A Late Spring Survey of Pelagic Prey in Lake Moultrie, South Carolina—Implications for Management

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Abstract: We performed a hydroacoustic survey of fishes in Lake Moultrie, South Carolina, in May 1993. Pelagic fish densities were less than 70/ha with an average size of approximately 13 cm; densities of benthic fishes, most likely catfishes (*Ictalurus spp.*), were much higher, approximately 600/ha. Fish densities encountered in May were nearly 2 orders of magnitude less than either those reported in 32 years of fall rotenone surveys or in fall hydroacoustic surveys in upstream reservoirs. Confirmation of these low fish densities will require expanding sampling efforts. If validated, our findings may suggest a seasonal pelagic prey shortage, indicating a need for maximizing anadromous fish passage and close scrutiny of management activities including aquatic vegetation control, harvest restrictions, and stocking.

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Reliable estimates of pelagic prey density and size distribution in Lake Moultrie, South Carolina, are needed by decision makers in state and federal agencies. The reservoir supports nationally recognized fisheries that are dependent on pelagic prey, primarily threadfin (*Dorosoma petenense*) and gizzard shad (*Dorosoma cepedianum*) (White and Lamprecht 1993). The South Carolina Wildlife and Marine Resources Department (SCWMRD) continually evaluates striped bass (*Morone saxatalis*) stocking requirements and is monitoring the effects of expanding hydrilla (*Hydrilla verticillata*) colonies on fisheries in Lake Moultrie. The U.S. Army Corps of Engineers and the SCWMRD operate a fish lift and a boat lock that pass blueback herring (*Alosa aestivalis*), American shad

(*Alosa sapidissima*), hickory shad (*Alosa mediocris*), and Atlantic menhaden (*Brevoortia tyrannus*) into the reservoir. Pelagic prey availability is an important consideration to managers evaluating these activities.

Lake Moultrie supports extensive commercial, guided, and recreational fisheries. A trophy blue catfish (*Ictalurus furcatus*) and striped bass fishery have a national reputation and support numerous local guide services (Sample 1990). The SCWMRD is considering creel and size restrictions to manage striped bass, crappies (*Pomoxis spp.*), and largemouth bass (*Micropterus salmoides*). Additionally, gear restrictions have been implemented for commercial and recreational trot line fisheries. Management of these diverse fisheries by harvest and gear restriction is enhanced with direct pelagic prey base information.

Striped bass historically had a self-sustaining population in the Santee Cooper system (lakes Marion, Moultrie, and connecting diversion canal). In recent years, striped bass have been stocked to supplement natural recruitment. Because stocking cultured striped bass is expensive and production is limited, direct estimates of pelagic prey availability are important to avoid overstocking relative to the food resource (Jenkins and Morais 1978).

Pelagic prey in Lake Moultrie may be affected by the spread of hydrilla. Hydrilla can potentially spread into 40% of the surface area of the reservoir and cause a shift in fish communities. Triploid grass carp (*Centopharygodon idella*) have been stocked into the Santee Cooper system to control hydrilla. Baseline information on pelagic prey is needed if managers are to 1) evaluate potential effects of hydrilla expansion on fisheries and 2) recommend further stocking of triploid grass carp.

Passage of anadromous clupeids into the Santee Cooper system is being maximized and future passage efforts may require adjustment based upon the contribution of these fish to the prey resource. The addition of anadromous clupeids into the system would be important if a shortage of pelagic forage was limiting the fisheries. Conversely, if pelagic prey were abundant maximizing anadromous clupeid passage might not be desirable because of competition for limited food resources.

For the last 32 years, fall rotenone surveys (Chance 1958) have been conducted on Lake Moultrie by the SCWMRD (White and Lamprecht 1993). While some studies suggest that rotenone surveys adequately describe clupeids (Jenkins 1979), SCWMRD biologists believe that estimates of pelagic prey from rotenone may be inadequate because coves sampled littoral zone waters averaging 1 to 1.25 m in depth. Because of sampling concerns and the requirements for managers to make decisions on fish passage, fisheries management, and the potential effects of spreading colonies of hydrilla, we conducted a mobile hydroacoustic survey in May 1993.

We thank Don Degan of Duke Power Company for sharing pelagic prey density data, the Santee Cooper Authority, and Jim Glenn (SCWMRD) for their assistance in performing this survey. We also thank John Chick and 2 anonymous reviewers for their helpful comments.

