Special Publication SJ94-SP5

Ichthyofaunal Studies as Part of the Trophic Structure Manipulation Project

Final Report for Segments I–III

For St. Johns River Water Management District

by

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Prepared for

St. Johns River Water Management District
Palatka, Florida

1994

EXECUTIVE SUMMARY

Lakes Denham (257 acres), Apopka (30,319 acres), and Beauclair (1,112 acres) were sampled from January 1989 through June 1992 to assess the fish community of each lake and evaluate the response of Lake Denham's fish community to the removal of a large percentage of gizzard shad. In January of 1990, the St. Johns River Water Management District (SJRWMD) installed a plastic mesh barrier to isolate Lake Denham from the other lakes of the Ocklawaha chain. A contractor employed by SJRWMD removed 87,356 pounds (lbs) of gizzard shad (340 lbs/acre) in 35 haul seine pulls. This was estimated to be an 82 percent reduction in the stock of gizzard shad that were vulnerable to capture by the haul seine. In May 1991, the contractor removed 20,040 lbs of gizzard shad (78 lbs/acre) in 13 haul seine pulls, which represented an 88 percent reduction in the catchable gizzard shad stock. In June 1992, 8 haul seine pulls removed only 6,887 lbs of gizzard shad (27 lbs/acre), and the effort was discontinued.

In the shallow water zone of Lake Denham, subharvestable fish of three sportfish species—largemouth bass (less than 9.5 inches) and bluegill or redear sunfish (less than 5.5 inches)—showed significantly ($P < 0.1$) increased abundance during 1991–92 (June through May) from measurements taken during 1989–90 and 1990–91. Lake Beauclair (a control lake) also showed a significant increase during 1991–92 in subharvestable bluegill and an increase (though not statistically significant) in subharvestable redear. No gizzard shad removal was conducted in Lake Beauclair. The influence of other factors that may have caused more juvenile game fish to be produced during this year (temperature, rainfall, or changes in nutrient inputs to the lake) was not explored within the scope of this report. None of the fish communities of the three lakes showed significant increases for harvestable-sized largemouth bass, bluegill, or redear.

Gizzard shad abundance in Lake Denham was effectively reduced by the use of a haul seine. Direct methods for measuring gizzard shad abundance (experimental gill nets and 1-acre blocknets) were inconclusive in documenting the decline, but indirect evidence (such as the shift in length frequency from larger to smaller fish) confirmed data derived from the haul seine catch. The gizzard shad population of Lakes Apopka and Beauclair showed no significant changes or trends.

It is not possible to attribute the increase in juvenile sportfish in Lake Denham to gizzard shad removal at this time. Increased sportfish abundance was observed for bluegill and redear sunfish in Lake Beauclair, where gizzard shad were not removed. There has also not been any increase observed in harvestable-sized (adult) sportfish in Lake Denham. Other factors (habitat type and extent) that may influence the abundance of juvenile fish and their subsequent recruitment to harvestable sizes were not considered within the scope of this report. This study should be continued for another season to determine if the increased abundance of juvenile sportfish produce increased numbers of adult fish.

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ABSTRACT

Lakes Denham (104 hectares), Apopka (12,270 hectares), and Beauclair (450 hectares) were sampled from January 1989 through June 1992 to assess the fish community in each lake and evaluate the response of the fish community of Lake Denham to a large-scale removal of gizzard shad (*Dorosoma cepedianum*). In January of 1990, Lake Denham was isolated from the Ocklawaha chain of lakes with a barrier. In 1990, 39,624 kilograms (kg) of gizzard shad were removed in 35 haul seine pulls, which was estimated to be an 82 percent reduction in stock available for capture by a Leslie regression of catch-and-effort. In May 1991, 13 haul seine pulls resulted in the removal of 9,090 kg of gizzard shad, representing an 88 percent estimated reduction of gizzard shad stock available for capture. In June 1992, 8 pulls with the haul seine removed only 3,124 kg of gizzard shad. No estimate of gizzard shad biomass available for capture was possible in 1992.

In the Lake Denham littoral zone, subharvestable (less than 24 centimeters [cm]) largemouth bass (*Micropterus salmoides floridanus*) increased significantly ($P < 0.1$) in abundance in electrofishing and blocknet samples during 1991–92 (June through May). Estimates of young-of-the-year (YOY) largemouth bass collected in fall blocknet samples increased from an average of less than 10 fish/hectare in 1989 and 1990 to 110 fish/hectare in 1991 samples. Harvestable bass (greater than 24 cm) abundance averaged less than 2 fish/5 minutes of electrofishing catch per unit effort (CPUE) in both Lakes Denham and Beauclair and less than 0.5 fish/5 minutes in Lake Apopka. In Lake Denham electrofishing samples, the CPUE for juvenile bluegill (*Lepomis macrochirus*) and redear sunfish (*L. microlophus*) (less than 14 cm) increased significantly ($P < 0.1$) during 1991–92. Lake Beauclair also demonstrated a statistically significant ($P < 0.1$) increase in CPUE for subharvestable bluegill and redear in electrofishing samples during the same time period. Lake Apopka showed some increased abundance of redear sunfish, but the increases were not significant. There were no other statistically significant changes in the littoral zone fish community of Lake Denham following the haul seine program for species composition or relative abundance of any species.

The limnetic zone of all three lakes was dominated by gizzard shad, as demonstrated by gill net and blocknet samples. The biomass of gizzard shad in Lake Denham was substantially reduced in 1990 and 1991 by the haul seine, as documented by the Leslie regression of haul seine catch-and-effort data and the shift in length frequency of gizzard shad collected in experimental gill net samples toward smaller-sized fish. Blocknet samples also indicated a declining average weight in gizzard shad, dropping from an average of 362 grams per fish (g/fish) in fall 1989 (prior to haul seine program) to 37 g/fish in fall 1992. The difficulty of measuring the biomass of a schooling pelagic species was evident from both blocknet and gill net sample results, which were inconclusive in directly

demonstrating a decline in abundance of gizzard shad following the haul seine program in Lake Denham. Indirect evidence gathered in gill net and blocknet samples supported the conclusion that a substantial portion of the gizzard shad stock of Lake Denham was removed by successive haul seine operations. There were no other statistically significant changes detected in the limnetic zone fish community.

Since there were statistically significant increases ($P < 0.1$) in juvenile sportfish abundance in both Lakes Denham and Beauclair, it was not possible to attribute the increase in Lake Denham solely to the removal of gizzard shad. The influence of other variables (e.g., water temperatures, nutrient loading, and plankton community composition and abundance) was not explored within the scope of this report. Harvestable-sized sportfish showed no appreciable increase in abundance in any lake. This study should be continued for another season to determine if the increased abundance of juvenile sportfish produces increased numbers of adult fish.

