Fisheries Session

Habitat, Accessibility, and Watershed Variables as They Relate to Largemouth Bass and Bluegill in Mississippi's National Forest Impoundments

Donald C. Jackson, *Department of Wildlife and Fisheries, Box 9690, Mississippi State, MS 39762*

Nancy J. Brown-Peterson,[1] *Department of Wildlife and Fisheries, Box 9690, Mississippi State, MS 39762*

Abstract: Small watershed impoundments provide the principal recreational fishing opportunities within national forests in Mississippi. Relative abundance and stock structure of bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) were assessed by electrofishing 18 national forest impoundments during spring 1990, autumn 1990, and spring 1991. There were no significant year-to-year or seasonal differences in catch per unit effort (CPUE) or proportional stock density (PSD) for either species. Mean CPUE for stock-size largemouth bass (total length $\geq$ 200 mm) ranged from 8.2 to 9.7 fish/hour of electrofishing and mean PSD ranged from 14.0 to 22.5. Mean CPUE for stock-size bluegill (total length $\geq$80 mm) ranged from 38.7 to 45.0 fish/hour and mean PSD ranged from 21.5 to 21.8. Twenty-five habitat, accessibility, and watershed variables were evaluated by multiple regression techniques to determine factors that significantly described largemouth bass and bluegill CPUE and PSD. Conductivity, population of the nearest town, and the percentage of upland hardwoods in the watershed accounted for 73% of the variation in bluegill CPUE, while 57% of the variation in largemouth bass CPUE was explained by surface dissolved oxygen, distance to the nearest paved road, and the percentage of wetlands in the watershed. Variation in bluegill PSD was best described by alkalinity, distance to the nearest paved road, and chlorophyll *a* concentration (R^2 = 61), while the population of the nearest town, chlorophyll *a* concentration and the percentage of upland hardwoods in the watershed accounted for 67% of the variation in largemouth bass PSD. These models suggest that emphasis should be placed on impoundments located in watersheds comprised principally of hardwoods. Improving water quality (i.e., fertility) of these impoundments should receive priority by fisheries managers, followed by management orientations addressing watershed characteristics and angler exploitation of the fish stocks. Application of fertilization programs with wetland-connected impoundments should probably be avoided in order to maintain the

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[1] Present address: Gulf Coast Research Lab, P.O. Box 7000, Ocean Springs, MS 39566.

integrity of wetland characteristics which may be sensitive to artifical nutrient loading.

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Small impoundments located throughout Mississippi's national forests provide excellent opportunities for recreational fishing. As access to private lands decreases, the importance of these public fisheries will increase. Accordingly, the protection and enhancement of fisheries on national forests are specifically prescribed by the Multiple-Use Sustained Yield Act of 1960 and the National Forest Management Act of 1976 (Robertson 1988).

Many small impoundments in Mississippi's national forests were created during the 1960s by the Soil Conservation Service (SCS) as flood retention ponds. Historically, management of these impoundments has consisted of constructing fish attractors (Ebert and Knight 1981) and supplemental stocking of popular sport fishes (Ebert et al. 1985). More recently, management of the impoundments has followed the classic stock assessment and management methodologies for largemouth bass and bluegill stocks as described by Davies (1973) and Smith et al. (1975). These include impoundment fertilization, liming, shoreline deepening, addition of brushtop structures and selective poisoning of undesirable species. However, factors such as system accessibility for angling and forestry practices in the surrounding watershed may also influence respective fisheries resources (Ebert et al. 1985).

Identification of factors influencing bluegill and largemouth bass stocks in Mississippi's national forest impoundments can assist U.S. Department of Agriculture (USDA) Forest Service biologists in optimizing their management resources as they work to enhance recreational fisheries in these systems. To accomplish this, a suite of environmental parameters can be analyzed to develop models which best describe fish stock characteristics in these small impoundments. Winkle et al. (1990) successfully used this approach to determine habitat parameters influencing brook trout (*Salvelinus fontinalis*) standing stocks in beaver ponds in Wyoming. Sabo (1989) used similar techniques for predicting abundances of larval sunfishes (*Lepomis* spp.) in borrow pits along the Mississippi River.

Our objectives were to describe relative abundances and stock structure of bluegill and largemouth bass in Mississippi's national forest impoundments, to determine factors which may be influencing these stock characteristics, and to suggest management approaches to enhance these fisheries.

