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Development of Reservoir Shad
Assessment Methods

Aquatic Biology Section
Technical Report

Michael J. Mounce
and
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Annual Performance Report
F-62-R1

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by

Michael J. Mounce and Ted W. Storck

Aquatic Biology Section
Illinois Natural History Survey

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Knowledge of the abundance, size composition, and dynamics of gizzard shad (*Dorosoma cepedianum*) is important to fishery managers, because this fish is the most abundant prey species in many large impoundments and is frequently the dominant food item in the diet of piscivores (Lewis et al. 1974, Pasch 1975, Storck et al. 1982, Storck 1986). Because overwinter survival of age-0 largemouth bass (*Micropterus salmoides*) is generally a function of length attained during the first summer (Shelton et al. 1979, Adams et al. 1982, Anderson 1984), it is important that bass make a rapid transition from small prey items to larger prey (Miller and Storck 1984, Gutreuter and Anderson 1985, Keast and Eadie 1985). An abundance of vulnerable, age-0 gizzard shad can contribute to the success of that transition (Miller and Storck 1984).

Large annual fluctuations in the biomass of gizzard shad occur frequently (Houser and Bryant 1967, Jenkins and Morais 1978), presumably due to sporadic winter die-offs of age-0 fish (Jester and Jenson 1972, Storck 1986). Decreased gizzard shad biomass may lead to an inadequate forage base for the piscivore population. The introduction of threadfin shad (*D. petenense*) has been suggested as a viable management strategy to add to the prey biomass in many large reservoirs. Therefore, it is important for the fishery manager to understand the factors that influence shad population dynamics.

The variables that determine reproductive success of gizzard shad, and thus the availability of age-0 shad, have not been adequately evaluated. The relationship between adult stock abundance and reproductive success, the importance of body condition to reproductive success, and the density-dependent growth of young shad are important aspects of shad ecology that must be measured.

However, non-uniformity of the spatial distribution of gizzard shad and threadfin shad, differences in the distribution of young and adults, and size-selectivity of sampling gears complicate estimates of abundance and size composition of shad. Therefore, this study is developing sampling methods to assess shad standing crops which require minimum sampling effort and use equipment readily available to fishery managers. The relationship between adult shad abundance and subsequent production, growth, and overwinter survival of age-0 fish is also being examined.
Job 1. Fish standing crop estimates using rotenone.

OBJECTIVE: To measure standing crops of all fish species in coves and to compare shad standing crop estimates with those derived from mid-water trawls.

INTRODUCTION: An inability to accurately measure the density of fish in reservoirs has long been an obstacle to understanding the dynamics of reservoir fish populations. The gizzard shad is of special concern because it is often the numerically dominant species, is a major component in diet of piscivorous species, and is subject to dramatic year-to-year fluctuations in abundance. The purpose of this job is to estimate the size-structure and the numerical and biomass standing crop of individual age groups of gizzard shad in coves in Lake Shelbyville, a 4,500-ha flood-control reservoir in central Illinois.

Unfortunately, the shad density in coves is highly variable (Aggus et al. 1979) and the relationship between abundance in coves and open-water areas has not been adequately documented. Nonetheless, cove poisoning is the best method currently available for estimating gizzard shad abundance. When corrected for differences in recovery rates of various size groups, these samples should produce accurate estimates of population size structure. A comparison of cove rotenone and trawling estimates of size structure and abundance must be deferred until 1987 because trawling estimates could not be obtained in 1986.

METHODS: During the last week of August and first week of September 1986, two coves on Lake Shelbyville were poisoned with rotenone to estimate the standing crop and size structure of gizzard shad population. Cove A, located in the Kaskaskia River arm of the reservoir (Fig. 1), had a surface area of 1.38 ha and a mean depth of 0.85 m; smartweed, Polygonum sp., was abundant in shallow water and covered approximately 20% of the surface area. Cove B, located in the north body of the lake near Eagle Creek State Park, had a surface area of 0.84 ha and a mean depth of 1.68 m; smartweed covered approximately 5% of the surface area.

Coves were mapped using the stadia survey method. Depth contours were determined by measuring depth with a sounding pole along transects between mapped points. Surface area and volume were determined planimetrically. Water volume was computed using the formula of Welschmeyer (1948).

Block nets, deployed across the mouth of each cove and across the mouth of the two arms preceding each cove, created three sections; one section (III) in each cove was relatively deep with...
Fig. 1. Lake Shelbyville, Illinois, showing sampling stations (I-IV) and rotenone sampling locations (coves A and B).
shoreline development and the other two (I and II) were relatively shallow with higher shoreline
development.

Timed electrofishing samples were taken in each section. Captured fish were given section-
specific fin clips and were then released into the section from which they were taken. The standing
crop of fish in each section was estimated by multiplying the total number of fish recovered in a
section by the reciprocal of the recovery rate of marked fish.