INTRODUCTION

The Ocklawaha Basin Fisheries Investigations Research Project of the Florida Game and Fresh Water Fish Commission has been involved with fisheries research problems on water bodies within the upper Ocklawaha basin for 19 years. Because Lake Apopka was specifically targeted for restoration under the Surface Water Improvement and Management Act (SWIM) legislation of July 1987, the Florida Game and Fresh Water Fish Commission designed and implemented a project in 1988 to evaluate sport fish populations in the lake.

Through a May 1989 cooperative agreement with the St. Johns River Water Management District (SJRWMD), the Florida Game and Fresh Water Fish Commission expanded the existing sampling program to include an assessment of the entire fish communities in Lakes Beauclair, Denham, and Apopka and an evaluation of the response of the fish community in Lake Denham to the large-scale removal of gizzard shad (*Dorosoma cepedianum*) undertaken by SJRWMD. Lakes Apopka and Beauclair served as controls.

Biomanipulation of fish communities as a lake restoration tool has been well documented in temperate lakes (McQueen 1990). However, it has been studied only on a small scale (Crisman and Beaver 1988), or it has been focused only upon the response of sport fish species in Florida lakes (Ware 1971). This project followed the response of the fish community in Lake Denham to removal of a substantial percentage of the stock of a planktivore, in this case, gizzard shad. Kautz (1981) showed that gizzard shad can dominate fish biomass in Florida lakes under hypereutrophic conditions similar to those found in Lakes Apopka and Denham. This manipulation of the fish community structure theoretically should invoke a series of changes at different trophic levels (McQueen 1990). Desired results of planktivore removal include (1) an increased abundance of large-bodied zooplankton to elevate grazing pressure on phytoplankton, thereby decreasing algal biomass and perhaps changing the species composition of the phytoplankton community; (2) a reduction in nutrient recycling induced by planktivorous fish; (3) an export of nutrients in the form of fish flesh; and (4) an improvement in water quality and aquatic habitat (e.g., increased macrophyte growth, improved dissolved oxygen profile, and reduced flocculent sediment volume), which is the key to maintaining a diverse fish community and lake ecosystem.

Ware (1971) showed that manipulation of a fish community through the use of a haul seine produced a positive change in the largemouth bass (*Micropterus salmoides floridanus*) population of Lake Hollingsworth (144 hectares) following the removal of 38,880 kg of fish (including gizzard shad, brown bullhead [*Ameiurus nebulosus*], bluegill [*Lepomis macrochirus*], and black crappie [*Pomoxis nigromaculatus*]). Theoretically, the fish population of Lake Denham should respond to the removal of substantial numbers of gizzard shad with increased reproduction and recruitment among other planktivorous fish, and predator (largemouth bass) abundance should increase due to greater prey availability. This report provides an assessment of the fish communities of Lakes Apopka, Beauclair, and Denham. It documents changes in the fish populations of Lake Denham following a large-scale gizzard shad removal by SJRWMD in 1990, with follow-up haul seine operations in 1991 and 1992.

METHODS

Lake Denham, the study lake selected for manipulation of the fish population, is a 104-hectare lake connected to the Ocklawaha chain of lakes (Figure 1). Lakes Apopka (12,270 hectares) and Beauclair (450 hectares) served as control lakes. SJRWMD isolated Lake Denham from the other lakes by installation of a plastic mesh barrier in January 1990. SJRWMD hired a commercial haul seine crew to remove as much gizzard shad biomass as possible in three consecutive years: between January and April 1990, during May of 1991, and during June of 1992.

The fish populations in all lakes were evaluated using similar methods; however, all sample methods were not used in all lakes and the intensity of sampling was greatest for Lake Denham. Limnetic blocknet-rotenone samples (0.4 hectares) were taken in selected sites in Lakes Apopka (N = 6), Beauclair (N = 4), and Denham (N = 4) during May and June of 1989, 1990, 1991, and 1992 to assess the open-water fish community. Lake Denham was also sampled with two 0.4-hectare limnetic blocknets in the fall of each year. Fish were collected for three days following application of rotenone to the enclosed area, sorted to species, measured into 2-cm groups, and weighed (in grams [g]) collectively in groups.

Blocknet-rotenone samples were taken in littoral habitats in Lakes Apopka (N = 8) and Denham (N = 4) during fall 1989, 1990, and 1991, using 0.1-hectare nets. In Lake Apopka, two sites contained no vegetation, one site contained *Scirpus californicus*, three sites contained *Typha latifolia* stands, and two sites contained *Panicum* sp. or *Paspalidium* sp. stands. In Lake Denham, two sites were in *Panicum* habitat, and two sites were in non-vegetated areas. Fish collection procedures were the same as for spring blocknet samples. Percent relative abundance was defined as the percentage by number or weight of a particular species to the whole sample and was useful in examining changes in littoral zone blocknet data.

Electrofishing samples were taken in the littoral zone of Lakes Apopka, Beauclair, and Denham using a 5.2-meter (m) aluminum boat, a 5-kW generator, and a Smith-Root Type VI-A pulsator. The electrical field was maintained at 500 V and 5 to 6 amps DC. Samples were 5 minutes (pedal time) in duration. All fish species were collected, identified, individually measured (in millimeters [mm]) and weighed (g), and returned alive to the sample area. In Lake Apopka, electrofishing was conducted at 2-month intervals along 30 transects (15 fixed sites and 15 random sites). In Lake Beauclair, 15 fixed sites were sampled at 2-month intervals in alternate months with Lake Apopka. Lake Denham was sampled monthly at 12 fixed sites. Electrofishing data were evaluated using catch per unit effort (CPUE), defined as the number or weight of a fish species captured per