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Methods

Eighteen impoundments, located on 4 national forests in Mississippi, were chosen on the basis of accessibility and potential as recreational fisheries. Each impoundment was sampled once during spring (April–July) 1990, autumn (September–November) 1990 and spring (May–June) 1991. With few exceptions, sampling was conducted during morning hours. Fish stocks in each impoundment were assessed by shoreline electrofishing (250–325 volts, 1–4 amperes) using a boat-mounted VVP-15 Coffelt electroshocking unit during continuous 10-minute runs. The number of 10-minute runs varied with lake size; 1 run was conducted in lakes <2 ha, 2 runs in lakes 2–8.2 ha, 3 runs in lakes 8.3–20.6 ha, and 4 runs in lakes >20.6 ha. The starting point for each sampling run was randomly determined. All fish collected during each run were identified to species, measured to the nearest mm total length, and returned to the water alive.

Twenty-five habitat, angler accessibility and watershed variables were determined for each impoundment (Table 1). Measurements of alkalinity, conductivity, pH, surface dissolved oxygen, and Secchi transparency were taken at the center of each impoundment prior to electrofishing. Average depth was determined following methods outlined by Boyd and Shelton (1983) by taking depth measurements every 15 seconds while moving in an "S" pattern along the long axis of the impoundment. Emergent open water and shoreline structures were counted in each impoundment, and overall accessibility to the impoundments was rated on a scale of 1—poor (poorly maintained dirt road, dirt ramp), 2—fair (well maintained dirt road, dirt or concrete ramp), 3—good (gravel road, concrete ramp), and 4—excellent (paved road and concrete ramp).

Water samples were collected and stored on ice in dark bottles for determinations of turbidity, chlorophyll *a*, and total suspended solids (TSS). Turbidity was determined within 24 hours using a La Motte Model 2008 turbidity meter. Chlorophyll *a* and TSS determinations followed procedures recommended by

Table 1. Habitat, accessibility, and watershed variables measured in 18 impoundments on national forests in Mississippi.

Variable	Method of determination
Habitat	
Conductivity (μmhos)	YSI model 33 meter
Alkalinity (mg/liter)	Hach kit
pH	Hach kit
Dissolved oxygen (mg/liter)	YSI model 72 meter
Depth (m)	"S" pattern (Boyd and Shelton 1983)
Secchi transparency (cm)	Meter stick
Total suspended solids (mg/liter)	Dry weight (APHA et al. 1980)
Turbidity (NTU)	La Motte model 2008 meter
Chlorophyll *a* (mg/liter)	Spectrophotometer (APHA et al. 1980)
Open water emergent structure	Counted
Shoreline emergent structure	Counted
Total emergent structure	Sum of open water and shoreline structure
Surface area (ha)	Aerial photography, PC-ARC/INFO software
Shoreline length (m)	Same as surface area
% Emergent aquatic vegetation (ha)	Same as surface area
Accessibility	
Overall access	1 = poor; 2 = fair; 3 = good; 4 = excellent
Distance to nearest paved road (m)	Same as surface area
Distance to nearest town (km)	Map
Population of nearest town	1990 census
Watershed	
% Upland hardwood (ha)	Same as surface area
% Pine (ha)	Same as surface area
% Pine-hardwood mix (ha)	Same as surface area
% Agricultural crops (ha)	Same as surface area
% Clear cut forest[a]	Same as surface area
% Wetlands (ha)	Same as surface area

[a] 0–5 years after clear cut.

the American Public Health Association (APHA) et al. (1980). Water samples were filtered within 24 hours after collection and filters were frozen at −20 C for no more than 3 months prior to chlorophyll *a* determinations. TSS determinations were made within 24 hours after collection.

Watershed vegetation within a 61-km radius of each impoundment was identified using aerial photographs and verified by ground truthing the vegetation immediately surrounding each impoundment. Vegetation information was digitized using PC-ARC/INFO mapping software (Environ. Systems Res., Inc., Redlands, Calif.). Surface area of each impoundment, shoreline length, distances to the nearest paved road and town, and percentage of each type of vegetation in the respective watershed were determined using the PC-ARC/INFO software.

Catch per unit effort (CPUE, number of stock-size fish/hour of electrofishing) and proportional stock density (PSD; Gablehouse 1984) were calculated from collections taken during the 10-minute electrofishing runs. Stock-size largemouth bass were ≥200 mm total length. Stock-size bluegill were ≥80 mm total length. Paired *t*-tests were used to determine if either CPUE or PSD in the same impoundments differed significantly between spring 1990 and spring 1991 samples. Student's *t*-test was used to compare both CPUE and PSD values for spring vs. autumn. All values are reported as $\bar{x} \pm$ SE. Stepwise multiple regression analyses were performed on habitat, accessibility and watershed parameters that significantly ($P \leq 0.05$) described CPUE and PSD. Correlation analyses were performed on the 25 independent variables to determine which parameters could be entered into the same regression model. All percentage data (watershed vegetation; PSD) were arcsin transformed prior to analyses. All statistical analyses were performed with SAS statistical software (SAS Inst. 1985).

