote sampling and model building at large spatial scales. Sampling adequacy is a major concern in fish-habitat relations and monitoring studies. Inadequate sample size or representation of environmental conditions can contribute to inadequate model performance and impact assessment. Excessive sampling diverts limited funds and efforts from other worthy projects. This project's goals are to develop, describe and evaluate a method of assessing sampling adequacy at large spatial scales. We used bootstrapping and nonlinear models to calculate species accumulation curves for stream fishes at selected spatial scales covering most of Virginia. Data were collected from a Virginia Department of Game and Inland Fisheries database. Our results indicate that while species richness and number of sample sites in a region are positively correlated with the calculated number of samples required, the dispersion of species among samples primarily determines the number of samples required and few regions in Virginia are adequately sampled. We are currently identifying environmental variables to stratify sampling and reduce the number of samples required while maintaining coverage of environmental variation and species collected.

DAM REMOVAL ISSUES IN THE SOUTHEAST

Use of Net Environmental Benefits Analysis to Evaluate Dam Decommissioning in Hydropower Licensing

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A Net Environmental Benefits Analysis (NEBA) approach offers a powerful set of tools for valuing and comparing the natural resource benefits of alternative actions in Federal Energy Regulatory Commission (FERC) licensing of non-federal hydroelectric projects. Significant, often contentious resource issues in hydropower licensing have included the effects of project operations on instream flows for riverine habitat and recreation, upstream passage for migratory fishes, fish entrainment mortality, and water quality. Many dam owners are pursuing cooperative efforts with stakeholders through FERC's alternative licensing process to reach agreement on key issues. At the same time, public debate escalates over dam decommissioning as an alternative to relicensing existing projects. The difficult challenges posed by relicensing

compel all participants in the process to seek new, more effective ways to obtain agreements that optimize net environmental benefits to the public, while recognizing the need for tradeoffs between power benefits and environmental enhancement. NEBA provides a scientifically credible, agency-proven framework for evaluating and ranking alternative enhancements or actions, including dam removal, in terms of greatest net environmental benefit. NEBA uses environmental metrics to measure change in ecological services from the site under alternative actions compared to the baseline condition. Combining the results of NEBA with an assessment of costs of the alternative actions shows which alternative(s) provide the best solution for achieving resource management goals and objectives. NEBA facilitates agreements by demonstrating that the public receives a net environmental benefit, while avoiding unnecessarily costly or ineffective environmental measures.

New Savannah Bluff Lock and Dam Removal- a Biological and Ecological No Brainer

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The New Savannah Bluff Lock and Dam at river mile 187.3 represents the first blockage to migratory fish on the Savannah River. Historically, some anadromous species ranged 384 miles inland to the headwaters of the Savannah to spawn. Besides blockages of migratory pathways, riverine habitat and physical processes in the Piedmont section of the Savannah River have been heavily affected by conversion of the Piedmont into a series of large reservoirs. Only approximately eight miles of Piedmont habitat remains on the mainstem Savannah (the Augusta Shoals) and it is affected by river regulation and withdrawals into the Augusta Canal, a four mile bypass of the natural river channel. In light of anadromous fish stock declines from historic levels, an interagency plan to reopen access to 37 miles of historic spawning habitat, the opportunity to restore cumulatively impacted Piedmont riverine habitat and an antiquated dam in a sad state of repair which no longer serves its authorized purpose, a dam removal decision seems obvious.

However . . .

NEW SAVANNAH BLUFF LOCK AND DAM -- The Complexities of Deciding the Future of an Old Structure

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The New Savannah Bluff Lock and Dam is managed by the Savannah District of the U.S. Army Corps of Engineers. Since commercial navigation hasn't used the lock since 1979, the Lock & Dam hasn't served its authorized purpose for over twenty years. The Corps is obligated to reduce its maintenance costs whenever it can, so it recently conducted a study to determine what should be done with this aging and deteriorating structure. As it evaluated the functions that the structure presently provides, the picture became more complicated. Industries now use the upstream pool as a source of water for their operations. Private residences line the shore of the upper pool, attracted by the waterfront view. Local governments have similarly placed public developments along portions of the shore. The community holds annual speedboat races on the stable pool, bringing visitors and their dollars to local businesses. On the environmental side, the higher stable water surface in the pool now supports wetlands

along the shore where they didn't exist before. The landside portion of the dam is highly used by fishermen. The area immediately upstream and downstream of the dam regularly attracts fishermen in boats, when no other boaters can be seen fishing that reach of the river. Regulatory discharge permits have been issued based on the pool being there. Yet removal of the structure would provide substantial benefits to fisheries by removing an impediment to migratory pathways and restoring the free-flowing character of a piedmont river. What initially appeared to be an easy decision – What to do with an old, deteriorating, structure that is a financial burden and no longer serves its authorized purpose – quickly became complicated. Savannah District struggled through its evaluation and has forwarded its recommendation to Atlanta on the way to Washington and the U.S. Congress. What will the ultimate decision be? Stay tuned ...

The Case for Removing Rodman Dam

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Rodman Dam, also known as Kirkpatrick Dam, was completed in 1968 as part of the now-abandoned Cross Florida Barge Canal project (CFBC). Situated on the Ocklawaha River, the largest tributary of the St. Johns River, the dam impounds 16 miles of river channel, floods over 9,000 acres of floodplain forest, and inundates approximately 20 natural artesian springs and spring runs. It serves no official or practical purpose for flood control, water supply, or power generation. The dam acts as a barrier to the free movement of fish and manatees from the St. Johns River to over 60 miles of upstream riverine habitat, and is a significant source of mortality to manatees. The impoundment, Rodman Reservoir, displaces thousands of acres of important wetland habitats, disrupts terrestrial wildlife movement along and across the river corridor, and all but eliminates important nutrient transfer from the Ocklawaha River watershed to the St. Johns River. Although the impoundment serves as a popular fishing area, provides open water wildlife habitat, and removes anthropogenic pollutants from upstream sources, it does so at a tremendous economic, ecological and environmental cost. Because these costs far exceed the benefits of the impoundment, the dam should be removed and the free-flowing Ocklawaha River restored.

Rodman Reservoir: "To Be or Not To Be," that is the SAME question.

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The Rodman Reservoir Complex includes the old Ocklawaha river and associated flood plain forest above and below the reservoir, a transitional wetland system and an open water pool totaling almost 9,000 acres of aquatic habitat. Many proponents of Oklawaha River restoration state that Rodman Reservoir is a weed choked dying system with little or no aquatic life that is used by only a handful of largemouth bass anglers. They also suggest that Rodman Reservoir is expensive to maintain and that a free flowing Oklawaha river would cost the State of Florida nothing. Proponents of the reservoir suggest that the system offers citizens of the state of

Florida a wealth of recreational activities including but not limited to; camping, canoeing, power boating, fishing, hunting and bird watching. They further suggest that these activities make the Rodman Reservoir Complex one of the most used recreational areas in Florida and with this use an economic benefit to the state. These and other statements about Rodman Reservoir will be examined in this paper.

Anadromous Fish Passage in Virginia – Dam Removal and Fishway Construction

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As a signatory of the Chesapeake Bay Agreement, Virginia provides fish passage for anadromous fishes by removing impediments or constructing fishways. Several dams in the fall zone of the James River at Richmond were either breached or notched. Boshers Dam, last in the fall zone, was recently retrofitted with a vertical slot fishway because removal was not feasible. After almost 200 years access to 137 miles of historical spawning habitat has been restored. American shad passage success is annually monitored by the VDGIF. Owned by Fredericksburg, Embrey Dam (1910) on the Rappahannock River was formerly used as a water supply but is now obsolete, as is the 1853 crib dam that is submerged behind Embrey. In 1998, a VDGIF feasibility study provided several options with removal yielding the best cost:benefit ratio. Entrapped sediments are non-toxic and, although the dam is historical, removal would be allowed. The VDGIF, the owner, the county, and the U.S. Army Corps of Engineers are currently in year three of a three-year feasibility study to further develop plans for removal. So far the new study has ruled out fishway construction and reconfirmed original sediment toxicity studies. Additional sediment fate transport models closely resemble previous studies and provide additional insight. Major issues include watering the historical canal and sediment release and/or pre-removal dredging, as well as the seasonal timing of removal. Significant politicians are working toward full federal funding of deconstruction and are hoping for a start date in 2002. In anticipation of providing passage, anadromous fish runs are monitored annually by the VDGIF to establish a pre-removal database. Post-removal fish passage evaluation plans are being developed.