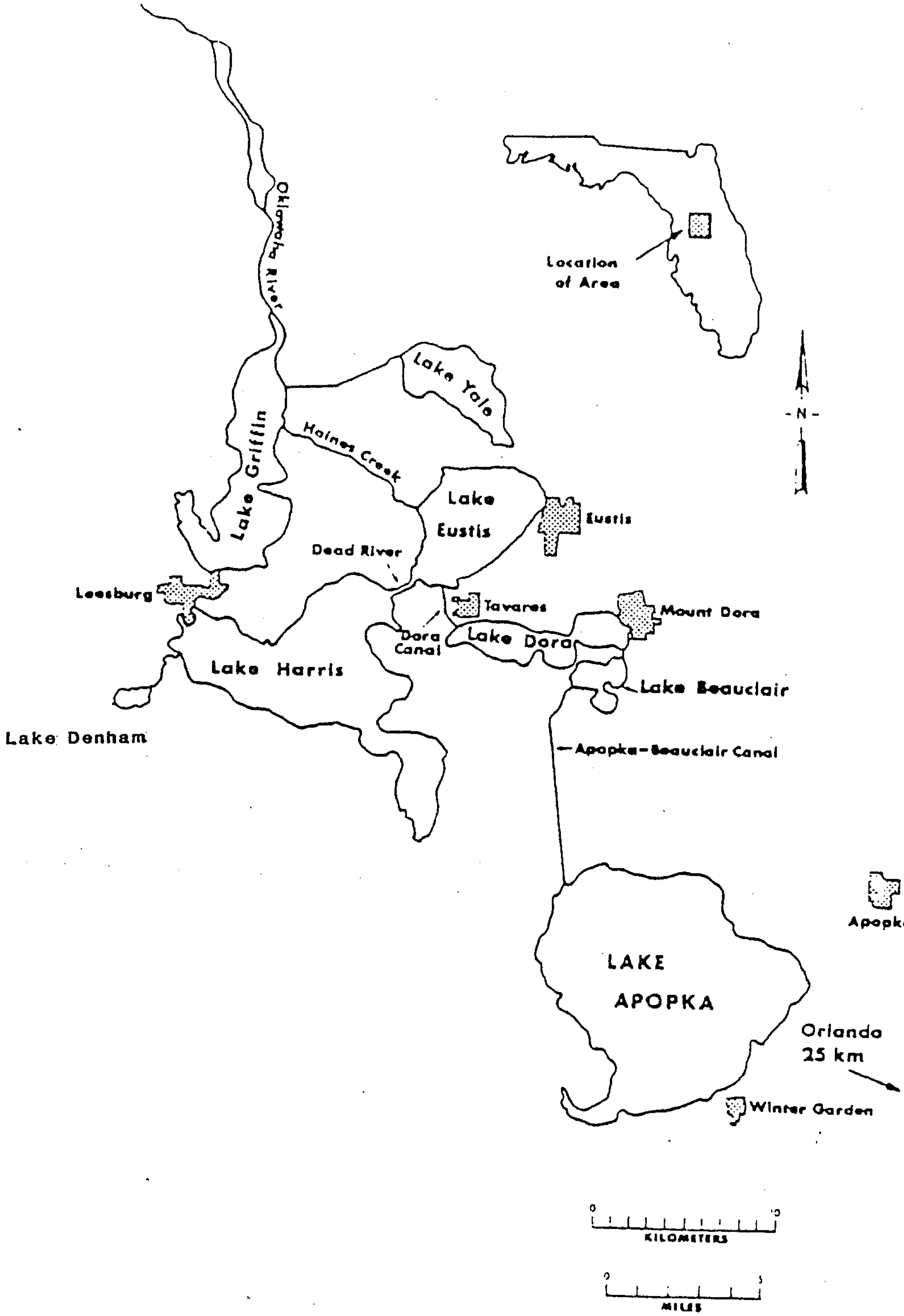

Figure 1. Ocklawaha chain of lakes

5 minutes. CPUE values for fractions of a particular population, such as harvestable or subharvestable largemouth bass, were often too small to report in terms of fish per minute (which is customarily used to report electrofishing results); therefore, CPUE per 5 minutes was used. For purposes of analyzing electrofishing data, the period from June 1989 through May 1990 was defined as the first sample year, June 1990 through May 1991 as the second sample year, and June 1991 through May 1992 as the third sample year.

Experimental gill nets 90 m in length (six sections of 6.4 to 12.7 cm, #139 stretch monofilament net in 1.3-cm increments) were set for 2 hours to assess the limnetic fish community. Fish caught were individually measured (total length, mm) and weighed (g). Ten samples were collected at 2-month intervals in Lakes Apopka and Beauclair, and five samples were taken monthly in Lake Denham. Gill net CPUE was measured as the number or weight of a species caught per 90 m of experimental gill net per hour.

Centrarchids collected in electrofishing or blocknet samples were classified for analysis according to harvestable and subharvestable sizes. Harvestable size for largemouth bass was defined as 24 cm or greater throughout the study, 22 cm or greater for black crappie, and 14 cm or greater for bluegill and redear sunfish (*Lepomis microlophus*).

A haul seine contractor was hired by SJRWMD to remove the target species of gizzard shad from Lake Denham during 1990, 1991, and 1992. Gar (*Lepisosteus* sp.) and blue tilapia (*Tilapia nilotica*) were also removed by the haul seine contractor. The haul seine varied from 823 m to 1,372 m in length, had a depth of approximately 4.5 m, and was constructed of 10.2-cm stretched mesh in the main body of the net, with a catch pocket constructed of 8.9-cm stretched mesh. The haul seine swept approximately 15 hectares per pull. All non-target species were immediately returned to the lake. Haul seine catches from Lake Denham were analyzed through randomly selected subsamples or "dips" from the catch pocket of the seine as it was emptied of fish. Approximately 10 percent of the total catch of each seine pull was sampled. Fish collected in the samples were sorted by species, and individual total lengths (mm) were measured for all fish. Weights of non-target species were estimated using weight-length relationships from experimental gill net and electrofishing data.

Most data were evaluated using the Kruskal-Wallis non-parametric test to determine differences (alpha = 0.1) among lakes and among years within lakes. With the exception of log transformed weight per unit length data, data from electrofishing, gill net, and blocknet samples violated the assumptions of homogeneity of variances (even when transformation was attempted), and the distribution of the data could not be assumed to fit the normal curve (Wilkinson 1990). Weight per unit length relationships for largemouth bass, bluegill, and gizzard shad were examined for changes using log transformations of data in an analysis of covariance by SYSTAT (Steele and Torrie 1980; Wilkinson 1990). Evaluations were made both among sample years within each lake and among lakes for a given year. The covariance evaluation for largemouth bass and bluegill was limited to the months of January through March, and to fish larger than 150 mm for largemouth bass. The evaluation for gizzard shad was limited to the months of October through December. The data sets were limited to minimize confounding factors of post-spawn weight changes in adult fish and the effects of large changes in weight per unit of length for smaller fish that tended to skew the analysis.