Synergized rotenone (2.5%) was applied in each cove at the rate of 3 ppm. Rotenone was applied
in shallow areas using a boat bailer and in deeper areas by pumping it through a weighted hose.
Approximately 1 hour after the rotenone was applied, it was neutralized by applying 3 ppm of
potassium permanganate (KMnO₄) using a boat bailer.

A large subsample of recovered gizzard shad were measured to the nearest cm total length;
thereafter shad were sorted into three length groups and counted. Fish not measured were
assigned to 1-cm length groups in proportion to the abundance of fish in those length groups in the
subsample. When available, two shad from each 1-cm length group were weighed to the nearest
0.1 g.

Shad were collected for aging in August and September using gill nets and electrofishing gear at
uplake (Station I) and downlake (Station IV) locations. At each station, 10 fish from each cm-
length interval, or all fish if less than 10 were available, were aged by counting annuli on otolith
sagittae. To estimate the population age structure of shad longer than 120 mm in rotenone
samples, fish in each length interval were assigned ages in proportion to the age composition of the
subsample. Smaller shad were assigned to age-0 on the basis of length-frequency distributions.

The Kolmogorov-Smirnov two-sample test (Siegel 1956) was used to compare the size structure of
any two samples of shad collected with various sampling gears at different locations on Lake
Shelbyville. This two-tailed nonparametric test is sensitive to differences in dispersion, skewness,
and central tendency. If the cumulative distribution of the two samples are too far apart at any
point, this suggests that the samples come from different populations. Thus a large enough
deviation between the two sample cumulative distributions is evidence for rejecting H₀. An α =
0.05 level was chosen as the level for rejection of H₀. When length distributions of more than two
samples were compared, the X² test was used (Snedecor and Cochran 1968).

RESULTS: The numerical and biomass standing crops of gizzard shad in Cove A were much
larger than those in Cove B (Table 1) and both differed substantially from an average of 168 kg/ha
Table 1. Estimates of gizzard shad standing crops (adjusted for marked fish not recovered) for two Lake Shelbyville coves poisoned with rotenone in 1986. Standing crops were estimated separately for young-of-the-year (0), yearlings (I), and age II and older fish (II+).

<table>
<thead>
<tr>
<th>Location</th>
<th>Section</th>
<th>Mean depth (m)</th>
<th>Volume (m$^3$)</th>
<th>Mean Surface area (ha)</th>
<th>Age group</th>
<th>Mean length (cm)</th>
<th>Mean weight (g)</th>
<th>Total number</th>
<th>Total weight (kg)</th>
<th>Total weight (kg) No/ha</th>
<th>kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cove A</td>
<td>I</td>
<td>0.62</td>
<td>0</td>
<td>9.9</td>
<td>I</td>
<td>17.8</td>
<td>66.7</td>
<td>24,376</td>
<td>351.0</td>
<td>39,316</td>
<td>566</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II+</td>
<td>27.9</td>
<td>197.2</td>
<td>370</td>
<td>73.0</td>
<td>597</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>0.27</td>
<td>0</td>
<td>9.8</td>
<td>I</td>
<td>17.8</td>
<td>66.7</td>
<td>7,114</td>
<td>102.4</td>
<td>26,348</td>
<td>379</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II+</td>
<td>28.1</td>
<td>197.2</td>
<td>110</td>
<td>21.7</td>
<td>407</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>0.49</td>
<td>0</td>
<td>9.8</td>
<td>I</td>
<td>17.8</td>
<td>66.7</td>
<td>32,765</td>
<td>471.8</td>
<td>66,867</td>
<td>962</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II+</td>
<td>27.9</td>
<td>197.2</td>
<td>156</td>
<td>30.8</td>
<td>318</td>
<td>62</td>
</tr>
<tr>
<td>Cove total</td>
<td></td>
<td>0.85</td>
<td>6,853</td>
<td>1.38</td>
<td></td>
<td>11.5</td>
<td>25.7</td>
<td>79,885</td>
<td>2,050.8</td>
<td>57,888</td>
<td>1,486</td>
</tr>
<tr>
<td>Cove B</td>
<td>I</td>
<td>0.35</td>
<td>0</td>
<td>10.4</td>
<td>I</td>
<td>19.3</td>
<td>58.7</td>
<td>599</td>
<td>5.9</td>
<td>1,711</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II+</td>
<td>27.7</td>
<td>207.0</td>
<td>338</td>
<td>19.8</td>
<td>966</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>0.27</td>
<td>0</td>
<td>10.4</td>
<td>I</td>
<td>19.2</td>
<td>58.7</td>
<td>418</td>
<td>4.1</td>
<td>1,548</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II+</td>
<td>27.5</td>
<td>207.0</td>
<td>155</td>
<td>6.8</td>
<td>574</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>0.23</td>
<td>0</td>
<td>10.4</td>
<td>I</td>
<td>19.1</td>
<td>58.7</td>
<td>706</td>
<td>6.9</td>
<td>3,070</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II+</td>
<td>27.4</td>
<td>207.0</td>
<td>499</td>
<td>29.3</td>
<td>2,170</td>
<td>127</td>
</tr>
<tr>
<td>Cove total</td>
<td></td>
<td>1.68</td>
<td>4,625</td>
<td>0.84</td>
<td></td>
<td>14.1</td>
<td>32.9</td>
<td>2,810</td>
<td>92.5</td>
<td>3,345</td>
<td>110</td>
</tr>
</tbody>
</table>