Comparison of spawning migrations for striped bass and American shad before and after dam removal

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Habitat loss is considered to be a key reason for historical declines in anadromous fishes. In the Neuse River in eastern North Carolina, our telemetry studies established that the low-head Quaker Neck Dam at river kilometer (rkm) 225 limited the spawning migrations of striped bass and American shad. Most spawning for both species was observed 0-2 km downstream of the dam, at sites characteristic of river reaches upstream of the dam (shallow with larger substrates). After the dam was removed, 12 of 22 telemetered American shad migrated into the restored habitat, compared to 15 of 23 telemetered striped bass. The maximum distance migrated upstream was greater for striped bass (302 rkm in 1999, 316 rkm in 2000) than for American shad (241 rkm in 1999, 282 rkm in 2000). Neither species reached the next dam located at rkm 344. Both species moved further upstream in 2000 than in 1999 due to higher spring flows. The primary spawning site for American shad after dam removal was an area of larger substrates (gravel, cobble, boulder) at rkm 239. Close correspondence between spawning sites and metavolcanic rock formations suggests that GIS approaches can be used to predict spawning habitat gains from dam removal.

Fish passage implementation and habitat restoration in the Susquehanna River Basin, Pennsylvania, through the removal of non-beneficial, low-head dams

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The Pennsylvania Fish and Boat Commission (PFBC) is reversing impacts of impounding rivers and streams and restoring lotic habitat through removal of non-beneficial, low-head dams. Facilitating the process, a permit waiver procedure adopted by the Pennsylvania Department of Environmental Protection makes it easier and more affordable to remove undesirable dams. Since 1995, over fifty dams have been removed; dozens of additional removals are planned. Most removals have occurred within the Susquehanna River Basin where funding from the United States Environmental Protection Agency's Chesapeake Bay Program is available for fish passage and stream habitat restoration as part of efforts to restore diadromous fish. Benefits of removing dams include: elimination of fish migration barriers; elimination of public safety and property hazards; reduced liability for dam owners; stream ecosystem restoration; reduced watercraft portage; and elimination of the construction and maintenance of fishways. Gaining support for projects is a challenging task because it requires changing core values, beliefs, and attitudes of the public regarding the damming of waterways. This presentation outlines the

PFBC=s Consultation and Grant Program for Fish Passage and Habitat Restoration, the dam removal process in Pennsylvania, and potential obstacles and concerns pertaining to dam removal project implementation. Information provided may be beneficial to dam removal projects of similar scope. A qualitative overview of pre and post dam removal projects will also be provided.

FISH EARLY LIFE HISTORY

Exploring the importance of larval density to recruitment success of white crappie.

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Variability in white crappie recruitment is common throughout North America. In Ohio, we are sampling multiple life history stages (e.g., eggs, larvae, juveniles, and adults) of white crappie in 8-12 reservoirs over 3 years to evaluate when recruitment (defined as survival to age-1) is set. Here, we explore mechanisms regulating larval density. First, we determined whether population fecundity, measured as the total number of eggs produced, or egg quality, measured as mean caloric density of ovaries, was related to the number of crappie larvae hatched. We also evaluated how abiotic factors, such as reservoir discharge and elevation, relate to production of larvae. Finally, by assessing whether density of larvae relates to catch per effort (CPE) of age-1 white crappie, we determined if reservoir characteristics before hatch or adult characteristics influence recruitment success. From our preliminary analysis, population fecundity and winter and spring reservoir elevation were unrelated to density of white crappie larvae. Egg quality has not yet been estimated. 1998 larval density was unrelated to 1999 CPE of age-1 white crappie (N=12 reservoirs). Thus, recruitment of white crappie in Ohio reservoirs appears to be set sometime beyond the larval stage.

Management of Tennessee walleye populations suffering chronic recruitment problems

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Fishable walleye populations exist in many tributary storage impoundments in Tennessee; however, most are maintained by a fingerling stocking program. Although two reservoirs supported wild populations through the mid- 1990s, recruitment has declined in one reservoir and there is concern that recruitment might fail in the other reservoir. Poor recruitment has

been linked to the invasion of alewives, which can compete with juvenile walleyes for prey, or prey on them directly. However, recent evidence from the Great Lakes indicates walleye fry may be suffering mortality due to a thiamine deficiency due to alewife consumption by adult walleyes. To test this hypothesis, we spawned 28 walleyes from three reservoirs with different alewife densities and measured fertilization rates, hatch rates, and thiamine concentrations in the females. Mean fertilization rates and hatch rates were low (46 and 29, respectively), and both rates tended to vary positively with thiamine concentrations, as expected. However, these rates did not vary with alewife density. Subsequent assays of gizzard shad and threadfin shad revealed high levels of the enzyme responsible for degrading thiamine, which had not been documented previously. If adult walleye diets are contributing to poor reproduction, factors other than alewife consumption are also involved.

Abundance and Distribution of Larval Fish in a Hydroelectric-Peaking Project Tailwater

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Douglas Dam on the French Broad River, Tennessee, operates primarily as a peaking hydroelectric facility; as a consequence, the tailwater elevation fluctuates > 2 m on a daily basis. To determine if these harsh conditions affected the spawning success of the diverse fish fauna, we sampled for larval fishes from April through August 2000. On a biweekly basis, we used drift nets, towed nets and light traps to collect samples at three fixed stations (5, 29, and 48 km below the dam). In all, we collected 489 larvae of 29 species. Species richness was lowest (14 species) at the most upstream site and was greatest (24 species) at the middle site. Larval catches were dominated by percids (73%). Although 63 species are known to occur in the tailwater, juvenile fish of many species were rare or absent in electrofishing samples collected in 1999. In general, species composition of our larval fish collections was similar to the occurrence of juveniles in 1999. During periods of generation, little suitable habitat (backwaters and other velocity refugia) is available for larvae and juveniles. The absence of larvae of many species in our catches suggests that the tailwater populations of adult fishes are maintained by immigration.

Growth and Survival of Larval Suckers (*Moxotoma* spp.) Exposed to Pulsed, High-Water Velocities

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Pulsed, high water-velocities that are characteristic of hydropower generating dams create an unnatural flow regime detrimental to riverine fishes. This study examined the effects of 0-hour, 4-hours, and 12-hours of pulsed, high water-velocities on the hatch length, final length, and overall survival of larval robust redhorse (*Moxostoma robustum*) and silver redhorse (*M. anisurum*) suckers. Twelve 38.0-L aquaria were modified and used to simulate pulsed, high-water velocities (> 35cm/s) and stable, low-water velocities (< 10 cm/s) each day for 38 days. Water quality (e.g., temperature, dissolved oxygen, zooplankton density) was maintained equally across all treatments. Fertilized eggs were placed in gravel nests in each aquarium. Mean larval lengths at 24-hours post-hatch were similar among treatments for both robust redhorse and silver redhorse (ANOVA; $P > 0.05$). Mean final length in the 0-hr treatments was longer than lengths in the 4-hr and 12-hr treatments (ANOVA; $P < 0.05$). Mean survival was highest in the 0-hr treatments, which was greater than survival in the 4-hr and 12-hr treatments for robust redhorse (ANOVA; $P < 0.05$), but not for silver redhorse (ANOVA; $P > 0.05$). Our results demonstrate potentially depressed growth and survival of larval suckers exposed to pulsed, high water-velocities that occur during hydropower generation.