A study to determine ages of gizzard shad collected from Lake Denham was initiated in January 1990. Otoliths were removed from a total of 1,435 fish collected in monthly samples over an 18-month period to determine existence and timing of annular ring formation, which is a prerequisite for using otoliths as a tool to accurately assess the age of fish (Jearld 1983). Concurrently, a sample of 435 gizzard shad was collected in November 1990 for age and growth studies. Otoliths were read whole under a compound microscope at 25X using reflected light, and ages were determined by agreement of at least two readers.

RESULTS AND DISCUSSION

LAKE DENHAM LITTORAL ZONE ASSESSMENT

Lake Denham contained the most fish species of the three study lakes, with 41 species representing 19 families (Table 1). Increased abundance for redear, bluegill, threadfin shad, and taillight shiners (*Notropis maculatus*) accounted for most of the 60 percent increase in total numerical abundance of fish in the fall 1991 blocknet samples over the average of 1989 and 1990 estimates (Table 2).

Littoral zone samples (electrofishing and blocknet) showed that abundance of subharvestable largemouth bass increased during 1991 and 1992. The abundance of young-of-the-year (YOY) largemouth bass in Lake Denham increased significantly ($P < 0.1$) in fall 1991 blocknet samples, from an average of less than 10 fish/hectare in 1989 and 1990 to an estimated 110 fish/hectare in fall 1991 (Table 3). Electrofishing catch rates for the number of subharvestable bass increased each year in Lake Denham. During the period of June 1991 through May 1992, catch rates for subharvestable bass increased significantly, from less than one subharvestable bass per 5 minutes to over 2 fish per 5 minutes (Table 4). Electrofishing CPUE for subharvestable largemouth bass was very similar between Lakes Denham and Beauclair during 1989–90 and 1990–91. Both lakes showed equivalent increases in juvenile bass CPUE in 1990–91, but only the Lake Denham CPUE increased in 1991–92.

Contrary to the increasing trend in juvenile largemouth bass, the abundance of adult bass declined in both blocknet and electrofishing samples in Lake Denham during 1991–92 (Tables 3 and 4). Fall 1991 littoral blocknet samples contained no largemouth bass greater than 30 cm, and the proportion of harvestable largemouth bass in littoral blocknet samples declined significantly. Only 5 harvestable fish/hectare were estimated from the fall 1991 blocknet data, down from an average of 15 harvestable bass/hectare in 1989 and 27 in 1990. Chapman and Fish (1991) concluded that a standing stock of at least 35 harvestable fish/hectare was necessary to support a good fishery for largemouth bass in a hypereutrophic strip mine pit. Lake Griffin (a 3,760-hectare hypereutrophic lake of the Ocklawaha chain) supported an estimated standing stock of 41.5 harvestable fish/hectare in 1987 at the peak of angler catch success following the 1984 drawdown (Benton et al. 1991a). Length-frequency histograms derived from spring electrofishing samples in Lake Denham (January through April combined data) showed a modal peak at 32 cm in 1989, which shifted upwards to 36 cm during 1990 and 1991 (Figure 2). In spring 1992, there was no dominant modal peak and a larger proportion of bass were in the 12- to 22-cm group, which indicated that reproduction and/or survival of the 1991 year class of largemouth bass was better

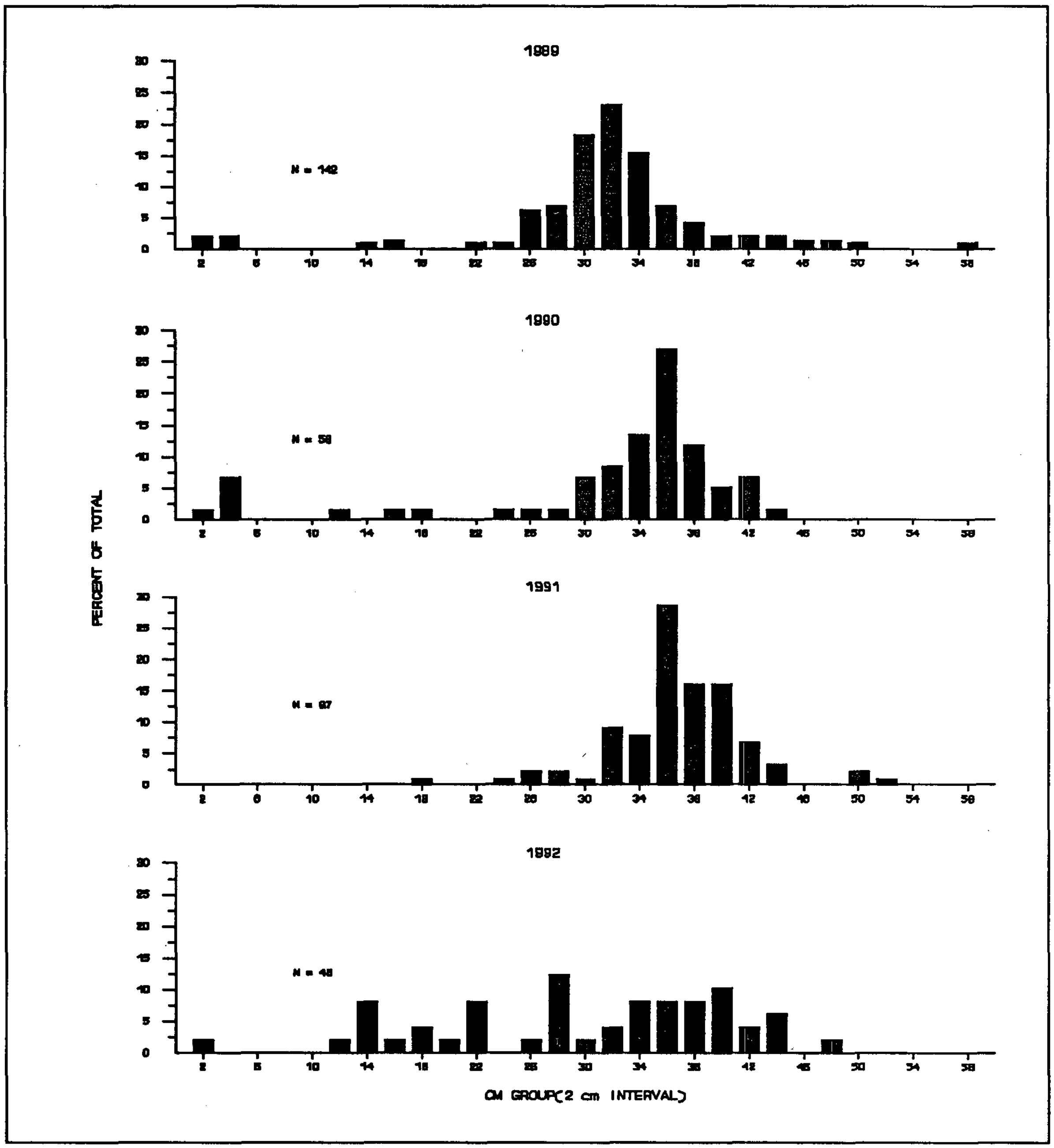

Figure 2. Composite length-frequency histograms for largemouth bass collected in electrofishing samples from Lake Denham from January through April of 1989 to 1992