Results

There were no significant differences ($P > 0.05$) between spring 1990 and spring 1991 CPUE or PSD values for bluegill or largemouth bass in all impoundments; therefore, spring data were combined for further analyses. There were no significant ($P > 0.05$) seasonal differences in mean CPUE for bluegill or largemouth bass for all impoundments. Mean CPUE for stock-size bluegill was 38.7 ± 7.0 in spring and 45.0 ± 7.6 in autumn. Mean CPUE for stock-size largemouth bass was 9.7 ± 2.0 in spring and 8.2 ± 2.2 in autumn.

There were no significant ($P > 0.05$) seasonal differences in mean PSD for bluegill or largemouth bass for all impoundments. Mean PSD for bluegill was 21.8 ± 3.3 during spring and 21.5 ± 8.6 during autumn. Mean PSD for largemouth bass was 22.5 ± 5.8 during spring and 14.0 ± 4.4 during autumn. Bluegill-largemouth bass PSD ratios for each of the 18 impoundments during the 3 sampling periods indicated that none of the impoundments had optimal stock structure for good fishing (Fig. 1).

The majority of the impoundments were shallow, clear, poorly buffered and slightly acidic, with low conductivity and low primary productivity (Table 2). Overall, access to the impoundments was rated fair, indicating a dirt or gravel road to the impoundment and a dirt launching ramp. Watersheds surrounding most impoundments were dominated by upland hardwoods, pine or mixed pine-hardwood stands.

Correlation analyses indicated that many of the 25 independent variables were significantly ($P \leq 0.05$) correlated with each other and subsequently they could not be entered into the same regression models. Therefore, the maximum number of independent variables entered into each model was 9. Intercepts were eliminated from models if they did not contribute significantly to the respective equation ($P > 0.05$). Overall regression models were composed of combined data from spring 1990, autumn 1990, and spring 1991 because no significant seasonal differences in PSD or CPUE were detected for bluegill or largemouth bass.

Multiple regression models describing CPUE of stock-size bluegill (Table

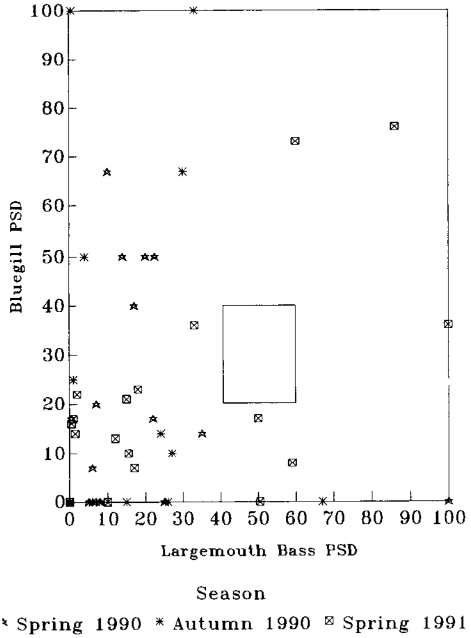

Figure 1. Proportional stock densities (PSD; Gablehouse 1984) of bluegill and largemouth bass from 18 impoundments on national forests in Mississippi sampled during spring (April–July) 1990, autumn (September–November) 1990, and spring (May–June) 1991. The box indicates the target area for balanced fish populations.

3) showed that 73% of the variation was described by conductivity, the population of the nearest town, and the percentage of the watershed covered by upland hardwoods. Bluegill CPUE increased as conductivity and the percentage of the watershed covered in upland hardwoods increased and as the population of the nearest town decreased. Upland hardwoods marginally contributed to the overall significance of the equation.

Fifty-seven percent of the variation in stock-size largemouth bass CPUE was described by surface dissolved oxygen, distance to the nearest paved road and the percentage of the watershed covered by wetlands (Table 3). Largemouth bass CPUE increased as surface dissolved oxygen increased and as the distance to the nearest paved road and the percentage of the watershed covered by wetlands decreased. All variables contributed significantly ($P \leq 0.05$) to the overall equation.