Larval salinity tolerance in opossum pipefish, *Microphis brachyurus lineatus*

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The opossum pipefish, *Microphis brachyurus lineatus*, is a tropical amphidromous syngnathid. Adults live and breed in freshwater tributaries in specific emergent vegetative habitats. Juveniles associate with pelagic *Sargassum* communities in the tropical western Atlantic. Pouch released larvae face sharp salinity changes as they drift from freshwater tributaries to the ocean. We propose that the speed at which this transfer occurs is critical for larval survival. Two hundred-fifty aquarium released larvae were transferred from freshwater (0 ppt) to mesohaline lagoon water (18 ppt) and then to seawater (32 ppt) in two successive replicated experiments, over a two week period. Survival was highest when larvae were transferred from 0 ppt to 18 ppt within 48 h. When transferred from 18 ppt to 32 ppt, larvae that remained at 18 ppt had the highest survival. We conclude that complete passage from freshwater to the ocean must

occur at least 2 weeks after larval release. The ecological significance of the necessary retention in 18 ppt water is investigated for the East Florida opossum pipefish population. A 3-D numerical model of the Indian River Lagoon is used to visualize hydrographic conditions capable of larval retention.

FISHERIES MANAGEMENT: SOCIOECONOMIC CONSIDERATIONS

Florida Fishing Communities: Integrating Identification, Definition and Dependence

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With the implementation of the Magnuson-Stevens Fishery Conservation and Management Act of 1996, came a new National Standard that requires the evaluation of regulatory impact upon fishing communities. The paper is a follow-up report on research that uses GIS mapping software to identify fishing communities in Florida reported at the 1999 AFS meeting in Charlotte, NC. Utilizing zip codes to aggregate data, a spatial analysis ties together census and permit data to assist in identifying fishing communities. The paper also discusses a typology developed to categorize fishing communities and their dependence upon fishing.

Fishing Communities, Economics or Anthropology?: The Case of Madiera Beach Florida

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This paper describes the method and outcome of an economic assessment of the fishing community of Madiera Beach, Florida. Fishery law requires that consideration of the impact of regulation occur for fishing communities. Yet, we have little guidance from the literature on what, economically, constitutes a fishing community. Most of the work defining and describing fishing communities has been done in the anthropological literature. In this paper we use an industrial organization approach to identify the economic community reliant on fishing enterprises. In addition to the locations where the fish are landed, the locations where the fishermen live and dock vessels, we find that in this case, the community extends geographically into Pinellas County.

Civil Restitution Values and Methods Currently in Use by State Fish and Game Agencies

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In an effort to determine values currently used by state agencies in assessing civil restitution (CR) penalties, and to ascertain the methods used in determining said values, agencies with fish and game responsibilities were either contacted directly or the information obtained from their web sites. Data were tabulated for all species for which values were documented in each state, and descriptive statistics such as range, max/min, mean, and median were calculated for species with multiple observations. This paper presents the data obtained, an analysis of the descriptive statistics, and a brief discussion of the methods and source data used by the various states in calculating their CR values.

The Economic Effects of *Pfiesteria* in the Mid-Atlantic Region

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While significant amounts of research are currently being conducted to assess the biological, ecological and environmental effects of *Pfiesteria piscicida* and other harmful algal blooms (HABs), very little work has been conducted to look at the economic impacts or lost benefits due to *Pfiesteria* outbreaks or HABs. We report on the results from a 2-year Mid-Atlantic (North Carolina, Virginia, Maryland and Delaware) study of the economic impacts of *Pfiesteria* and HABs, on seafood consumption. The study consisted of a phone-mail survey of 2,000 Mid-Atlantic residents focusing on current seafood consumption patterns and reactions to harmful algal blooms, *Pfiesteria* outbreaks, and various education materials. Preliminary results suggest that localized *Pfiesteria* associated fish kills significantly decrease the demand for seafood over large geographic regions creating large short-term economic losses. Reducing consumer uncertainty in relation to the risks from a *Pfiesteria* outbreak significantly mitigates the negative consumption effects of an outbreak. Demand models of seafood consumption demonstrate that perceived reductions in risk associated with an outbreak can significantly lessen the economic losses during and after an outbreak. Public distribution of scientific findings regarding the risks associated with *Pfiesteria* can reduce demand uncertainty and consequently reduce the economic losses.

Management Implications of Market Segmentation of Virginia's Anglers

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We surveyed 5,378 anglers in Virginia to determine their characteristics, behaviors, motivations, attitudes, and opinions. Using cluster analysis, we segmented anglers based on level of specialization and found results similar to past studies. We also segmented anglers based on species preference. While anglers tended to agree on the importance of aesthetic reasons for fishing, major differences were observed in preferences and attitudes between anglers who specialized for different species. Black bass anglers generally sought large fish, rarely kept fish, and favored more restrictive regulations. Catfish, panfish and crappie anglers were highly consumptive and were opposed to most regulations. Preferences and attitudes varied widely among trout anglers, suggesting the need to further segment trout anglers based on the type of preferred fishery (stocked or wild). Angler groups also differed in their preferences for location characteristics, sources of information, reasons for fishing, and several demographic characteristics. Our results demonstrate the importance of understanding the diverse groups of anglers so that management policies can meet angler needs. Market segmentation based on species specialization provides an effective way to segment the angler population to better understand the desires and satisfactions sought by anglers.

Economic Analyses and Federal Mandates

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Economic analysis of the impacts of fisheries management regulations is fairly new to most fishery managers. Traditional management regimes often focus on adjusting biological parameters to achieve management goals. In most discussions, little attention is given to the economic analysis of the impacts of regulations. Various reasons have been provided for the lack of attention to the economic impacts of fishery management regulations. However, the tide has turned in recent times as management regulations increasing focus on devising methods to allocate fishery resources to various user groups once the biological parameters are set. This paper examines changes in federal mandates that require more in-depth consideration of the economic impacts of fishery management regulations and that make some of these impact assessments judicially reviewable. It discusses the recently revised National Marine Fisheries Service: *"Guidelines for Economic Analysis of Fishery Management Actions"* in terms of its utility and flexibility. Finally, some insight is provided on cooperative efforts between the National Marine Fisheries Service and other agencies to improve the quality of economic analysis for meeting the requirements of various mandates.

Georgia's Socio-Economic Pilot Study of its Blue Crab Fishery: An ACCSP Exercise

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With the creation of the Atlantic Coastal Cooperative Statistics Program (ACCSP) in 1995, the Atlantic States Marine Fisheries Commission edged ever closer to a more reliable fisheries database. The ACCSP seeks to assure timely collection and reporting of accurate standardized information about fisheries throughout the Atlantic states. In 1999, the Georgia Department of Natural Resources, Coastal Resources Division was funded to conduct a three-year pilot study of its Blue Crab fishery. Georgia sought the grant because this fishery is small and fairly homogenous, and it was felt that an accurate test of the ACCSP sociocultural and economics survey instrument could be conducted on it. Along with the typical logbook/trip ticket information collected, a sociologist was hired to collect information pertaining to the socio-economics surrounding this industry. Individual trip costs, annual costs and social and demographic data are collected on a panel subset of the industry. A methodological discussion as well as preliminary results of the socio-economic portion of the pilot study will be presented.

Capacity, Excess Capacity, and Fisheries Management II

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Excess capacity like overcapitalization and overfishing is a symptom of our regulated, open access fishery management system. It results because fishermen do not have an incentive to conserve fish in-the-sea causing them to over-invest in the factor inputs, such as capital, used to harvest fish. Excess capacity exists in a fishery when the yield from the fishery exceeds the point where net benefits to society are at a maximum; i.e., once maximum economic yield (MEY) is exceeded. In developing fisheries where MEY occurs before maximum sustainable yield (MSY) is achieved, excess capacity can exist when the fish stock is fully utilized. The adverse effects of excessive capacity levels can be corrected. However, achieving this objective is a matter of great debate. For example, with economically rational fisheries management, fishermen behave as if a private property right exists for the in situ marine resource which creates a market incentive for fishermen to conserve the fish stock by divesting capital. Alternative methods such as vessel buy-backs, limited entry, harvest input restrictions, and total catch levels have also been proposed to control capacity. Without an unbiased and objective capacity measurement metric, the success or failure of regulations designed to reduce capacity cannot be accurately assessed. As a result of international initiatives and domestic fishery management objectives, the National Marine Fisheries Service has developed definitions and metrics to measure capacity to determine excess capacity levels in our domestic fisheries.