Table 1. Common and scientific names of fish species sampled in Lakes Denham, Beauclair, and Apopka by electrofishing (E), gill net (G), and blocknet (B), January 1989 through May 1991

Common Name	Scientific Name	Lake Denham	Lake Beauclair	Lake Apopka
American eel	*Anguilla rostrata*	E		
Atlantic needlefish	*Strongylura marina*	E,G,B	E,G,B	E,B
Black crappie	*Pomoxis nigromaculatus*	E,G,B	E,G,B	E,G,B
Blue tilapia	*Tilapia aurea*	E,G,B	E,G,B	E,G,B
Bluefin killifish	*Lucania goodei*	E,B		
Bluegill sunfish	*Lepomis macrochirus*	E,G,B	E,G,B	E,G,B
Bluespotted sunfish	*Enneacanthus gloriosus*	E		
Bowfin	*Amia calva*	E,G,B	E	E,B
Brook silversides	*Labidesthes sicculus*	E,B	E	E,B
Brown bullhead	*Ameiurus nebulosus*	E,G,B	E,G,B	E,G,B
Chain pickerel	*Esox niger*	E,G,B		
Channel catfish	*Ictalurus punctatus*	G	G	E
Dollar sunfish	*Lepomis marginatus*	E,B	E	
Eastern mosquitofish	*Gambusia holbrooki*	E,B	E	E,B
Florida gar	*Lepisosteus platyrhincus*	E,G,B	E,G,B	E,G,B
Gizzard shad	*Dorosoma cepedianum*	E,G,B	E,G,B	E,G,B
Golden topminnow	*Fundulus chrysotus*	E		
Golden shiner	*Notemigonus chrysoleucas*	E,G,B	E,G,B	E,B
Grass carp	*Ctenopharyngodon idella*		B	
Inland silverside	*Menidia beryllina*	E,B	E,B	E,B
Lake Eustis pupfish	*Cyprinodon hubbsi*	B	E	
Lake chubsucker	*Erimyzon sucetta*	E,G,B		
Largemouth bass	*Micropterus salmoides*	E,G,B	E,G,B	E,G,B
Least killifish	*Heterandria formosa*	E,B	E	B
Longnose gar	*Lepisosteus osseus*	E,G,B	E,G,B	E,G,B
Palmetto bass (hybrid)	*Morone chrysops X M. saxatilis*	G	E,G,B	E,G,B
Pirate perch	*Aphredoderus sayanus*	B		
Pugnose minnow	*Notropis emiliae*	E,B	E	E
Pygmy sunfish	*Elassoma* sp.	B		

Table 1. ***Continued***

Common Name	Scientific Name	Lake Denham	Lake Beauclair	Lake Apopka
Redbreast sunfish	*Lepomis auritus*	E,B	E,B	E
Redear sunfish	*Lepomis microlophus*	E,G,B	E,G,B	E,G,B
Sailfin molly	*Poecilia latipinna*	E,B	E	E,B
Seminole killifish	*Fundulus seminolis*	E,B	E,B	E,B
Spotted sunfish	*Lepomis punctatus*	E,B	E	E,B
Swamp darter	*Etheostoma fusiforme*	E,B	E,B	
Tadpole madtom	*Noturus gyrinus*	E,B	B	E,B
Taillight shiner	*Notropis maculatus*	E,B	E,B	E,B
Threadfin shad	*Dorosoma petenense*	E,G,B	E,G,B	E,G,B
Warmouth	*Lepomis gulosus*	E,B	E,B	E,B
White catfish	*Ameiurus catus*	E,G,B	E,G,B	E,G,B
Yellow bullhead	*Ameiurus natalis*	E,B	E,G	E,B

Table 2. Mean number (fish/hectare) and weight (kg/hectare) of fish species collected from littoral blocknet samples in Lake Denham in fall 1989 (N = 4), 1990 (N = 4), and 1991 (N = 4)

	1989		1990		1991	
	No.	Wt.	No.	Wt.	No.	Wt.
Atlantic needlefish	-	-	-	-	7	0.6
Black crappie	1,751	26.1	1,260	18.2	1,815	20.6
Bluegill	10,426	123.1	10,712	29.0	12,350	80.3
Blue tilapia	5	5.1	74	57.3	79	65.4
Bluefin killifish	-	-	-	-	296	<0.1
Brook silverside	-	-	-	-	12	<0.1
Bowfin	10	9.9	25	23.6	10	6.1
Brown bullhead	422	10.7	106	5.8	304	4.3
Dollar sunfish	-	-	-	-	138	0.3
Eastern mosquitofish	2,524	1.1	2,130	0.6	756	0.1
Eustis pupfish	25	<0.1	-	-	-	-
Florida gar	-	-	15	2.9	47	17.8
Gizzard shad	128	8.2	126	6.6	170	7.0
Golden shiner	62	0.4	306	1.6	222	1.3
Grass carp	-	-	2	13.6	-	-
Inland silverside	94	<0.1	-	-	284	0.1
Lake chubsucker	45	19.6	20	9.3	15	3.0
Largemouth bass	22	9.1	32	18.7	116	3.0
Least killifish	-	-	62	<0.1	12	<0.1
Longnose gar	-	-	-	-	2	2.3
Pirate perch	-	-	12	<0.1	-	-
Pugnose minnow	-	-	-	-	12	<0.1
Redbreasted sunfish	-	-	-	-	49	<0.1
Redear sunfish	2,275	169.2	1,043	17.3	8,240	15.5
Sailfin molly	240	0.4	119	0.1	64	<0.1
Seminole killifish	-	-	5	<0.1	59	0.3
Spotted sunfish	-	-	-	-	7	0.1
Swamp darter	366	0.1	82	<0.1	378	0.1
Tadpole madtom	294	0.4	240	0.3	287	0.3