reported for gizzard shad and other clupeids in large reservoirs (Patriarche 1952, Carlander 1955, Aggus and Lewis 1977, Grinstead et al. 1977, Aggus et al. 1979, Rainwater and Houser 1982). The size structure of shad populations in the two coves were different ($P < 0.05$) because young-of-the-year shad were relatively more abundant but were smaller in Cove A than in Cove B. In Cove A, age-0 shad accounted for 80% of the shad present, averaging 98 mm TL while in Cove B they accounted for only 61% of the total but averaged 104 mm.
The size structure of the two populations differed even when age-0 fish were excluded from the analysis (\(P < 0.05\)) because age-I shad in Cove A were also smaller and relatively more abundant than in Cove B. Hayne et al. (1968) found that the numerical and biomass standing crops of both young shad (<150 mm) and harvestable shad (>150 mm) in an embayment, were overestimated in all sizes of coves but that cove estimates of size structure were typical of the entire embayment. In contrast, Aggus et al. (1979) found that total standing crops of shad in coves were unbiased estimates of the standing crop in an entire arm of a reservoir, but that cove-to-cove variation was relatively large.

The age structure of gizzard shad collected in coves demonstrated that annual recruitment to age I is variable in Lake Shelbyville (Table 2, Fig. 2 and 3). The 1985 year class was very strong, accounting for about 90% of the recruited population. Moreover, year classes produced in 1979 and 1980 were still more abundant in 1986 than year classes produced in 1981, 1982, and 1983. The strength of the 1979 and 1980 year classes was evident in 1981 when they made up nearly 100% of the recruited shad (Storck 1986). The absence of individuals of the 1981 year class in 1986 probably reflected their failure to survive the first winter of life due to poor first-summer growth (Storck 1986).

### Table 2. Percent composition of individual age groups and mean total lengths (cm) of gizzard shad in Lake Shelbyville coves poisoned by rotenone in 1986.

<table>
<thead>
<tr>
<th></th>
<th>Cove A (n = 79,885)</th>
<th>Cove B (n = 2,810)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent composition</td>
<td>Mean length</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>80.4</td>
<td>9.8</td>
</tr>
<tr>
<td>I</td>
<td>18.7</td>
<td>17.8</td>
</tr>
<tr>
<td>II</td>
<td>0.2</td>
<td>25.8</td>
</tr>
<tr>
<td>III</td>
<td>0.0</td>
<td>--</td>
</tr>
<tr>
<td>IV</td>
<td>0.1</td>
<td>29.0</td>
</tr>
<tr>
<td>V</td>
<td>0.0</td>
<td>--</td>
</tr>
<tr>
<td>VI</td>
<td>0.3</td>
<td>28.7</td>
</tr>
<tr>
<td>VII</td>
<td>0.2</td>
<td>28.9</td>
</tr>
</tbody>
</table>
Age-0 and -I shad were more abundant and smaller in Cove A than in Cove B. The large difference in abundance of age-0 shad could reflect random variation in their distribution among coves, but more probably it reflects the same longitudinal trend in abundance that is characteristic of larval shad in Lake Shelbyville (Storck et al. 1978). The difference in size attained by shad at the two stations is consistent with a hypothesis of density-dependent growth. The difference in size attained by age-0 shad is important to predator-prey relationships within the reservoir, because
the availability of young shad to smaller predators can vary substantially with prey growth. If the
two cove estimates of size-structure and abundance of age-0 shad reasonably reflect population
parameters for the respective areas of the lake, shad potentially contribute more to the food supply
of small piscivores at the upper end than at the lower end of the reservoir.

In Cove A, the size structure of the gizzard shad population was dissimilar among sections.
Young-of-the-year made up a much larger fraction of the total shad population in section III than in
the two shallower sections \( P < 0.05 \). In contrast, the size composition of age-I and older shad
was similar in all three sections. The numerical and biomass standing crops (no./ha, kg/ha) of age-
0 shad in section III were nearly twice as large as in sections I and II, while standing crops of older
age groups were more similar among sections (Table 1).

In contrast to the distribution of shad within Cove A, young-of-the-year in Cove B made up a
smaller fraction of the shad population in section III than in sections I and II \( P < 0.05 \). The size
structure of age-I and older shad was similar in all three sections. In addition to differences in the
distribution of age-0 fish among sections, the numerical and biomass standing crops of three major
age groups \( 0, I, II+ \) were substantially greater in section III than in sections I and II (Table 1).