Use of the Classic Fishery Production Function to Illustrate the Interaction between Biology and Economics in Fishery Management – Focus on the Lobster Fishery

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The author has studied fishery management from the perspective of a fisherman, a representative of fishermen, and a participant in the fishery management system. All too often, fishery management is viewed as requiring a choice between economic survival and resource conservation. But the field of fishery bio-economics has demonstrated that fisheries that are managed for maximum economic yield are also managed very conservatively. A lack of consideration of fundamental principles of fishery population dynamics and fishery economics, and their interaction, has led to fishery management programs that reduce the contribution of our fisheries to the community, state, and national economies. Because many fisheries have been poorly managed in the past, there is an opportunity to improve the biological and economic productivity of fisheries, with resulting benefits to coastal communities. The realization of this opportunity requires that stakeholders and policy-makers understand basic principles of fishery bio-economics and their relevance to fishery management choices. This Power Point presentation uses the classic fishery production function to illustrate and analyze common fishery policy issues, with specific reference to management options for the American lobster fishery.

Industry Heterogeneity, Collective action and Commons Management: Lessons from Industrial Fisheries

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This paper proposes a new, multidisciplinary model of fishery management that can both offer explanations for varied success and track sustainability over time. Bureaucratic freedom in setting a sustainable total allowable catch is based, first, on the distribution of political support among lobbying organizations and, second, on issues of collective action within lobbies. Fishery managers confront strong opposition when confronted with one large coalition speaking on behalf of the greater part of the fishing industry. As lobby concentration increases, resource regulators are increasingly constrained in setting catch limits. The vast political science literature on collective action attempts to explain one puzzle of group influence: larger political groups tend to be less successful in achieving their objectives. The ability to solve collective action problems suggests both the power of lobbies and their preferences on stock management. Larger lobbies tend to be less powerful and less conservative in approaching natural resource management. The comparative statics above also serve as a foundation for a dynamic model of common property management. Steady-state bioeconomic equilibriums or corner solutions can be modeled by incorporating political variables of competition among groups and ability to solve collective action problems within groups.

Market Quota System: A Foundation of Fairness

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The Market Quota System is an auction based (or set price) comprehensive fisheries management system that covers the economic social and environmental aspects of fisheries. It accomplishes this through incentives and penalties tied to the TAC poundage auction of the public resource. It is a free enterprise style tool to be used by international, federal and local governments. My paper will confront the myths of free and arbitrary resource distribution and what that translates into in terms of socio-economic damage to working fishermen and consumers. The distinctions between working fishermen and fishing boat investors are a key consideration in choosing a system for fisheries. The Market Quota System advantages the working fisherman. Our current systems are designed to advantage those investor fishermen who have lobbied for special consideration through regulation. The paper will discuss a compromise proposal to phase the old limited entry system out and phase in a new socio economically acceptable system. Public ownership of resources will be a needed cornerstone in providing fairness to fishermen. The Market Quota System achieves fairness to working fishermen and their families by leveling the access to public resources.

STOCK ENHANCEMENT

Survival and Movement of Hatchery-Reared Red Drum (*Sciaenops ocellatus*) Released Out-of-Season into the Chassahowitzka National Wildlife Refuge

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Red drum (*Sciaenops ocellatus*) have been under strict management in Florida since 1988 due to increasing fishing pressure. With successful hatchery production of red drum, restocking using hatchery-reared fish has become a tangible management strategy for a few state regulatory agencies. The success of these programs is widely unknown, however, especially releases conducted out-of-season. The goal of the proposed research was to estimate post-release survival and movement of hatchery-reared red drum released out-of-season in June into the Chassahowitzka National Wildlife Refuge (CNWR). Two groups of ~10,000 juvenile red drum each were released into two tidal creeks located in the CNWR. Transport mortality from the hatchery to the creeks of release was estimated to be 2-10%. Acute 24-hour post-release mortality was assessed by placing fish in live bags at the release sites and was estimated to be 26-44 %. Of the ~12,000 fish estimated to have survived the release, 33 were recovered up to 5 days post-release at fixed sampling sites located primarily downstream of the release sites. Emigration potential was also studied by tracking 12 redfish with ultrasonic transmitters in the creeks of release during the post-release period. Tracking results combined with recapture data suggested that redfish did not remain resident in the tidal creeks and appeared to emigrate out of the tidal creeks within the first week of release.

Assessment of red drum *Sciaenops ocellatus* stock enhancement in Tampa Bay, Florida: an experimental approach

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The use of marine stock enhancement must be approached responsibly and in an empirical fashion to ensure the adequate assessment of the benefits to the fishery and possible effects on natural fish populations. A series of release experiments were designed to determine the effects of size-at-release, release season, and habitat on the relative abundance and survival of hatchery reared red drum. Coded wire tags and genetic markers were used to distinguish hatchery-reared red drum from wild red drum. Over 52,000 hatchery-reared red drum were equally dispersed among eight release sites over a series of five release events. Relative abundance of both wild and hatchery-reared red drum was monitored following each of the release events.

From 252 post-release seine collections, 275 red drum were collected, 58% of which were hatchery-reared. Preliminary results suggest that recapture rates of phase II hatchery-reared red drum were higher than phase III. Most recaptured hatchery-reared red drum were collected within four weeks post-release; however, some phase II fish were at large for >100 days. Most hatchery-reared red drum (97%) were collected in close proximity (<0.5 km) to their original release sites. Hatchery-reared red drum that moved from their release sites typically moved upriver, suggesting a preference for lower saline waters, muddy substrates, or shorelines containing marsh grass (*Juncus*) habitat.

An Objective Treatment of Gulf Sturgeon Stock Enhancement

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Stocking protocols for Gulf sturgeon need to be developed based on the responsible approach concepts of Blankenship and Leber (1995). Small-scale projects need to be conducted and evaluated before large-scale projects are undertaken.

For example, a breeding plan, including culture methods to minimize potential detrimental effects of conventional stocking programs has been implemented for Kootenai River white sturgeon. The purpose of this program is to guide managers in the systematic collection and spawning of wild sturgeon adults before they are lost from the wild breeding population (P. Anders, University of Idaho, Aquaculture Research Institute, S. Ireland and J. Siple, Kootenai Tribe of Idaho Fisheries Department, personal communications).

Success of the Kootenai River program will be determined by: 1- an increase in the number of juvenile white sturgeon in the system; 2- survival of hatchery produced fish to sexual maturity; 3- retention of wild sturgeon life history and population genetics characteristics; and 4- an

increased understanding of white sturgeon life history characteristics and factors limiting natural recruitment (P. Anders, University of Idaho, Aquaculture Research Institute, S. Ireland and J. Siple, Kootenai Tribe of Idaho Fisheries Department, personal communications). A similar program could be adopted for Gulf sturgeon for Florida.

Stock enhancement of shortnose sturgeon, *Acipenser brevirostrum* : colonization of non-target rivers

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The amphidromous shortnose sturgeon (*Acipenser brevirostrum*) is an endangered species that inhabits river systems from Canada to Georgia on the east coast. A trial stock enhancement program was conducted on the Savannah River between 1984 and 1992. A total of 97,483 shortnose sturgeon of differing year classes were released at various sites on the river. Of these, 18,213 were initially marked. Project sampling has indicated that stocked fish make up at least 37% of the population to date on the Savannah River. However, Savannah stocked fish have also been captured in a number of rivers in South Carolina and Georgia and appear to have colonized at least some of these systems. The wandering fish were stocked at advanced ages relative to other stockings. This suggests that shortnose sturgeon imprint to their natal river like anadromous salmonids. The age of imprinting should be determined prior to future stock enhancement efforts so that fish can be stocked prior to imprinting. The only apparent alternative is to build hatcheries on each river to be stocked so fish can be cultured in water from that system.