Table 2. ***Continued***

	1989		1990		1991	
	No.	Wt.	No.	Wt.	No.	Wt.
Taillight shiner	1,072	0.4	988	0.4	2,082	1.1
Threadfin shad	2,700	3.5	1,829	2.6	5,380	11.2
Warmouth	440	4.0	64	0.8	566	5.7
White catfish	-	-	-	-	12	0.1
Yellow bullhead	35	3.4	-	-	30	4.0
Totals	22,936	394.7	19,252	208.3	33,801	250.6

Note: - = no catch

Table 3. Percentage of harvestable and subharvestable centrarchids by number collected in fall littoral blocknet samples (0.1 hectare) in Lakes Denham and Apopka from 1989 through 1991

		Denham			Apopka		
		1989	1990	1991	1989	1990	1991
Largemouth bass	Total No.	22	32	116	40	19	37
	Subharv.	33.3	15.4	95.7*	53.2	26.7	30.0
	Harv. (≥ 24 cm)	66.7	84.6	4.3*	46.8	73.3	70.0
Black crappie	Total No.	1,751	1,260	1,815	541	726	1,207
	Subharv.	98.4	99.0	99.5	76.5	66.0	79.7
	Harv. (≥ 22 cm)	1.6	1.0	0.5	23.5	34.0	20.3
Bluegill	Total No.	10,426	10,712	12,350	9,187	6,735	11,105
	Subharv.	95.7	98.9	98.7	97.5	98.2	98.3
	Harv. (≥ 14 cm)	4.3	1.1	1.3	2.5	1.8	1.7
Redear sunfish	Total No.	2,275	1,043	8,240	571	510	1,681
	Subharv.	77.4	95.3	100.0	81.4	77.5	92.3
	Harv. (≥ 14 cm)	22.6	4.7	0.0	18.6	22.5	7.7

*Significant difference at alpha = 0.1, within lake

than observed for preceding year classes. Although a low number of bass were captured during the 1992 spring electrofishing sample, data indicated that a greater proportion of subharvestable bass existed in Lake Denham in spring 1992 than in previous years and that there were fewer large bass present. This 1991 year class should recruit to adult sizes by the spring of 1993, which would produce increased CPUE in electrofishing samples for harvestable-sized fish and shift the modal peak of the length-frequency histogram.

For largemouth bass in Lake Denham, analysis of covariance for weight to total length relationships among sample years showed no significant differences ($P \geq 0.1$) (Figure 3). The weight-length relationships were statistically different ($P < 0.1$) among the three lakes, although the differences are not dramatic enough

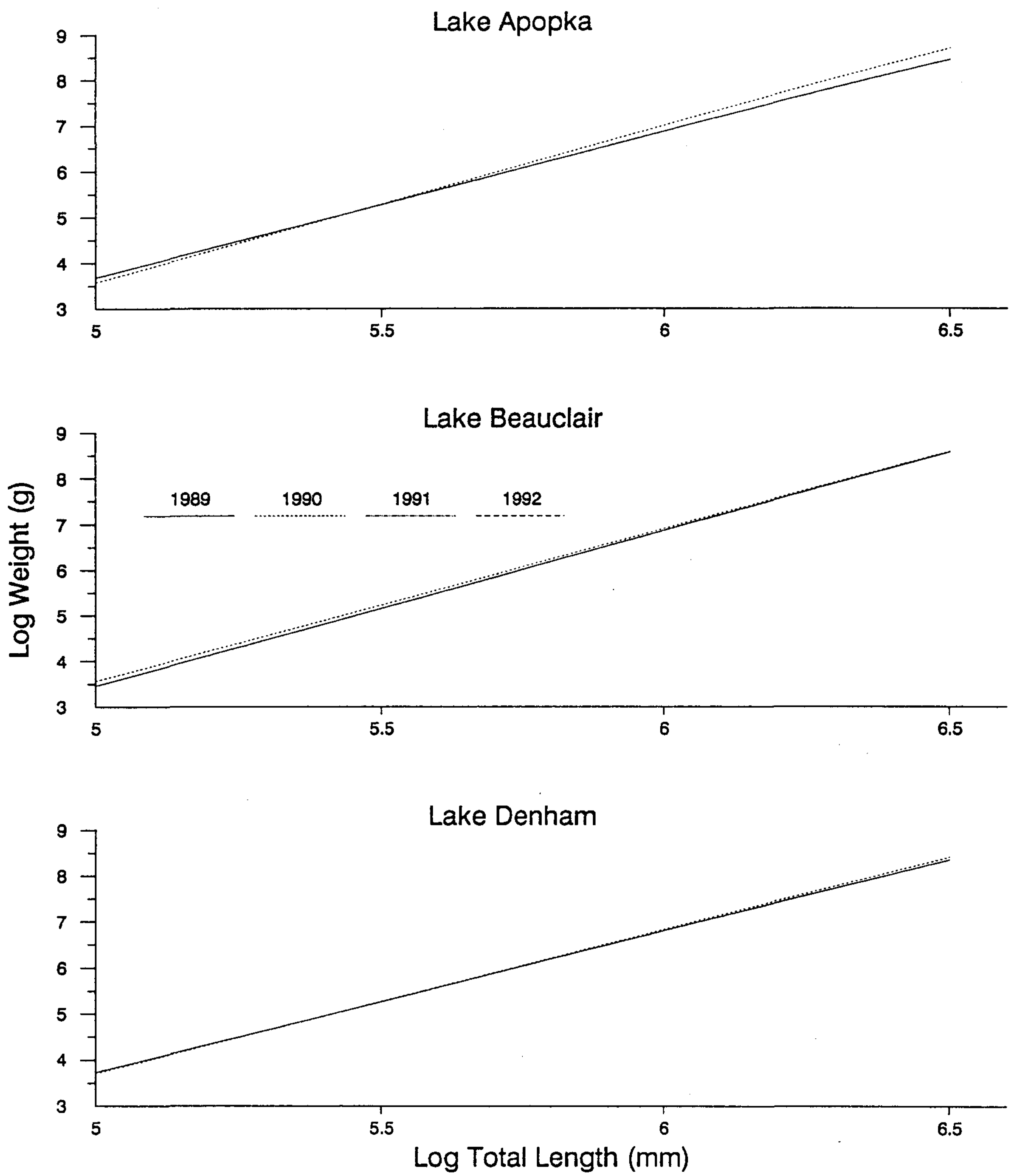

Figure 3. Natural log weight (g) vs. natural log total length (mm) for largemouth bass collected from Lakes Apopka, Beauclair, and Denham during 1989 through 1992 in spring electrofishing samples