The observed differences in the size structure and standing crops in sections within each cove are
important because the relative contribution of each section to the total cove area is determined by
the placement of the block net. A more lakeward placement of the net would serve to increase the
relative contribution of habitat typical of section III and may alter estimates of both density and size
structure of the shad population. However, Hayne et al. (1968) found that numerical and biomass
standing crops were not higher, for either young or harvestable shad, in the outer 1.2-ha portions
of coves than in the inner 0.8-ha.

RECOMMENDATIONS: The same sampling program should be repeated in Segment 2 to determine
if the patterns in abundance and size structure within and between coves are consistent from year to
year.

Job 2. Trawl-derived estimates of standing crops of gizzard shad and threadfin shad.

OBJECTIVE: To estimate the standing crops of vulnerable size classes of gizzard shad and
threadfin shad in open-water areas of Lake Shelbyville and to compare these estimates with cove
rotenone estimates.
INTRODUCTION: All size classes of gizzard shad are found in the deeper, open-water areas of large reservoirs. Although this habitat constitutes a large fraction of the total water volume available to shad, quantitative estimates of abundance in this area are difficult to obtain using conventional, fixed entrapment gear. Consequently, there has been a conspicuous gap in knowledge concerning the structure and size of gizzard shad populations in the mid-water zone of reservoirs. This job develops methods for estimating gizzard shad abundance in the open-water areas of Lake Shelbyville using mid-water and bottom trawls. The intent of this research is to develop a sampling program that minimizes both the complexity of sampling gear and the sampling effort required to obtain accurate and precise estimates of abundance.

METHODS: Two tubular aluminum-frame, mid-water trawls were purchased for sampling open-water areas in Lake Shelbyville. The large trawl (1.8 x 1.8 m frame) was 7.9 m long, and consisted of four tapered sections with graduated mesh sizes (bar measure) of 10.2, 7.6, 3.8, and 1.9 cm. The small trawl (1.5 x 1.5 m frame) was 7.0 m long and consisted of three tapered sections with graduated mesh sizes of 5.1, 2.5, and 1.3 cm. Both trawls had 0.6-cm mesh cod ends (2 m long).

Towing bridles made of 0.63-cm diameter steel cable were attached at the sides of each trawl frame, at a point one-third of the distance from the top of the trawl. A third bridle was attached at the center of each frame bottom to insure that the plane of the trawl mouth remained perpendicular to the water surface. Bridle lengths were 7.5 and 4.6 m on the large and small trawl, respectively. A single towing warp (0.95-cm diameter steel cable), attached to the bridles, was fed from a winch (1:1 gear ratio) mounted on the gunwale, and ran over a pulley hanging from an A-frame support mounted on the boat stern. The trawl was deployed from a 5.2-m aluminum jon-boat, equipped with a 50-hp outboard engine.

A 7.5-kg bronze depressor was attached at the junction of the bridles and towing warp to increase towing depth. The depth of the trawl was estimated from the angle of the towing warp and the length of wire out, using the cosine relationship. Boat speed was measured using a calibrated flow meter.

A Lowrance X-16 computer sonar graph unit was used to monitor the vertical distribution of fish and provide a warning of bottom obstructions when sampling near the bottom.

A small otter trawl (head rope = 3 m) was tested as a method for determining species composition and abundance near the bottom where mid-water trawling was not possible.
RESULTS: The trawls arrived too late in 1986 to initiate a quantitative sampling program. Instead, we used all available time to improve gear performance. Initial problems encountered included the spinning of the trawl frame; a tendency of the bottom of the trawl frame to ride up in the water; and a lack of control of trawling depth. The addition of a third bridle, and adjustments in bridle lengths successfully stabilized the trawls in the water. In contrast, trawling depth was relatively insensitive to changes in the length of the towing warp because the towing warp angle was very large (82-85°) at all useful towing speeds. Thus, the length of towing warp cable necessary to achieve desired depths was prohibitive. Numerous depressor and weight combinations were tested in an effort to reduce the towing warp angle, and thus gain control of sampling depth. No suitable solution to this problem was found in 1986, and the trawl continued to run at or near the surface. To remedy this problem, additional depressors, with a larger surface area and a greater downward thrust, have been purchased for use in 1987.

We used relatively large-mesh netting in the forward panels of the large mid-water trawl because many pelagic species orient to visual cues, and thus tend to move along, instead of through, mesh panels (Hayes 1983). However, while testing the 1.8-m trawl, we observed many age-0 shad escaping through the large mesh. The 1.5-m trawl, which was constructed using panels of smaller mesh, was more effective at capturing young shad, but there was no certainty that some age-0 shad were not also passing through the forward panels in this trawl. Consequently, two additional trawls, constructed of smaller mesh panels, were purchased for testing in 1987.

Net drag increases, and maximum towing speed decreases, with decreasing mesh size. The maximum towing speed of trawls constructed with meshes sufficiently small to collect age-0 shad may be too slow to capture adult shad. Consequently, it may necessary to use two trawls in the sampling program, one with large mesh in the forward sections for capturing yearlings and adults and one with a smaller mesh for capturing age-0 shad.