Contribution of Stocked Fingerling Brown Trout in the Lake James Tailrace, North Carolina

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The Lake James tailrace extends for 29 km in western North Carolina. Hypolimnetic releases provide suitable temperatures for trout, but seasonally low dissolved oxygen levels and a heavy bedload of sand were seen as potential limiting factors to a quality trout fishery. The North Carolina Wildlife Resources Commission (NCWRC) has managed the upper 1 km of the tailrace as a put-and-take trout fishery for over 30 years. The NCWRC began annual stockings of 25,000 brown trout *Salmo trutta* fingerlings into the upper 18-km of the tailrace in 1996. This study was conducted to determine if stocking fingerling brown trout is a suitable management strategy for maintaining a brown trout population in the tailrace. In March 2000, 25,000 brown trout fingerlings (mean, 90 mm) were coded wire tagged and stocked. Tag retention at 30 days was 100%. Twenty-three sites were boat electrofished in September 2000. A total of 81 age-0 brown trout were captured and 71 (88%) were tagged. Age-0 brown trout CPUE was 13.6/h and growth was 18.2 mm/month. There were no differences in mean lengths between

wild and stocked age-0 brown trout. The overall trout CPUE was 29.5/h and captured brown trout ranged from 142-400 mm total length. Preliminary results of this study indicate that spring stocking fingerling brown trout is creating a quality trout tailrace fishery in western North Carolina.

Successful Establishment of Redear Sunfish in a Crowded Predator Lake Through Supplemental Stocking

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Many established bass-bream lakes experience a significant decline or even disappearance of redear sunfish (*Lepomis microlophus*) over time. The fish population in these lakes are often dominated by large numbers of small adult and sub-adult bass. Stocking paradigms indicate the necessity to introduce an intermediate size (100-125mm) fingerling for successful survival and subsequent spawning.

A single fall introduction of 625 50mm redear per hectare into an 8ha crowded bass lake was successful in establishing a redear fishery. Significant redear reproduction occurred at year two post stocking. Stocked fingerlings began to enter the fishery at sizes of 225g or greater at year three.

The fish population was monitored through five years of spring electrofishing.

Efficacy of Clove Oil as an Anesthetic and Stress Reducer in Yearling Rainbow Trout (*Oncorhynchus mykiss*)

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We examined the use of clove oil as a stress reducer and as an anesthetic in yearling rainbow trout. When exposed to a 25 mg/L dosage of clove oil, trout lost equilibrium and became anesthetized within approximately one minute (range of 45-90 seconds) after exposure. They recovered and swam normally within 5-10 minutes after being placed in fresh water. When blood cortisol levels (an indicator of stress) were measured in trout exposed to an anesthetizing dose of clove oil for a 60-minute period, there was a significant increase in cortisol concentration (166.2 ng/mL) after 10 minutes in the anesthetizing solution. Cortisol concentrations then decreased to levels lower than that of Time 0 fish after 30, 40, 50, and 60 minutes in the clove oil solution. The mean cortisol concentration level (163.5 ng/mL) in fish from the "standard" handling practice used in culture operations was significantly higher after 15 minutes in clove oil than the mean cortisol concentration level (93.1 ng/mL) of fish with no exposure to clove oil (control), and to the mean cortisol level (65.7 ng/mL) of undisturbed fish

being exposed to clove oil. Clove oil is readily available, safe and easy to use, inexpensive when compared to MS-222, and has no FDA regulations. Its advantages are that it induces a quick induction time and an adequate recovery time in rainbow trout. One potential disadvantage is that at concentrations of 25 mg/L clove oil stimulates a cortisol stress response.

GEAR AND SAMPLING CONSIDERATIONS

Shad abundance comparisons using mid-water trawls and hydroacoustics in a southern impoundment

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Late summer shad *Dorosoma* spp. abundance data (number/m³) were collected using mid-water trawls and hydroacoustics in Hugo Reservoir, Oklahoma from 1995 to 1999. Trawl and hydroacoustic data were collected simultaneously in the downlake area. Paired comparisons were made between trawl and hydroacoustic estimates in the downlake area. Uplake and downlake hydroacoustic estimates were made on consecutive nights. Threadfin shad *Dorosoma petenense* dominated the population samples and a kill of threadfin shad during the winter of 1995-1996 drastically reduced abundance estimates.

Abundance estimates using trawls and hydroacoustics were different. However, which gear gave the higher estimates was not consistent. Hydroacoustic estimates were higher in 1995 and 1996 with trawl estimates typically being higher from 1997 through 1999. Correlations between the trawl and hydroacoustic transects were highest in the September samples. Differences in the hydroacoustic estimates from the downlake and uplake areas were also inconsistent. Estimates from the uplake area were higher in 1995 and 1996 with the estimates from 1997 through 1999 being generally similar or higher in the downlake area. Variability estimates of the samples from both gears were similar.

Comparison of two electrofishing methods utilized in surveying fish assemblages in warmwater streams in central Tennessee

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Assessments of small stream (mean width <15m) fish assemblages are commonly conducted through electrofishing depletion estimates. Depletion estimates are labor and time intensive and can result in biased estimates. Depletion samples and concurrent single-pass electrofishing samples were conducted from April-September 1999 and April-June 2000 in 40 warmwater streams in central Tennessee. Comparison of diversity values and relative abundance values were used to determine how well the single-pass electrofishing method predicts the results of a

three-pass depletion sample. Diversity indices for single-pass sampling were positively correlated to three-pass diversity indices, ($r^2 = 0.947$). Assemblage structure (i.e., relative proportions) also were similar between single-pass and three-pass approaches (SIMI values: 0.756-0.999). This study indicates that estimates of diversity and relative abundance from a single-pass electrofishing method adequately represent estimates obtained from the three-pass depletion method, and three-pass sampling is only needed when population estimates are required.

Use of Low-frequency Electrofishing for Sampling Ictalurid Populations in Virginia's Tidal Rivers

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Virginia's tidal rivers support reproducing populations of native white catfish *Ictalurus catus* as well as non-native blue catfish *I. furcatus*, channel catfish *I. punctatus*, and flathead catfish *Pylodictis olivaris*. Although these populations have supported commercial and/or recreational fisheries for years, little data exists regarding their status. The use of low-frequency (15 pps) electrofishing for sampling catfish in these systems was evaluated. Exploratory sampling indicated that this method was highly effective for collecting blue, flathead, and white catfish, but less so for channel catfish. At some stations, it was not unusual to observe up to several hundred catfish on the surface simultaneously. The breadth of the effective field was large; catfish frequently surfaced up to 20 m from the electrofishing boat, and substantial catches were made from water as deep as 28 m. In most cases, this gear exhibited no overt size selectivity; samples often contained catfish < 10 cm and > 90 cm total length. For blue catfish, catch per unit effort in the best habitats typically ranged between 400 and 2200 fish/hr of pedal time. Results suggest that low-frequency electrofishing can be used as an effective sampling tool for several catfish species in Virginia's tidal rivers.

Effects of Sampling Season, Gear, and Area on Population Characteristics of Crappies in Tennessee Reservoirs

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Population characteristics of crappies were examined from twelve Tennessee reservoirs sampled either in spring or fall with either trapnets or electrofishing. Total annual mortality from age 2 to age 5 averaged 64% for black crappies and 54% for white crappies. The distributions of lengths at age-3 were variable across reservoirs in terms of range and skewness, often encompassing the entire length range seen for the whole sample. Based on mean lengths at age-3, black crappies grew slower than white crappies in five of seven reservoirs. Species composition varied greatly among reservoirs, and often one species was dominant. The percentage of black crappies in each reservoir was negatively correlated with chlorophyll-a

concentrations. Species compositions also varied spatially within reservoirs, with white crappies usually more abundant in the upper reaches of reservoirs and black crappies more abundant in the lower reaches. Species composition was also affected by sample gear. Crappie species compositions in concomitant electrofishing and trapnet samples were relatively similar in Kentucky and Barkley Reservoirs. However, in Woods and Normandy Reservoirs, black crappies represented much higher proportions of trapnet samples than they did in electrofishing or angling samples. Length-frequencies of crappies collected in concomitant electrofishing and trapnet samples were distinctly different; electrofishing collected larger fish than trapnets in both systems. Managers desiring to obtain a good random sample of crappies from their systems should be aware that characteristics of these samples can be completely different depending on the sampling area, season, and gear chosen.