Study Area

Lake Moultrie is the furthest downstream reservoir of the Santee Cooper system, covering approximately 25,000 ha. It was impounded in 1941 for hydropower and flood control. Extensive commercial and recreational fisheries have been established (Sample 1990). A total fishing effort of 682,328 hours was expended in 1988 with 65% of the effort occurring between March and June. Effort for catfishes and striped bass, pelagic piscivores, accounted for almost 60% of the total fishing effort (Sample 1990). Rotenone sampling over 32 years generated total standing crop estimates of approximately 100 kg/ha (White and Lamprecht 1993), suggesting an impoundment of low productivity in which prey may be limiting. Such standing crops may be inadequate because previous statewide studies indicate better predator/prey relationships and greater densities of sportfish when standing crop estimates range from 200 to 400 kg/ha (Kirk and Nash 1991).

Methods

A mobile hydroacoustic survey was conducted 11 May 1993 in pelagic-zone waters (depths 2 to 13 m) near the Pinopolis Pool region of southeastern Lake Moultrie, South Carolina (Fig. 1). The survey covered a 3,000-ha region of inundated river channel and adjacent waters. Surveys were conducted from a 7-m acoustic survey boat. Surveys consisted of a series of transects using a downward-looking transducer towed along side of the survey boat about 20 cm beneath the surface of the water. The survey consisted of 16 transects of approximately 23 km total length (Fig. 1).

Hydroacoustic data were collected with a calibrated echosounding system that was leased from Biosonics Inc., Seattle, Washington. The acoustic system consisted of a 420 kHz Biosonics Model 101 dualbeam echosounder with a 6°/15° dualbeam transducer. We sampled with a 0.5-msec long sound pulse transmitted at a source level of 216 dB || μPa re 1m and a repetition rate of 10 pulses per second. Echo returns were frequency-filtered to 420 kHz ±2.5 kHz and amplified by a 40Log(R) Time Varied Gain (TVG) to remove range-dependent effects. The voltage envelope from echo returns was then digitally sampled at 48 kHz and recorded on tape. System calibration was verified before and after the survey period by dualbeam analysis of data collected on a standard target of known acoustic size. With these data, we verified laboratory calibration to within approximately 1 dB.

Tape-recorded echo returns were used as the basis for estimating fish density and fish size-distribution. The measurements taken from echoes for echo counting and size analysis were all made with a Biosonics Model 221/281 Echo Signal Processor, Version 2.1. Estimation of fish density consisted of identifying fish echoes in the water column, isolating individual fish within the sequences of echoes arising from successive acoustic transmissions, summing range-

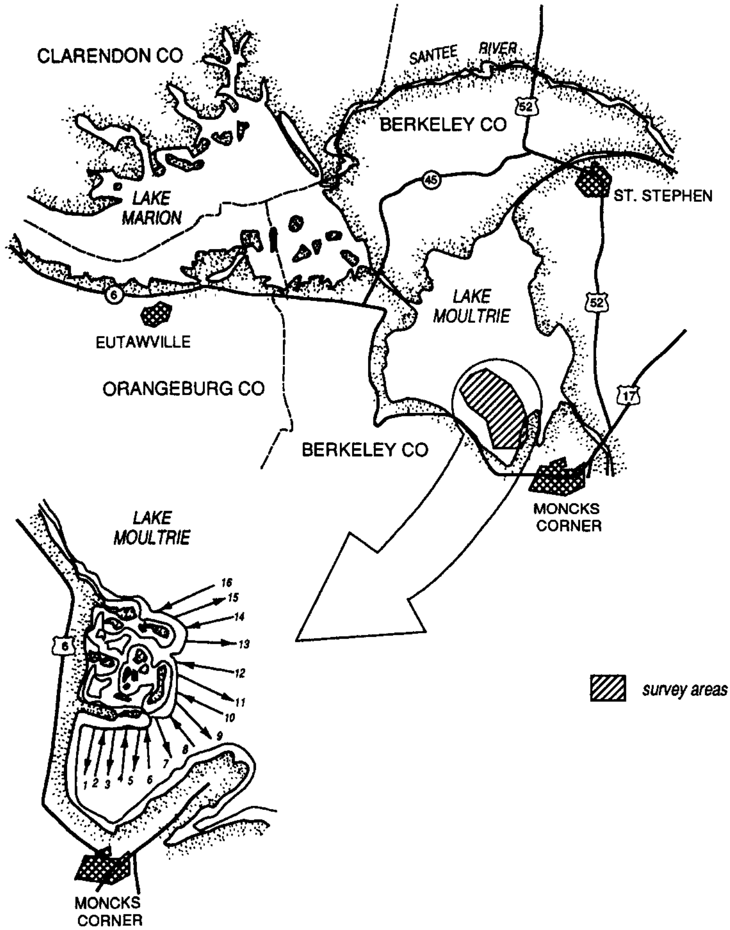

Figure 1. Location of acoustic sampling sites in Lower Lake Moultrie, South Carolina.