In October 1986, the distribution of fish was monitored using the sonar graph unit. In early October, large diel changes in fish distribution were evident. During daylight hours, fish were concentrated in creek channels, and at the edges of the channel, in large schools extending from near the bottom to near the surface. Few fish were detected by sonar on the extensive flats adjacent to the channels. By night, these large schools had dispersed and the fish were abundant and widely dispersed on the flats, mostly near the bottom. In late October, however, the night-time distribution changed dramatically, with few fish being observed on the flats near the bottom.

Because the vertical distribution of fish in October was variable, and because fish were most abundant near the bottom, mid-water trawling is not an effective technique this late in the year.
However, the sonar data did confirm that age-0 shad are dispersed at night, a distribution pattern more conducive to obtaining precise estimates of abundance. Because the lake is generally chemically stratified during the summer, fish may be generally higher in the water column, and consequently more vulnerable to mid-water trawling, during that period. Although mid-water trawling should be useful in mid-summer, it will be necessary to sample the near-bottom habitat with otter trawls to quantify use of that habitat by shad.

RECOMMENDATIONS: Although quantitative estimates of shad abundance could not be obtained in 1986, the mid-water trawl did demonstrate potential for sampling gizzard shad; a maximum of 702 age-0 shad and 33 adults were collected in individual 5-minute tows. Therefore, sampling should continue in 1987 with efforts in the spring directed toward developing control of sampling depth and determining the optimum mesh sizes needed to collect various size groups of shad.

Job 3. Sampling gizzard shad with gill nets.

OBJECTIVE: To measure the catch rates of age-I and older gizzard shad in gill nets fished at various depths and to determine if any depth deployment can produce an index of shad abundance that is proportional to true abundance and that can produce an unbiased estimate of population size and age structure.

INTRODUCTION: Gill nets are useful for collecting gizzard shad but individual meshes are size selective. Moreover, fish are not necessarily caught in gill nets at a uniform rate, since the efficiency of a net decreases as fish accumulate in it (Hamley 1975). Thus, estimates of abundance and age structure of shad derived from gill net catches may require adjustments for size selectivity of various meshes. Gizzard shad are better suited for developing selectivity curves than are many other species, because the curves are less skewed for species such as shad that are wedged rather than tangled in the mesh. Selectivity curves are most easily developed and are most suitable for making adjustments in estimated size structure, when based on numerous closely spaced meshes.

This job compares estimates of size and age structure of a shad population using fish captured in IDOC gill nets, and in gill nets that include a larger number of closely spaced meshes (INHS), with estimates obtained from rotenone and trawling samples. Adjustments for mesh selectivity will be applied to 1987 catches in an effort to reduce bias in gill net estimates of population parameters. Gill net catches of young-of-the-year are not being examined in this study because rotenone and trawl samples should provide substantially better estimates of size structure and abundance of age-0 shad.
METHODS: Gizzard shad were sampled with gill nets at four locations on Lake Shelbyville (Fig. 1). Station I was located in the Kaskaskia River arm; Station II was immediately downlake from the junction of the Kaskaskia and Okaw River arms; Station III was in the main body of the lake near Eagle Creek State Park; and Station IV was located near the dam. These four stations were sampled during August and September 1986 with monofilament nylon gill nets (INHS) that were 46 m long x 1.8 m deep; the nets were hung on a 0.7 basis and consisted of six 7.6-m panels with meshes of 1.9, 2.5, 3.2, 3.8, 4.4, and 5.1 cm (bar measure). A unit of effort consisted of two nets set for 20-24 hours at each sampling station. Nets were set either on the bottom or at the surface. Bottom sets were made in water at least 4 m deep. When nets were deployed at the surface, they were suspended by floats approximately 1 m below the surface in the same areas as the bottom sets.

Gill net catches from IDOC fall censuses were also evaluated. Their nets were 76 m long x 1.8 m deep; they were hung on a 0.5 basis and consisted of five 15.2-m panels with meshes of 1.9, 2.5, 3.8, 5.1, and 6.3 cm (bar measure). Two nets with these dimensions were also set in Cove B for 2 consecutive days preceding the application of rotenone. Gill nets were not set in Cove A because the water was too shallow.