Field Identification Accuracy for White Bass and Hybrid Striped Bass

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We estimated the accuracy of field identification of white bass (*Morone chrysops*) and palmetto bass (*M. chrysops* x *M. saxatilis*) by Texas fisheries workers and evaluated the reliability of meristic and morphometric characteristics commonly used to differentiate between these two fishes. Electrophoretic and isoelectric focusing analyses of diagnostic proteins were used to verify the fisheries workers' identification of fish (1,087) sampled from 16 reservoirs in Texas. Overall, accuracy of field identification was high and fisheries workers correctly identified all sampled white bass, however 5% of hybrid striped bass were incorrectly identified as white bass, and 12% of these fish were found to be F_x hybrids. The majority of white bass (78%) exhibited one basihyal tooth patch while most hybrid striped bass (89%) had two tooth patches. Hybrid striped bass had a significantly higher number of lateral stripes extending to the tail, and a significantly higher incidence of broken lateral stripes than did white bass. Genetic analysis showed a low incidence (1.8%) of F_x hybrids, indicating reproduction of hybrid striped bass is an uncommon event in Texas reservoirs. Managers desiring to regulate white bass and palmetto bass with different harvest restrictions should consider basing regulations on a single characteristic and accepting the consequent harvest of some protected individuals, since identification based on a single characteristic or combination of characteristics does not result in 100% accuracy. Alternatively, managers might consider setting *Morone* harvest regulations based on length and bag limits alone, without regard to species to reduce angler confusion and the concerns of law enforcement.

Evaluation of Onsite versus Offsite Data Collection for Predicting Thermal Habitat

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Stream temperature models can be used to predict thermal regimes with changes in watershed hydrology, land use, and riparian conditions. Whether the increased time and costs of onsite weather data collection are warranted in terms of model predictive ability is not known. To address this we (1) evaluated differences between air temperature and relative humidity measured onsite (Back Creek, Roanoke County, Virginia) and obtained at four weather stations 15, 175, and 240 km from the stream for January and July 2000, (2) evaluated differences between Stream Segment Temperature model (SSTEMP) predictions using onsite versus weather station data, and (3) determined sensitive input parameters. Although we found statistical differences in weather data between onsite and the weather stations, model predictions of stream temperature were not statistically different. The most sensitive parameters during July were air temperature and relative humidity, and during January were lateral inflow temperature and the A coefficient in the width equation. Onsite weather data is more critical during July if weather station conditions differ from those at the stream. The model predicted most accurately with onsite data, however when considering time and cost, use of offsite data may be an acceptable compromise.

Sampling fish populations in contaminated environments

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Fisheries scientists are accustomed to sampling fish populations in a wide variety of situations using a plethora of gear. We are trained when to sample and how best to sample fish populations relative to our data needs and gear selectivity. Increasingly fishery scientists are called upon to sample fish in areas that are significantly contaminated with pollutants. This contamination poses a threat to the health and safety of the workers. To minimize the risk of the exposing workers to the contaminants there are a number of precautions that must be taken and a different set of regulations that must be considered before sampling is initiated.

First and foremost is consideration of worker safety. Sampling in contaminated areas requires that workers be trained under 29CFR 1910 requirements. This includes an OSHA 40 hour HAZWOPER course, annual refreshers and an occupational health physical. Additional training may include site specific hazard training; radiation worker training; and implementing a hazard analysis plan.

In this presentation we will outline the steps for sampling fish populations in a hypothetical contaminated environment.

Considering the Effects of Time in Experimental Design of Fisheries Research

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The effects of time are inherent in many experimental designs used in fisheries research, but often these effects are given insufficient consideration. This oversight is often due to a lack of awareness of analytical methods which may provide information pertaining to time effects. Additionally, although regression and analysis-of-variance are commonly used analytical tools in fisheries research, time effects may invalidate assumptions key to the underlying statistical theories governing the effectiveness of these techniques. Other less-commonly known statistical methodologies are available, however, which incorporate the effects of time more effectively. For example, Box-Jenkins methodologies are a popular tool used in the specialized area of statistics known as "time series analysis", which provides powerful tools to identify trends, cycles, or seasonal variations in data collected over time. Although specific structural requirements must be met by data used in Box-Jenkins methodology, some of the ideas from this methodology may be applied to regression and analysis-of-variance, to increase the utility of these techniques with data that is collected over time, but does not meet the structural requirements for Box-Jenkins methods.

ESTUARINE FISH ECOLOGY

Habitat Use by Nearshore Fishes in the Estuarine Portion of the St. Johns River

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I examined how fish abundance and community composition varied among habitats at nine widely separated locations in the estuarine portion of St. Johns River, Florida. A combination of throw traps and trawls were used to collect fishes from a mosaic of grass beds, sand flats, and adjacent channel habitat at each estuarine location. The system supported a mixture of freshwater and marine derived species over a large spatial scale (ca. 100 km). Although location within this estuarine system was important, much of the variation observed in fish abundance and community composition could be explained on a smaller spatial scale by habitat type. The abundance and diversity of fishes was consistently higher in grass beds than in adjacent sand flats. Small fishes such as gobies and rainwater killifish dominated grass beds, schooling fishes such as silversides and anchovies dominated sand flats, and larger fishes such as croaker and flounder dominated non-vegetated channel habitats. Patterns in habitat use were generally consistent between day and night collections. Large predatory fishes were common in these habitats and behavioral experiments indicated that risk of predation likely plays an important role in shaping habitat use by vulnerable fishes in this system.

Density, growth and biomass production of Atlantic croaker and spot in the Weeks Bay National Estuarine Research Reserve, Alabama

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We collected juvenile and sub adult Atlantic croaker and spot with a 4.9m otter trawl in Weeks Bay, Alabama from May 1996 to December 1997 to investigate temporal and spatial trends in density and biomass production. Statistically significant temporal (monthly and interannual differences) and spatial (differences between sampling stations) trends in density and biomass production rates were detected. Hydrographic and biogeochemical variables were measured along with chlorophyll- α concentrations, phytoplankton productivity, and zooplankton densities in an attempt to relate these variables with observed trends in density and daily production rates. Sampling variance, inherent in estuarine systems, was too large for any statistically significant relationship between these factors to be determined. However, during late winter and early spring, increases in fish abundances and production rates corresponded with increases in phytoplankton and zooplankton. Fish abundance and production rates were highest in the areas of Weeks Bay where nutrient uptake and phytoplankton/zooplankton production was highest. Spatially, higher observed densities and daily production rates were observed in areas of the bay that had increased nutrient uptake and productivity (phytoplankton-zooplankton). These production data, along with data on other sources and sinks of nutrients in Weeks Bay, will enable us to estimate nutrient export via biomass export of croaker and spot from the estuary.

Recruitment, growth and distribution of juvenile *Mugil cephalus* within the Charleston Harbor Estuary, South Carolina

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Daily growth increments from striped mullet (*Mugil cephalus* L.) were validated using wild caught fish from the Charleston Harbor Estuary system. The distribution of back calculated birthdates indicates that striped mullet spawn from October to late April with the heaviest period of recruitment occurring from February through May. The growth of these juvenile mullet after they recruit into the estuary can be described by the following relationship: Total Length (mm) = $0.341 (\text{Age})^{1.04} \pm 20.5$ ($r^2 = 0.787$, $p = 0.001$ and $F = 891.3$). A similar comparison was made using size frequency data from rotenone surveys conducted from 1986 to 1991 in the same estuaries. In the case of the rotenone collected fish, month of capture was substituted for age as the time variable and growth was determined from the change in mean size at capture per month. This relationship can be described by the equation:

Total Length (mm) = 8.77 (Month)^{1.12} ($r^2 = 0.950$, $p = 0.001$, and $F = 235.6$). There was no significant difference between the slopes of these two curves indicating that juvenile striped mullet maintain consistent annual growth patterns within the Charleston Harbor Estuary during the first year of life.