weighted fish numbers within the sample volume, and then expressing the result on a per ha basis. Echoes that were at least 1.3 m from the transducer, were larger than a −57 dB noise threshold, and had half-amplitude pulse widths between 0.4 and 0.6 msec and quarter-amplitude pulse widths between 0.4 and 0.68 msec were classified as fish echoes. Fish echoes occurring in sequences that differed in range by not more than 0.4 m and having no more than 1 consecutive missing echo were classified as individual fish. Fish detections were confirmed on echograms, and suspicious targets, primarily those resulting from bottom-tracking errors in areas with flooded timber, were removed from the data. From the resulting data, fish per ha were estimated separately for each transect by summing all fish detections occurring in an 8° conical sample volume using the following density estimator:

$$\text{fish/hectare} = \frac{10{,}000}{L} \sum[1/(2 \cdot R \cdot \tan(\theta/2))]$$

where,

L = length of transect in meters,
R = detection range of each fish in meters,
θ = width of transmit detection beam in radians (8°).

The acoustic size or target strength of each fish echo was estimated from the sonar equation

$$TS = V_n - SL - G_1 - 2 * BP$$

where,

V_n = 40Log(R) TVG-corrected narrow-beam echo amplitude (dB),
SL = transmit source level = 216dB,
G_1 = narrow-beam receiving sensitivity = −166.6 dB,
RG = receiver gain during data collection = −6 dB,
BP = beam pattern factor

The effect due to the fish's position in the beam (BP) was estimated by the dual beam technique (Ehrenberg 1978; Traynor and Ehrenberg 1979). Fish length was estimated from target strength using a regression relationship developed for air-bladder fishes (Love 1971).

Results

Echograms show that fish were sparsely and widely distributed over the survey area (Fig. 2). A total of 82 fish were encountered in the survey. Fish density on the 16 transects varied from 7 to 206 fish/ha with a mean density of 67 fish/ha and a coefficient of variation of 19% (Table 1).

The acoustic size of echoes from these targets ranged from −51 to −28 dB, or approximately 5 to 83 cm standard length (Fig. 3). Mean size was −43.4 dB, or approximately 13 cm.

Inspection of echograms show numerous targets with echoes not longer than one pulse length in size that partially overlap the bottom echo (Fig. 2). These echoes arise from targets that are either in contact with the bottom or occur not more than 1/2 pulse length above the bottom, a distance of approximately 0.25 msec (0.4 m) or less. The per transect density of these targets varied from approximately 250 to 2,000 per ha and mean density was approximately 600 per hectare (Table 1). Visual inspection on an oscilloscope of echoes from bottom targets suggests that on the average they may be roughly twice the size (+6 dB) of targets observed in the water column. While these observations are not conclusive, they would place the mean size of these targets (approx −37 dB, e.g., 26 cm) near the mean size of catfish taken from this area in net samples (White and Lamprecht 1993). The much higher density of bottom targets than