RESULTS: Although some of the meshes used in INHS and IDOC nets differed, both nets sampled most of the size classes of age-I and older shad present in Lake Shelbyville in the fall of 1986 (Fig. 4 and 5). The largest (5.1 cm) and smallest (1.8 cm) meshes in the INHS nets collected few fish (Fig. 6). The large mesh was apparently efficient only for shad larger than were present in Lake Shelbyville in 1986. The smallest mesh failed to collect small age-I shad (15-17 cm) that were too small to be effectively sampled by the second smallest mesh (2.5 cm). Based on rotenone samples, this length range of shad made up 60% of the recruited population in September 1986. The failure to sample them in proportion to their abundance may reflect either inadequate overlap in the selectivity curves of the 1.8- and 2.5-cm meshes or the failure of small age-I shad to use habitat sampled by gill nets. The fact that the 1.8-cm mesh failed to capture either small age-I shad or large age-0 shad suggests that its selectivity curve is extremely narrow or that vulnerable size groups were not present in the area sampled. The largest shad (33-38 cm) apparently did not use cove habitats, since they were absent from both of the rotenoned coves (Fig. 4 and 5). Too few shad were collected in gill nets set in Cove B (IDOC mesh complement) to evaluate the vulnerability of shad to the various size meshes.

Catch curves for 3 of 4 intermediate mesh sizes in INHS nets (Fig. 6) were unimodal and relatively smooth, presumably because shad are generally wedged rather than gilled or tangled. The absence of substantial skew in these curves will allow for more accurate adjustments of size structure data.
Fig. 4. Length-frequency distribution of age-I and older gizzard shad recovered in Cove A and captured by gill nets at Station I in September 1986.

Fig. 5. Length-frequency distributions of age-I and older gizzard shad recovered in Cove B and captured by gill nets at Station III in September 1986.

in 1987. Bimodality in the catch curve of the 3.1-cm mesh likely occurred because this mesh was most efficient for size classes of shad that were poorly represented in the population in 1986.

The size structure of the shad population may change from year to year depending on the relative abundance and growth of individual year classes. Consequently, individual mesh sizes will not be
Fig. 6. Catch curves by mesh size for gizzard shad captured by experimental gill nets at Station I on Lake Shelbyville in 1986.
equally important to the estimate of size structure in all years. For example, the absence of a 3.2-cm mesh from the IDOC net had no major effect on the estimate of size structure of the catch because the capture efficiency of this mesh was greatest for lengths of shad that were rare in 1986 (Fig. 4 and 5). This mesh may become important in 1987 as individuals in the strong 1985 year class increase in size. In contrast, because the 4.4-cm mesh was absent from the IDOC nets, they collected relatively fewer shad in the 28- through 31-cm size classes than did INHS nets.

The size and age structure of shad collected in IDOC and INHS gill nets set in offshore areas near Cove A were dramatically different from those of shad collected in the rotenone cove. The gill net samples were made up of proportionately fewer (25%) but larger age-I fish. This difference may reflect size selectivity of gill nets, differences in the size structure of shad occupying offshore and cove habitats, or some combination of the two. Trawling catches in 1987 will help distinguish between these alternate explanations.

In contrast, differences between size structure in Cove B and in gill net samples from adjacent offshore areas were relatively small. The estimates of size structure were similar because the small age-I shad (15-17 cm) not captured in IDOC and INHS nets were not as abundant in Cove B as in Cove A.

The IDOC gill net catch rates decreased in a downlake direction, which was consistent with a difference in abundance of shad in uplake and downlake coves and with a nonsignificant longitudinal trend in IDOC electrofishing catch rates. Trawl catches in subsequent years will be used to determine if these catch rate statistics reflect true differences in the abundance of shad within the reservoir.

It is certain that regardless of the mesh complement used, gill net catches cannot estimate population size structure of shad adequately without making adjustments for mesh selectivity. Gill net catches consistently included proportionately fewer age-I shad than did electrofishing or rotenone catches.

RECOMENDATIONS: This job should be continued in 1987 with more replicates being made at each station to estimate population density. Also length-frequency distributions of the catch should be adjusted to correct for the selectivity of individual mesh sizes.
Job 4. Electrofishing catch rates of gizzard shad.

OBJECTIVE: To measure catch rates and age and size structure of gizzard shad captured in shoreline electrofishing collections taken during the day and at night; these estimates will be compared with estimates obtained using other gears and with those obtained by Illinois Department of Conservation biologist in routine fall electrofishing surveys.

INTRODUCTION: Electrofishing is a valuable sampling method for collecting gizzard shad but is generally effective only along the shoreline. Moreover, the potential for electrofishing catches to estimate population size structure or abundance has not been evaluated. The use of shoreline habitat by shad differs seasonally and perhaps among age groups in all seasons; capture efficiency may be influenced by fish size, turbidity, water temperature, conductivity, and physical characteristics of the habitat. Electrofishing catches can be especially variable in the spring when mature fish are concentrated in optimum spawning habitat.

The purpose of this job is to determine if day or night electrofishing samples taken in late summer can provide estimates of population age and size structure and if electrofishing catch rates reflect true population abundance.

METHODS: Segments of the shoreline were sampled at the same four stations used for gill netting (Fig. 1). It was hypothesized that shad are distributed differently in coves than along the main lake shoreline and that density is least variable along shorelines with similar slopes. Therefore, two mainlake habitats (slopes of 8 and 20%) and one cove were sampled at each station. On each sampling date, two 10-minute replicate runs were made in each of the three habitats, during both day and night hours. An attempt was made to capture all stunned shad except young-of-the-year and all captured shad were measured to the nearest cm total length.