Formulation and transferability of habitat-suitability criteria for fishes in two western Florida estuaries

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We are conducting fish-habitat modeling in two Gulf-coast estuaries in Florida, to map the distributions of three species by life stage and season. The methodology consisted of uni-, bi-, and multivariate statistics to verify, validate, and test the transferability of models, i.e., a combination of within- and among-estuary tests. We derived habitat-suitability criteria (HSCs) by regressing catch-per-unit-effort (CPUE) data against five independent habitat (pelagic or benthic) variables. Development of separate regressions for up- and downslope zones (1) improved model fit relative to a single polynomial curve and (2) eliminated model bimodality. We then developed composite habitat-suitability models (HSMs), in which HSCs were aggregated across habitat variables via regression equations. As the geometric-mean equation usually worked best and interaction terms were usually significant for multiple-regression analyses of CPUE vs. habitat conditions, fish typically selected habitat variables somewhat interdependently. Because CPUE vs. HSM regressions were typically linear within and between estuaries and our HSCs were moderately similar to literature-based HSCs, our models were usually transferable between study estuaries and thus useful for transferring to unsampled Florida estuaries.

REPRODUCTIVE BIOLOGY

Production of a monosex female Florida largemouth bass (*Micropterus salmoides floridanus*) population using intersex broodstock: A Progress Report.

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To produce intersex genetic female broodstock, Florida strain largemouth bass fingerlings (mean total length (TL) = 29mm) were fed diets containing 17 - methyltestosterone at concentrations of 0 mg/kg of food (control), 25 mg/kg of food and 50 mg/kg of food for periods of 42 and 60 consecutive days. Samples were sacrificed for sex determination at 8 and 14 months after initiating the androgen treatment. Intersex individuals were identified by the

presence of both testicular and ovarian tissue in the same organ. The control group had a male:female:intersex ratio of 46:54:0, while treatment groups had sex ratios ranging from 86:9:5 to 51:33:16. No direct relationship between either treatment level or duration and the proportion of intersex individuals produced was observed. Surviving individuals from all treatment groups will be maintained until spring 2001, at which time we will determine gamete viability and initiate spawning trials.

Isolating the parentals of a late spawn of threadfin shad in Hugo Reservoir, Oklahoma

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The presence of larval threadfin shad (*Dorosoma petenense*) in summer trawl collections from Hugo Reservoir, Oklahoma in 1997 and 1998 established evidence of multiple or protracted spawning bouts. Weekly gill-net samples were collected from March through August 1999. Threadfin shad were grouped into 20mm length classes, and ovaries and saggital otoliths of 10 fish from each length class were removed and examined. A gonadal somatic index (GSI) was created for each length class to follow ovarian development over the course of the entire spawning period. Ova diameter analysis was also conducted on dissected ovaries. GSI patterns showed a peak in ovary weights from late April through May in all length classes. A secondary increase in ovarian weight occurred during early July in all length classes. Ova diameter analysis reflected the GSI trends with the largest ova corresponding to GSI peaks in the spring and in July. Aging by otolith annuli revealed only the largest and smallest length classes to be relatively consistent. A chronologically varying combination of age-1 and age-0 shad comprised the other length classes. It is concluded that all length classes, including a small proportion of fish spawned in the spring, contributed to the late spawn.

Effects of Surgically Implanted Acoustic Transmitters on Survival and Spawning Success of Spotted Seatrout (*Cynoscion nebulosus*) in Captivity

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We studied the effects of surgically implanted transmitters (4.5 g) on survival, healing, and spawning success of spotted seatrout (*Cynoscion nebulosus*) (mean weight 275.8g) held in captivity. Our objectives were to develop a surgical procedure, to observe fish recovery times, and to evaluate the condition of wounds and sutures at two sample times. Two groups of spotted sea trout-- a control without implants and a group with implants--, were brought to spawning condition via photo-thermal treatments. Implanted and control fish had no mortality two months after surgery, and both groups were observed to spawn repeatedly. Examination of 14 implanted fish, sacrificed after two months, indicated most wounds had healed and only

three fish had developed a degree of necrotic tissue at the incision site. The coated vicryl absorbable sutures used in the surgical process remained in all but one fish at two months and appeared to be a source of hemorrhaging. By the final sacrifice date (four months) implanted fish had spawned 18 times and the control group 7. With a good surgical procedure, the use of implanted acoustic transmitters in spotted seatrout appears to be a suitable technique for observing movement and spawning behavior in natural conditions.

Spawning habitat characteristics of recreationally important sciaenid species in the Savannah Harbor

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Members of the sciaenid (drum) family communicate using signature noises that can be heard using passive acoustic techniques. In the lower Savannah River, such soniferous fish include spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), and weakfish (*Cynoscion regalis*), which form audible aggregations during their respective spawning seasons. Better understanding the habitats used by sciaenid spawning aggregations may help avoid impacts to these recreationally important species from proposed dredging activities in the Savannah Harbor.

Throughout the fall spawning season, evening surveys were conducted in and around the Savannah River's shipping channel to find and characterize habitats used by local aggregations of spotted seatrout and red drum. Five large aggregations of spotted seatrout and two of red drum were located using a hydrophone, and eggs were collected using plankton nets to determine if drumming fish were actively spawning. Sounds associated with spawning were recorded and sites were portrayed in a Geographic Information System (GIS). Depth, temperature, dissolved oxygen concentration, salinity, current speed, tide stage, adjacent structures, and timing relative to sunset were recorded to define temporal patterns in and the physical features of spawning habitats.

FISH PHYSIOLOGY AND HEALTH

Temperature and Hypoxia Tolerance of Selected Fishes from a Hyperthermal Tidepool in the Dry Tortugas

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During hot summer months, fishes living in shallow tidally influenced rockpools on northwest Loggerhead Key in the Dry Tortugas National Park, experience marked diel temperature shifts. We sampled these pools in July 2000 and documented thermal characteristics, ichthyofauna

diversity, and quantified high-temperature and low-oxygen tolerance of three pool fishes. Mid-morning rockpool temperatures increased from 30.0 to 35.8°C by late afternoon. Unlike typical extreme habitats of this genre, which usually contain one or two tolerant species, Loggerhead Key rockpools were populated by at least seven tropical fishes. Another unusual finding was that rockpools were inhabited by reef species usually found in deeper and cooler tropical waters. High temperature tolerances for three of these species, the cocoa damselfish *Pomacentrus variabilis*, French grunt *Haemulon flavolineatum*, and white mullet *Mugil curema*, were not significantly different and ranged from 35.7 to 37.3°C. Hypoxia tolerances of French grunt (1.8 mg/L) and white mullet (2.1 mg/L) were also not significantly different; however, cocoa damselfish was significantly more tolerant of hypoxic conditions (1.36 mg/L) than the other two species. French grunt and cocoa damselfish augmented their oxygen tolerance strategy through use of aquatic surface respiration when dissolved oxygen levels reached 2.00 mg/L, whereas, white mullet did not. Various degrees of physiological adaptation allow Loggerhead Key fishes to exploit resources in hyperthermal habitats.

Thermal Acclimation Kinetics of the Sheepshead Minnow, *Cyprinodon variegatus*

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Sheepshead minnow, *Cyprinodon variegatus*, inhabit some of the most variable thermal environments known, yet little is known about their acclimation dynamics. We used critical thermal methodology to quantify rates of gain or loss of heat and cold tolerance for sheepshead minnow abruptly transferred between 10 and 18, 18 and 26, or 26 and 34°C. Critical thermal maxima (CTMax) of fish plunged into high temperatures for 30 d increased from 32.1, 37.0 and 41.3°C to 38.8, 41.1 and 43.6°C, respectively. Critical thermal minima (CTMin) in these same groups showed respective increases from 3.0, 4.2 and 6.2°C to 5.6, 5.6 and 9.9°C. Reciprocal transfers demonstrated that while CTMax and CTMin returned to pre-transfer levels within 30 d, rates of heat and cold tolerance loss or gain differed based on the direction of temperature transfer. Maximum heat tolerance at higher temperature transfer was achieved within approximately 10-15 d and not completely lost until 20-25 d following transfer to lower temperatures. Conversely, cold tolerance loss occurred within 15 d, but gain of cold tolerance was not complete until 20-25 d. Sheepshead minnow did not rely on faster rates of acclimation than other fishes but rather responded to small shifts in environmental temperature by making large changes in tolerance. The varied and independent rates of heat and cold tolerance gain and loss suggest that high and low temperature tolerance are separate physiological processes.