Table 4. Number of harvestable and subharvestable centrarchids collected per 5 minutes of electrofishing in Lakes Denham, Apopka, and Beauclair during 3 years (June through May of 1989-90, 1990-91, and 1991-92)

	Denham			Apopka			Beauclair		
	89/90	90/91	91/92	89/90	90/91	91/92	89/90	90/91	91/92
No. Harvestable									
LMB	1.3	1.3	0.7	0.4	0.4	0.5	1.3	1.9	2.0
BLSU	9.0	5.5	6.0	1.9	1.5	1.7	17.8	16.0	17.0
RESU	2.4	2.0	1.5	0.8	0.8	0.8	3.8	3.9	5.1
BLCR	0.5	0.5	0.5	2.0	2.5	2.9	0.4	0.7	0.5
No. Subharvestable									
LMB	0.5	0.9	2.2*	0.2	0.1	0.1	0.4	1.0	1.0
BLSU	3.9	3.2	18.1*	3.4	4.5	5.5	4.7	3.6	17.3*
RESU	0.4	0.6	1.2*	0.4	0.5	1.0	0.1	0.6	2.6*
BLCR	0.4	0.3	0.9	0.4	0.7	0.8	0.2	0.4	0.3

LMB = Largemouth bass (harvestable ≥ 24 cm)
BLCR = Black crappie (harvestable ≥ 22 cm)
BLSU = Bluegill (harvestable ≥ 14 cm)
RESU = Redear sunfish (harvestable ≥ 14 cm)

*Significant difference at alpha = 0.1, within lake

to be biologically meaningful. The only year in which the weight-length regression line was notably different from other years was 1990, not only in Lake Denham, but in the other study lakes as well. This trend was also evident for weight-length relationships of bluegill and gizzard shad, which indicated some general factor influenced all study lakes during that year.

During 1989 and 1990, the CPUE for subharvestable bluegill in electrofishing samples for all three lakes was similar, ranging from 3.2 to 4.7 fish/5 minutes. Abundance of subharvestable bluegill in Lake Denham increased significantly ($P < 0.1$) during 1991–92 (Table 4). The CPUE for subharvestable fish increased five-fold over the average of the two previous years, increasing from an average of 3.5 fish to 18.1 fish/5 minutes of electrofishing. A significant ($P < 0.1$) increase also occurred for subharvestable bluegill in Lake Beauclair during 1991–92. The electrofishing CPUE for harvestable-sized bluegill was not significantly ($P > 0.1$) different among study years in Lake Denham. The average electrofishing CPUE for harvestable bluegills in Lake Denham was intermediate to Lakes Apopka and

Beauclair in all years, with the estimate for Lake Apopka averaging one-fourth to one-third the value of Lake Denham, and the estimate for Lake Beauclair averaging two to three times the CPUE value for Lake Denham. There was no statistically significant difference (P >0.1) in the CPUE for juvenile bluegill between Lakes Denham and Beauclair; however, the large number of harvestable-sized fish present in Lake Beauclair electrofishing samples were not evident in Lake Denham. The increased number of juvenile bluegill that were evident in electrofishing samples in Lake Denham during 1991 may generate an increase in harvestable-sized individuals during 1992–93. Fall littoral blocknet samples (1989–91) in Lake Denham showed no statistically significant (P >0.1) change in bluegill abundance, either by total number or weight (Table 2). The percentage of subharvestable fish remained at 98 percent in fall 1991 blocknet samples (Table 3).

The weight-length relationship for bluegill in Lake Denham did not change following the haul seine operations. Analysis of covariance for weight-length relationships for bluegill in Lake Denham did indicate statistically significant differences (P <0.1) among years, but the only year in which a difference was visually apparent was 1990 (the initial year of haul seining) (Figure 4). The difference in weight per unit length among years was so small as to be biologically unimportant. This trend was also evident for largemouth bass and gizzard shad in all three lakes, indicating some common factor influenced all three lakes during that year.

As with bluegill, abundance of juvenile redear increased significantly (P <0.1) during 1991–92. The number of redear in fall 1991 littoral blocknet samples in Lake Denham increased five-fold over the average of the fall 1989 and 1990 values, while biomass in 1991 was similar to the 1990 estimate because subharvestable fish accounted for 100 percent of the sample (Tables 2 and 3). The 1989 redear biomass estimate was larger than the estimate of both 1991 and 1992 and reflected an unusually large number of adults captured in the samples. The percent relative abundance (PRA) by number of redear sunfish in littoral blocknet samples showed the only major increase among sportfish species, which increased from an average of 7.6 percent of all fish sampled in 1989 and 1990 to 24 percent in 1991. The PRA by weight for redear varied widely among years. The fall 1989 sample was dominated by adult redear of large average size, while the fall 1991 sample was dominated by juvenile fish (Table 5). Electrofishing samples also indicated a statistically significant (P <0.1) increase in CPUE for subharvestable redear, which doubled from 0.6 fish/5 minutes in 1990–91 to 1.2 fish/5 minutes during 1991–92 (Table 4). There was a declining trend observed for harvestable redear in Lake Denham in both electrofishing and blocknet samples, though differences were not statistically significant (P >0.1). The electrofishing CPUE value of 1.5 harvestable fish/5 minutes during 1991–92 was