Timed electrofishing samples were taken in coves by IDOC personnel immediately before rotenone was applied. One circuit was made around the perimeter of each cove and an attempt was made to net all size classes of all fish species. Electrofishing samples were also collected by IDOC personnel in mid-September at six locations on Lake Shelbyville. The IDOC sampling procedure differed from that used in INHS collections in that their biologists collected all age groups of shad and all other species of fish. Three 6-minute replicates samples were taken at each station, with no attempt being made to restrict sampling to similar habitats.

RESULTS: In both rotenone coves, electrofishing catch rates by IDOC personnel substantially underestimated the proportion of the shad population made up of age-0 fish ($P < 0.05$). In Cove
A, young-of-the-year shad accounted for 47 and 77% of shad recovered in electrofishing and rotenone samples, respectively. Similarly at Cove B, they accounted for 33 and 62% of the shad in electrofishing and rotenone collections. Exclusive of age-0 shad, the size structure of shad in electrofishing and rotenone collections was similar \((P > 0.05)\). Shad were not sampled efficiently by shoreline electrofishing since no more than 1% of age-0 shad and no more than 3.5% of age-I and older shad present in each cove were captured in the electrofishing samples.

Daylight electrofishing collections of age-I and older shad were made by INHS personnel in August and September at both rotenone coves. The age structure of the catch in these collections was similar to the age structure in the coves \((P > 0.05)\); however, the size structure of shad in the electrofishing collection differed from the population structure in Cove A \((P < 0.05)\) because age-I shad averaged 5 mm larger in the electrofishing collections.

Night electrofishing collections (INHS) in the two coves in mid-August produced conflicting results. At Cove A, electrofishing samples greatly underestimated the relative abundance of age-I shad in the cove \((P < 0.05)\), while at Cove B the size and age structure of electrofishing and rotenone samples were similar \((P > 0.05)\).

The age structure of shad in IDOC fall electrofishing samples at stations I and III and in nearby rotenone coves were similar \((P > 0.05)\). However, because the electrofishing and rotenone samples were taken approximately 3 weeks apart and included different habitats, the similarity of the catches may be coincidental.

Electrofishing catch rates were not proportional to shad density in coves. Shad density (no./ha) was 17 times greater in Cove A than in Cove B, while the electrofishing catch rate was only 3.5 times greater in Cove A. Exclusive of age-0 fish, shad were 8 times more abundant in Cove A than in Cove B but less than 2.5 times more abundant in the electrofishing catch. Turbidity was not responsible for the differences in capture efficiency; secchi disc readings were 43 and 42 cm at coves A and B, respectively. Likewise, conductivity was similar at the two stations, 420 and 440 \(\mu\)mhos/cm at coves A and B, respectively.

At each of four stations sampled, INHS electrofishing catch rates of age-I and older shad were similar in the three habitats sampled and did not differ over the sampling interval (July-September); however catches were greater during the day than at night and there was a significant interaction between time of day and habitat type (Table 3). The results suggest that any habitat in an area sampled during a relatively large part of summer will yield similar estimates of shad density. However, the value of these catch rates statistics for comparing shad density among areas in the...
Table 3. Analysis of electrofishing catch rates of age-I and older gizzard shad at Station I, Lake Shelbyville, 1986. Three habitats (locations) were sampled during daylight and at night (time) on three dates.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
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<tbody>
<tr>
<td>Replication</td>
<td>1</td>
<td>283</td>
<td></td>
</tr>
<tr>
<td>(T)ime</td>
<td>1</td>
<td>10,370</td>
<td>33.5^a</td>
</tr>
<tr>
<td>(L)ocation</td>
<td>2</td>
<td>404</td>
<td>1.3 ns</td>
</tr>
<tr>
<td>(D)ate</td>
<td>2</td>
<td>108</td>
<td>0.3 ns</td>
</tr>
<tr>
<td>T x L</td>
<td>2</td>
<td>2,081</td>
<td>6.7^a</td>
</tr>
<tr>
<td>T x D</td>
<td>2</td>
<td>427</td>
<td>1.4 ns</td>
</tr>
<tr>
<td>L x D</td>
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<td>505</td>
<td>1.6 ns</td>
</tr>
<tr>
<td>T x L x D</td>
<td>4</td>
<td>172</td>
<td>0.6 ns</td>
</tr>
<tr>
<td>Error</td>
<td>17</td>
<td>310</td>
<td></td>
</tr>
</tbody>
</table>

^aP < 0.01; ns = not significant

reservoir is questionable, because electrofishing catch rates appear not to be proportional to true abundance.

At individual stations, day electrofishing collections (INHS) along gentle and steeply sloping shorelines in the main lake produced similar estimates of population size structure (P > 0.05). Moreover, the size structure in coves did not differ from the size structure of pooled samples from steep and gently sloping shorelines (N = 7). However, even though the differences were never significant, age-I shad made up a smaller fraction of the population in coves in every comparison.