The Largemouth Bass Virus Experience in Texas

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Significant largemouth bass (*Micropterus salmoides*) kills attributed to the largemouth bass virus (LMBV) occurred on Sam Rayburn (1998) and Lake Fork reservoirs (1999), two of Texas' most prestigious and popular bass fisheries. These kills drew considerable public and media attention, resulting in misinformation about potential causes and their fisheries-related effects. In response, the Texas Parks and Wildlife Department (TPWD) launched an aggressive effort to: 1) increase angler understanding and awareness about LMBV; 2) study population and angling effects from kills associated with LMBV; 3) determine the distribution of LMBV in Texas and what factors might be associated with its occurrence; and 4) assess potential impacts on TPWD largemouth bass management and stocking programs. This effort included a close examination of population and angling-related effects following kills on Sam Rayburn and Lake Fork reservoirs and the initiation of a statewide LMBV survey on five Texas state fish hatcheries and 49 Texas reservoirs. Preliminary results of these investigations will be presented. Our work may benefit other resource management agencies dealing with LMBV disease problems and help guide future research in this area.

ENDANGERED AND INTRODUCED FISHES

Microhabitat use and Conservation Status of the Endangered Okaloosa Darter

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We have monitored patterns of microhabitat use, recruitment, and response to human and natural disturbances by the endangered Okaloosa darter since 1995. Each year, we perform underwater visual counts along replicate transects at each of 14 permanent census sites located on Eglin Air Force Base. We measure depth and substrate preferences for each fish and assess changes in several habitat parameters such as substrate, canopy cover, stream flow, pH, and conductance. Based on these data, it appears that local populations of Okaloosa darters are either stable or increasing. Okaloosa darters reside along stream margins near substrates that provide significant cover and have low to moderate flow. There is some evidence that microhabitat use of Okaloosa darters changes in the presence of brown darters, but there is

little evidence that the Okaloosa darter is being competitively displaced from sympatric sites. The abundance of Okaloosa darters declines significantly in sections of streams that have been impounded by human or natural disturbances (e.g., culverts, beaver dams). However, juveniles and adults recolonize these sites rapidly after hydrogeomorphic conditions are improved. Overall, the Okaloosa darter appears to be responding positively to restoration efforts being undertaken by Eglin.

Size-related shifts in habitat use by the federally endangered Roanoke logperch (*Percina rex*): Implications for conservation

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Conservation of the federally endangered Roanoke logperch (*Percina rex*) necessitates protection of habitat that is critical for all age classes of this species. In the summer of 2000, we observed 17 logperch < 4cm total length (TL), 10 subadult logperch (4 - 8cm TL), and 42 adult logperch (> 8cm TL) in the upper Roanoke River, Virginia. Observations of individuals < 4cm TL are rare, and their habitat use is not well understood. Standard snorkeling survey methods were used for adult and subadult observations; however, we observed 0 logperch < 4cm TL during these surveys. To search for small logperch, 2-3 individuals equipped with polarized glasses and binoculars surveyed shallow backwaters, secondary channels, and river edges. Adult and subadult logperch primarily used medium- to high-flow run habitat, often over gravel substrate in areas dominated by cobble. Logperch < 4cm TL, in contrast, were found in shallow, low-flow backwaters and secondary channels. These areas are heavily loaded with silt; however, small logperch foraged in small patches of silt-free, lightly embedded gravel. Apparent age-related shifts in habitat use indicate that a variety of threatened habitats require protection in order for Roanoke logperch to persist in the Roanoke River.

Adverse Effects of Introduced Fishes in South Florida: What do the Data Show?

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South Florida has been described as a "biological cesspool" of introduced organisms. Indeed, Florida is now home to more exotic fish species than any other state. Ecological harm is a common assumption when studying introduced fishes and there are well-documented examples of such harm in the United States and elsewhere. However, the existence of widespread documentation of large adverse effects caused by introduced fishes in the south Florida canal and Everglades systems is a common misconception of many citizens, politicians, resource managers, and biologists. An examination of the literature revealed that there are few or no data regarding adverse effects for most introduced fishes in south Florida. For many species, the best information available is that due to high numbers they must cause harm. Herein I briefly review the data for peacock cichlid *Cichla ocellaris*, walking catfish *Clarias batrachus*, pike

killifish *Belonesox belizanus*, and Orinoco sailfin pleco *Pterygoplichthys multiradiatus*. The purpose of this review is not to assert that introduced fishes cause no harm, it is, however, to bring about awareness of the lack of data in this unique system, spur research to address this need, and remind us that we must carefully evaluate the data and clearly delineate speculation.

POSTER SESSION

Mercury Levels in Recreationally Important Fish Species from Inshore and Offshore Waters of Florida. (D. H. Adams, R. H. McMichael, Jr.)

The Examination of a Blue Catfish *Ictalurus furcatus* Population in a Large Southeastern Reservoir, Lake Norman, North Carolina (J. D. Grist*, B. R. Murphy)

Longitudinal Patterns in the Smith River, Virginia, Tailwater Fishery (M. R. Anderson, D. C. Novinger, D. J. Orth, T. J. Newcomb, A. K. Holloway, C. A. Dolloff)

Phylogeography of the Tallapoosa Darter - A Preliminary Report (S. M. Brogdon, C. R. Tabit, S. D. Fonseka, L. G. Kral)

The Role of Temperature on Behavior and Movement of Atlantic Stingray, *Dasyatis sabina* from St. Joseph's Bay, Florida (N. A. Fangué*, W. A. Bennett)

Reproductive Behavior and Resource Partitioning Between Gulf Toadfish, *Opsanus beta* and Florida Blenny, *Casmodes saburrae* (K. J. Fitchett*, W. A. Bennett)

Using Long-term Monitoring Data as a Tool to Determine Essential Fish Habitats for Juvenile Red Drum and Spotted Seatrout in Tampa Bay, FL (K. Y. Guindon-Tisdell, R. E. Matheson, L. L. Brant, J. M. Fine, R. H. McMichael, Jr., G. Nelson)

Principal Habitats of Several Recreationally Important Fishes in the Indian River Lagoon, Florida (C. Harnden)

Trophic Responses of Large Predatory Fishes to Habitat Restoration (F. Jordan, D. A. Arrington)

Effects of Flooding and Drought on Redbreast Sunfish (*Lepomis auritus*) Growth in Southwest Georgia (M. Kearns, S. W. Golladay, M. Freeman, J. J. Isely)

Trophic Patterns of An Everglades Freshwater Fish Community Across Habitats And Seasons (W. F. Loftus, J. C. Trexler)

Status of Florida's Shad and River Herring (*Alosa* species) (R. McBride, R. McMichael, S. Rider, G. Nelson)

Fish and Aquatic Invertebrate Assemblages in Everglades National Park in Relation to Changes in Hydrology (E. B. Nelson, E. L. Nance, S. A. Perry)

Age and Growth of Halfbeak, *Hemiramphus* spp., Populations in South Florida (P. Thurman, R. S. McBride)

The Relationship Between Size Differences and Bioenergetics of Largemouth Bass Populations from Brackish and Freshwater Habitats in the Escambia River and Marsh (B. P. Whitlock*, R. A. Krause, W. A. Bennett)

Preliminary Examination of Stable Isotope Analysis as a Technique to Verify Annual Growth Band Deposition in the Shells of Four Freshwater Mussels (Bivalvia: Unionidae) from Florida (H. N. Blalock-Herod)

Fecundity Estimation of American Shad, *Alosa sapidissima*, along the East Coast of the United States (T. D. Piper, R. Jesien, K. Friedland)

Life History Parameters and Population Dynamics of Freshwater Fishes of South Florida Canal Systems: Common Large-Bodied Species (J. J. Herod, L. G. Nico, W. F. Loftus)

The Asian Swamp Eel: A Recent Invader in Peninsular Florida (L. G. Nico, J. J. Herod, W. F. Loftus)