Multiple regression models describing bluegill PSD (Table 4) showed that 61% of the variation was described by alkalinity, distance to the nearest paved road, and chlorophyll *a* concentration. Bluegill PSD increased as all 3 variables increased, although the contribution by chlorophyll *a* to the significance of the overall equation was only marginal.

Sixty-seven percent of the variation in largemouth bass PSD was described by the population of the nearest town, the percentage of the watershed covered by upland hardwoods, and chlorophyll *a* concentration (Table 4). Largemouth bass PSD increased as all 3 variables increased, and all variables contributed significantly ($P \leq 0.02$) to the overall equation.

Table 2. Means (± SE) and ranges of 25 independent variables measured in 18 impoundments on national forests in Mississippi.

Variable	Mean	Range
Habitat		
Conductivity (μmhos)	39.0 ± 1.4	25.0–65.0
Alkalinity (mg/liter)	13.5 ± 0.6	6.8–27.4
pH	6.7 ± 0.1	5.8–8.8
Dissolved oxygen (mg/liter)	7.9 ± 0.3	4.2–13.1
Secchi transparency (cm)	86.7 ± 5.5	28.2–194.0
Total suspended solids (mg/liter)	59.0 ± 7.6	25.5–403.0
Turbidity (NTU)	14.0 ± 1.6	2.9–64.7
Chlorophyll *a* (mg/liter)	14.6 ± 2.7	0.0–77.8
Emergent open water structure	30.0 ± 5.8	1.0–121.0
Emergent shoreline structure	140.7 ± 24.7	0.0–700.0
Total emergent structure	149.8 ± 21.9	1.0–755.0
Surface area (ha)	17.8 ± 3.6	1.3–90.2
Shoreline length (km)	2,284.0 ± 247.4	709.6–7,145.0
% Emergent aquatic vegetation (ha)	1.9 ± 0.6	0.0–13.7
Accessibility		
Overall access[a]	2.2 ± 0.2	1.0–4.0
Distance to nearest paved road (m)	2,183.0 ± 331.7	0.0–7,598.0
Distance to nearest town (m)	16.6 ± 1.0	6.5–33.0
Population of nearest town	1,799.0 ± 439.6	124.0–10,864.0
Watershed (% watershed area)		
Upland hardwoods	33.7 ± 1.3	17.2–56.8
Pine	30.4 ± 1.3	10.3–48.6
Pine-hardwood	26.4 ± 1.2	15.5–46.1
Agricultural crops	10.0 ± 1.2	0.0–24.2
Clear cut[b]	12.6 ± 1.0	0.0–21.3
Wetlands	6.8 ± 0.6	0.0–12.8

[a] Data are ranks (see Table 1).
[b] 0–5 years after clear cut.

Table 3. Regression models best describing electrofishing catch per unit effort (CPUE, stock size fish/hour) of bluegill (≥80 mm) and largemouth bass (≥200 mm) in 18 impoundments on national forests in Mississippi. Data from spring 1990, autumn 1990, and spring 1991 were combined for analyses.

Variable	Slope(B)	Standard B	*P*
Bluegill CPUE			
Model R^2 = 73.0 Adjusted R^2 = 71.0 P = 0.0001			
Conductivity	0.726	0.529	0.0366
Population of nearest town	−0.003	−0.230	0.0293
% Upland hardwoods	0.676	0.433	0.0731
Largemouth bass CPUE			
Model R^2 = 57.0 Adjusted R^2 = 54.0 P = 0.0001			
Surface dissolved oxygen	2.180	1.264	0.0001
Distance to paved road	−0.002	−0.300	0.0413
% Wetlands	−0.713	−0.404	0.0480

Table 4. Regression models best describing PSD of bluegill and largemouth bass in 18 impoundments on national forests in Mississippi. Data from spring 1990, autumn 1990, and spring 1991 were combined. PSD values were arcsin transformed prior to analyses.

Variable	Slope(B)	Standard B	P
Bluegill PSD			
Model $R^2 = 61.0$ Adjusted $R^2 = 58.0$ $P = 0.0001$			
Alkalinity	0.849	0.368	0.0145
Distance to paved road	0.003	0.309	0.0220
Chlorophyll *a*	0.319	0.228	0.0835
Largemouth bass PSD			
Model $R^2 = 67.0$ Adjusted $R^2 = 64.0$ $P = 0.0001$			
Population of nearest town	0.003	0.331	0.0020
% Upland hardwoods	0.358	0.390	0.0036
Chlorophyll *a*	0.421	0.304	0.0130

Discussion

The impoundments sampled in this study were primarily in forested watersheds and can be described collectively as clear-water, poorly-buffered systems with low chlorophyll *a* productivity and fair angler access. CPUE and PSD values for bluegill and largemouth bass tended to consistently reflect low relative abundances of fish and poor fish stock structure.