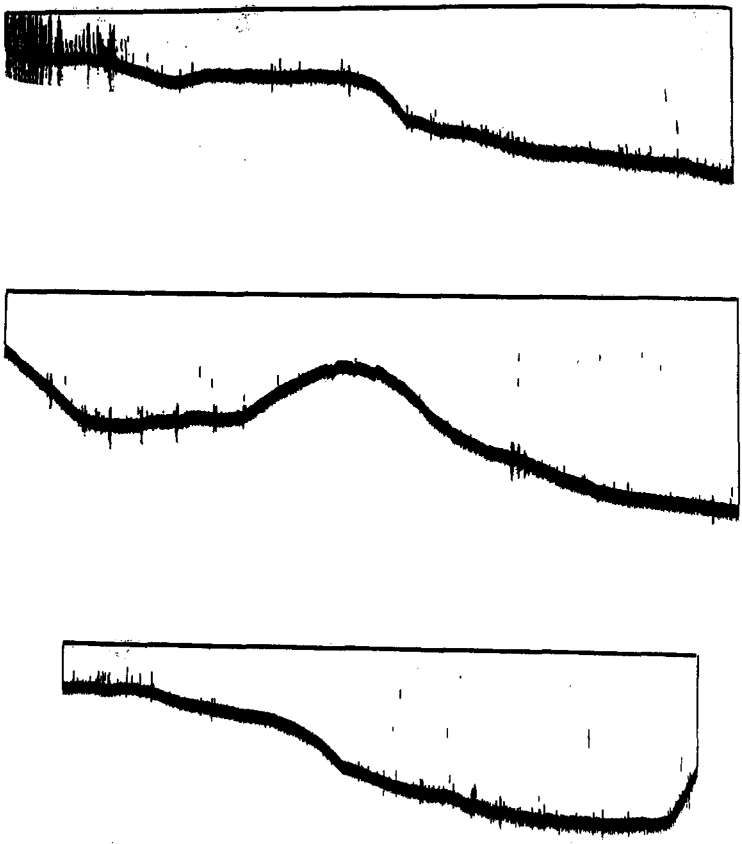

Figure 2. Echograms of fish detections from Lake Moultrie near Pinopolis Pool. Maximum displayed depth is approximately 11 m.

pelagic targets would suggest a predominately benthic fishery in this region of Lake Moultrie.

Discussion and Management Implications

Two major issues should be addressed regarding the low fish densities measured by this survey. The first issue is the validity of these density estimates and the second concerns the management implications if these estimates are indeed accurate. To validate our estimates, more intensive hydroacoustic surveying is justified because this survey was a "snapshot" of exiting conditions. Only part of the reservoir (approximately 3,000 ha) was surveyed and comparisons were made to summer and fall estimates when prey densities should have been at their highest. Future surveys should have an expanded scope to include both day and night sampling, stratifying the sampling to include the entire reservoir, and perhaps some fall sampling (Don Degan, pers. commun.).

Table 1. Density of acoustic targets near the Pinopolis Pool region of Lake Moultrie, South Carolina.

Transect	Length in m	Pelagic detections *N*	Pelagic detections Fish per Hectare	Pelagic detections Fish per Acre	Bottom detections[a] *N*	Bottom detections[a] Targets per Hectare	Bottom detections[a] Targets per Acre
1	760	8	206	83	33	301	122
2	850	6	124	50	45	447	181
3	950	6	120	49	45	278	113
4	1,270	3	56	23	51	315	127
5	1,130	1	12	5	58	431	174
6	900	1	42	17	26	255	103
7	1,300	1	11	4	49	397	161
8	750	2	26	10	21	253	102
9	1,460	10	106	43	58	1,220	494
10	2,940	7	77	31	74	468	189
11	1,430	5	66	27	46	250	101
12	2,270	10	65	26	84	597	242
13	1,690	5	52	21	117	2,093	847
14	2,040	5	23	9	78	666	270
15	1,660	1	7	3	87	981	397
16	1,780	11	73	30	80	923	373
Mean			67	27		617	250
Std Error			13	5		123	50

[a]Acoustic targets with echoes that partially overlap the bottom echo with a visible pulse of length 0.33–1.33 times the transmission pulse length clearly present above the leading edge of the bottom echo.

If expanded hydroacoustic sampling confirms our original estimates, then the management implications can be considerable. The density of prey in Lake Moultrie during May was quite low compared to that in fall hydroacoustic surveys performed by Duke Power Company on lakes Wiley, Wateree, and Norman (Table 2). The densities were also considerably lower than the mean of 32 years of late summer rotenone sampling performed on Lake Moultrie (Table 2). Mean sampling densities over this 32-year period were approximately 7,600 fish per ha with a standing crop of approximately 100 kg per ha (White and Lamprecht 1993). Differences in fish density within the reservoir may be due to the time of year that sampling was performed, the morphometry of the reservoir, and that rotenone samples tend to collect both littoral and pelagic species.

However, the densities we measured in May were extremely low and suggest that late-summer rotenone sampling may not adequately characterize year-round pelagic prey availability. Density estimates of less than 70 fish per ha would imply insufficient pelagic prey were available during the period sampled (Jenkins 1975, Jenkins and Morias 1978). Jenkins (1975) stated that predatory fishes need as much as 4–5 kg of prey for every 1 kg of body weight. In this case, almost no prey was available to support pelagic predators. Our survey also detected a significant density (approximately 600 per ha) of benthic fishes. If these fishes are catfishes, additional predation would be exerted on threadfin shad during winter months, thus contributing to low spring prey abundance.