The age structure of shad collected with electrofishing gear differed among the four INHS stations ($X^2 = 10.26, df = 3$). Age-I fish made up a relatively larger fraction of the population at Station I, a smaller fraction at Station IV, and intermediate fractions at stations II and III. The age structure statistics may reflect a true longitudinal trend in the age structure of shad in Lake Shelbyville, because age-I shad were also relatively more abundant in the uplake cove (Cove A) than in the downlake cove (Cove B). In contrast, age structure did not differ at IDOC fall electrofishing stations ($X^2 = 6.8, df = 5, P > 0.05$).
The fall electrofishing catch (IDOC) rates of gizzard shad did not differ among stations for young-of-the-year ($F = 1.85, df = 4, 10$) or for age-I and older fish ($F = 1.98, df = 4, 10$). For both age classes, differences in mean catch rates were large, with a trend of decreasing abundance in a downlake direction. Nonetheless, differences were not significant because the variation among replicates at each station was extremely large. Even if shoreline electrofishing catch rates reflect population abundance, only very large differences in density can be detected using the current IDOC sampling design. Greater power in the statistical test could be achieved by increasing either the duration of each replicate (currently 6 minutes) or the number of replicates at each station (currently three).

August electrofishing catch (INHS) rates also did not differ among the four stations sampled ($F = 2.38, df = 3, 12$). The downlake trend of decreasing abundance indicated in IDOC collections was not evident in INHS collections. Moreover, the test was more powerful than that used in the IDOC analysis, because the number of replicates and their duration was increased.

Job 5. **Fecundity and age structure of adult gizzard shad in the spring.**

**OBJECTIVE:** To measure age-specific fecundity of gizzard shad, to determine the age structure of the spawning population, and to determine length at age for age-I and older shad.

No work was scheduled for this job during this segment.

Job 6. **Analysis and reporting.**

**OBJECTIVE:** To compare estimates of relative abundance and size and age distributions of shad collected by Illinois Department of Conservation biologists by electrofishing and gill netting in routine fall surveys with estimates derived from cove rotenone and mid-water trawling surveys; and to recommend appropriate sampling gears and methodology for use by IDOC biologists that will enable them to follow shad population dynamics, monitor abundance, and determine changes in population structure.

**INTRODUCTION:** Many of the planned comparisons of sampling gears could not be made in 1986 because estimates of abundance and size structure of shad in trawls were not obtained. Moreover, the evaluation of the potential of various gears for estimating population parameters and the development of optimum sampling methodologies must await analysis of trends in shad abundance.
and size structure that will occur over the course of the study. Catch statistics of the various sampling gears are evaluated in the appropriate jobs. Only proportional stock density (PSD) and relative weight (Wr) are examined in this job.

METHODS: PSD and Wr statistics are defined for gizzard shad by Anderson (1980).

RESULTS: The PSD of gizzard shad was 5% in both of the rotenone coves. Electrofishing estimates derived from INHS and IDOC collections were generally similar but slightly lower than the cove rotenone values, while gill net estimates averaged 10-20%. The differences among estimates were relatively small and do not necessarily reflect gear biases since each gear sampled different habitats. Gill net estimates of PSD may become more similar to those of the other gears once adjustments are made for mesh selectivity. Trawl catches in 1987 should help determine the true population PSD.

Regardless of which gear estimated PSD most accurately, the population value in Lake Shelbyville was clearly well below the 30-60% considered desirable in small impoundments (Anderson 1983). The low PSD reflected highly variable recruitment. An abundant and rapidly growing 1985 year class contributed more than 80% of the fish in the stock category (>18 cm) but none in the quality category (>28 cm).

If dominant year classes are typically formed at intervals in Lake Shelbyville, as suggested by an earlier study (Storck 1986), PSD will likely follow a cyclic pattern, being low when the dominant year class is 1 year old and increasing as individuals in this year class reach quality size. Thus PSD will be associated with the age and growth rate of the dominant year class, and may serve as an indicator of the abundance of adult stock.

At Station I, Wr was low for most size classes of shad while at Station IV it was high for younger fish but low for older fish (Fig. 7). The between-station difference in Wr of younger shad is consistent with a hypothesis that shad are more abundant in uplake areas and that food consumption is density dependent. The similarity of Wr values for older fish suggests that factors other than competition for food may be important. Trends in Wr values and population density in subsequent years will be used to evaluate this hypothesis.
Fig. 7. Relative weight (Wr) of age-I and older gizzard shad at stations I and IV in 1986. Sample size was five fish from each 1-cm length interval.

Literature Cited


Jester, D. B., and B. L. Jensen. 1972. Life history and ecology of the gizzard shad, Dorosoma cepedianum (LeSueur), with reference to Elephant Butte Lake. New Mexico State University, Agricultural Experiment Station Research Report 218.