All CPUE values for bluegill captured in Kansas, Missouri, and Illinois ponds (46–273 fish/hour) exceeded values of Mississippi's national forest impoundments (Eder 1984, Novinger 1990). Largemouth bass CPUE values for impoundments located in Mississippi's national forests were an order of magnitude lower than largemouth bass CPUE values in Missouri, Ohio, Kansas, and Illinois ponds and impoundments (Eder 1984, Hall 1986, Gablehouse 1987, Novinger 1990).

Mean bluegill PSD values in Mississippi's national forest impoundments during both seasons fell in the low end of the recommended 20%–40% range for a balanced fish population (Novinger and Legler 1978). Mean largemouth bass PSD values were well below the recommended level of 40%–60% for a balanced fish population (Reynolds and Babb 1978). Regardless of season sampled, none of the 18 impoundments contained bluegill-largemouth bass PSD ratios within the range for optimal fishing.

Addressing variable categories identified in our regression models provides a foundation for establishing priorities for improving bluegill and largemouth bass stock structures and relative abundances in Mississippi's national forest impoundments. Paramount among orientations suggested by the models was water quality. Increased alkalinity, conductivity, and chlorophyll *a* concentration, which could result from a carefully monitored liming and fertilization program, can directly enhance bluegill stock characteristics and dynamics through plankton production (Boyd 1976, 1982) and subsequently improve piscivory potentials for largemouth bass stocks (Swingle 1950, Davies 1973). Secondarily, because better bluegill stocks occurred in the least accessible impoundments (those further from a paved road and with a small, rather than large, town nearby), impoundment-specific harvest regulations may be necessary to enhance the fisheries in the more easily accessible impoundments. Size limits for bluegill may be particularly appropriate in light of Coble's (1988) finding that angling significantly affected size distribution of bluegill in ponds and impoundments, resulting in many small fish and stocks with relatively low PSD values. Finally, bluegill stocks in Mississippi's national forest impoundments improved as the percentage of upland hardwoods in the watershed increased. This is perhaps related to more alkaline soils that are characteristic of watersheds supporting hardwoods, the higher nutrient content and more rapid decay of hardwood leaves relative to pine needles and reduced logging operations normally characteristic of hardwood-dominated areas. Therefore, concentrating management practices on impoundments characterized by a high percentage of upland hardwoods in the watershed may yield the best results for enhancing bluegill stocks.

The influences of water quality and watershed characteristics on largemouth bass stocks in Mississippi's national forest impoundments are likely indirect and operative through their influences on forage fish (e.g., bluegill) stocks. According to our models, largemouth bass stock structure and relative abundance could be enhanced by increasing primary productivity in the systems. The inclusion of wetlands in the CPUE model may relate to water quality (i.e., primary production potentials) and suggests that wetlands may be filtering watershed-derived nutrients before these nutrients can be incorporated into phytoplankton production. Additionally, largemouth bass CPUE and PSD values were better in the more accessible impoundments. This likely reflects USDA Forest Service management emphasis on impoundments that are closer to larger towns and accessible by paved roads (J. R. Dillard, pers. commun.). Efficiency in allocating future management efforts for largemouth bass can be enhanced by focusing on (1) improving water quality in and (2) access to impoundments with a high percentage of the watershed in upland hardwoods and a low percentage of the watershed covered by wetlands. Application of fertilization programs with wetland-connected impoundments should probably be avoided in order to maintain the integrity of wetland characteristics sensitive to artifical nutrient loading.

Conclusion

The inclusion of accessibility and watershed variables into our regression models provides information addressing the direct and indirect influences of extra-system variables on fish stocks in Mississippi's national forest impoundments. These variables are typically not included in fisheries management programs, but their potential importance has been suggested by this study. If management priorities must be established for enhancing Mississippi's national forest impoundments, we suggest (1) emphasis be placed on improving water quality in impoundments with a high percentage of the watershed covered by upland hardwoods; (2) intensive management of impoundments with substantial wetlands in the watershed be avoided in order to safeguard these potentially sensitive environments; and (3) managers carefully consider the labor and cost ramifications of improving angler access to the systems (e.g., those associated with liming and fertilization programs and the construction and maintenance of roads and ramps, as well as those that would result from imposition and enforcement of harvest restrictions).

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