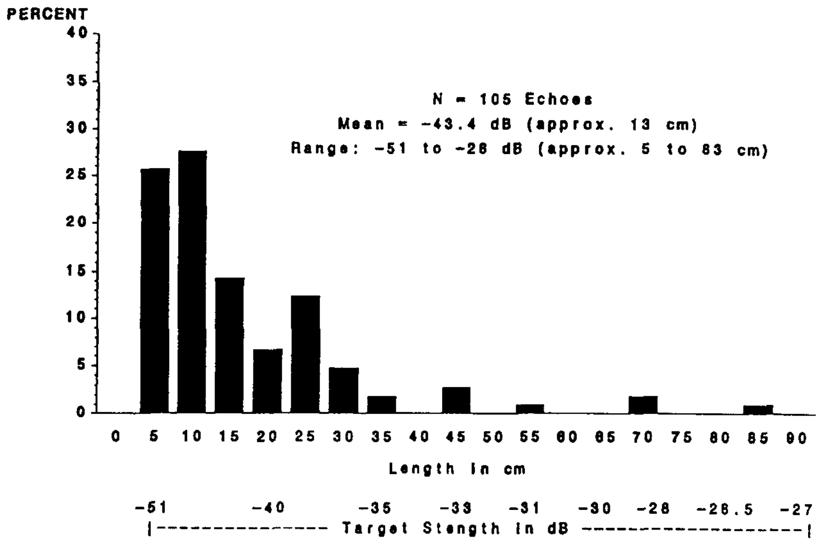

Figure 3. Acoustic size distribution of pelagic targets near the Pinopolis Pool region of Lake Moultrie, South Carolina.

Table 2. A comparison of fish densities measured by hydroacoustic and rotenone surveys in North and South Carolina.

Reservoir	Mean density/ha
Hydroacoustic surveys[a]	
Lake Wiley, SC/NC	17,905
Lake Wateree, SC	12,110
Lake Norman, NC	17,902
Fall rotenone samples[b]	
Lake Moultrie, SC	7,600

[a]Information provided courtesy of Duke Power Company.
[b]Based upon mean density estimates provided by fall rotenone sampling from 1960–1992.

While the density of pelagic prey may increase during the summer, the shortage encountered in May could represent a seasonal bottleneck (Werner 1979) in pelagic prey. In addition to evaluating growth and condition, we need to examine predator-prey relationships more closely before deciding whether harvest restrictions are appropriate for striped bass, largemouth bass, catfishes, and crappies (Jenkins 1979). Similarly, striped bass stocking may warrant greater scrutiny. Declining recruitment of striped bass to reproductive age may be affected by angling mortality or by a shortage of appropriate sized prey at a critical life period. Jenkins and Morias (1978) warned against stocking additional predators into prey-deficient reservoirs and Stevens (1969) documented a collapse of the clupeid prey base in the reservoir thought to be caused by striped bass predation.

Hydrilla is spreading into substantial areas of both Lakes Marion and Moultrie and may have already impacted the pelagic prey base. Bettoli et al. (1993) noted a shift from centrachids to clupeids after grass carp removed hydrilla from Lake Conroe, Texas. Conversely, expanding hydrilla is expected to shift the prey base away from clupeids to centrachids. This shift may detrimentally affect open water predators like striped bass and white bass (*Morone chrysops*) (Bettoli et al. 1974).

Under present conditions, maximization of anadromous clupeid passage appears justified solely on the basis of augmenting the Lake Moultrie prey base. Addition of anadromous clupeids would certainly be beneficial when the late spring density of fish in the pelagic areas is less than 70 per ha. However, if reservoir prey densities are sufficient during some years then maximum addition of anadromous fish may prove counter productive because of increased competition. The contribution of anadromous clupeids to the Santee Cooper reservoirs needs further evaluation.

Management of gamefishes requires considerations of predatory-prey relationships. In light of an expanding hydrilla infestation and its likely effects on Lake Moultrie fish populations, we need to closely scrutinize management strategies based on harvest restrictions and stocking. Hydroacoustic technology appears to provide an additional tool for this purpose. Additional use of this technology to accurately evaluate pelagic prey, especially during late spring and early summer, would enhance management efforts in this system.

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