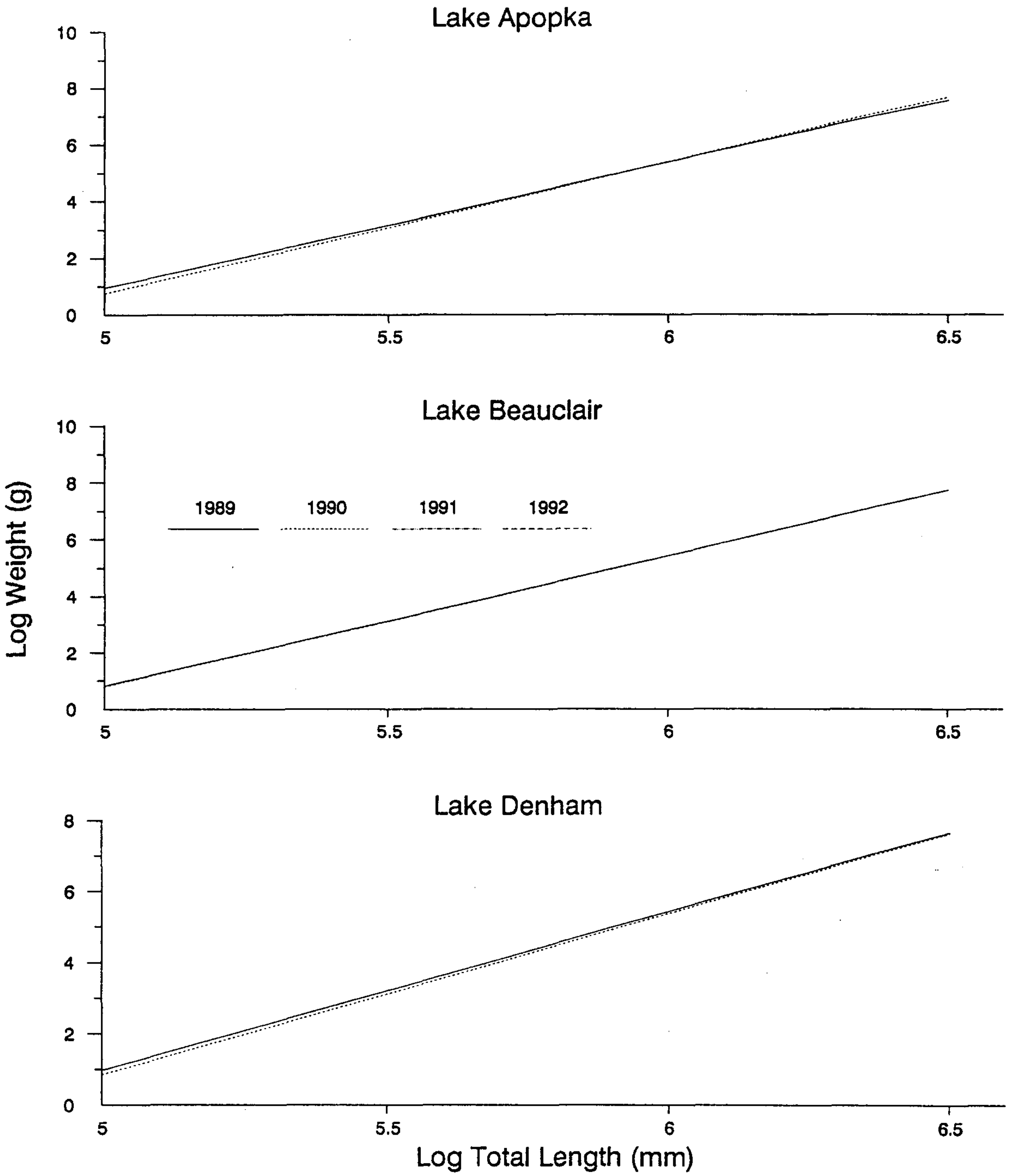

Figure 4. **Natural log weight (g) vs. natural log total length (mm) for bluegill collected from Lakes Apopka, Beauclair, and Denham during 1989 through 1992 in spring electrofishing samples**

Table 5. Percent relative abundance by number and weight for selected species from littoral blocknet samples in Lake Denham (N = 4) in fall 1989, 1990, and 1991

Species	1989		1990		1991	
	No.	Wt.	No.	Wt.	No.	Wt.
Largemouth bass	0.1	2.3	0.2	9.0	0.3	1.2
Black crappie	7.6	6.6	6.5	7.7	5.4	8.2
Bluegill sunfish	45.4	31.2	55.6	22.6	36.5	32.0
Redear sunfish	9.9	42.9	5.4	8.3	24.4	6.2
Gizzard shad	0.6	2.1	0.7	3.2	0.5	2.8
Treadfin shad	11.8	0.9	9.5	1.2	15.9	4.5
Blue tilapia	<0.1	1.3	0.4	27.4	0.2	26.1
Bowfin	<0.1	2.5	0.1	11.3	<0.1	2.4
Florida gar	0.0	0.0	0.1	1.4	0.1	7.1
Brown bullhead	1.8	2.7	0.6	2.8	0.9	1.7

intermediate to the other two lakes, with Lake Apopka averaging 0.8 and Lake Beauclair averaging 5.1 fish/5 minutes.

Black crappie abundance in fall 1991 littoral blocknet samples in Lake Denham showed no change from the average of the previous 2 years (Table 2). Subharvestable fish in blocknet samples typically constituted 99 percent of the black crappie numerical abundance (Table 3). Electrofishing data also indicated no statistically significant ($P > 0.1$) change among years for either harvestable or subharvestable fish (Table 4). Electrofishing CPUE values for subharvestable fish were similar among lakes, averaging less than 1 fish/5 minutes. Lakes Denham and Beauclair had similar CPUE values for harvestable-sized fish (averaging 0.5 fish per 5 minutes), while Lake Apopka CPUE values were five times greater (averaging 2.5 fish per 5 minutes).

Lake Denham Limnetic Zone Assessment

During the January through April 1992 peak catch period for gizzard shad in Lake Denham, CPUE increased 10 percent from the same period of 1991 (to 47 fish/h/90 m of experimental gill net), but remained 28 percent below the value of nearly 65 fish/h/90 m experimental gill net recorded in 1989, which was the baseline study year and 1 year prior to the initial haul seine activity (Table 6).

Table 6. Average experimental gill net CPUE (fish/hr/90 m) for gizzard shad collected from January through April from Lakes Apopka (N = 20), Beauclair (N = 20), and Denham (N = 20)

	1989		1990		1991		1992	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Apopka	59.4	23.5	64.8	28.3	55.5	27.5	30.1	13.4
Beauclair	63.0	29.7	74.7	33.4	81.5	32.7	54.7	21.6
Denham	64.5	37.1	55.8	35.5	42.6	23.2	46.7	25.5

The CPUE in terms of kilograms of gizzard shad caught per hour also increased 10 percent from the 1991 peak season estimate, to 25.5 kg/h/90 m of net. This estimate was still 31 percent below the 1989 value of 37 kg/h per 90 m of net. A Kruskal-Wallis test indicated that significant differences ($P < 0.1$) existed among years in Lake Denham for both numbers and biomass of gizzard shad sampled in experimental gill nets during the peak sample months of January through April. Therefore, the portion of the gizzard shad population of Lake Denham that was vulnerable to the experimental gill nets and haul seine capture had not returned to the level of abundance and biomass that existed prior to the initiation of the 1990 haul seine effort.

A plot of average monthly gizzard shad gill net catches fitted with a locally weighted scatterplot curve was similar to the pattern observed in previous years, with gizzard shad abundance in Lake Denham peaking in February and March and then declining (Table 7, Figure 5). This seasonal, cyclic trend was evident in 1989 prior to the haul seine program and also in 1991 and 1992 when haul seine activities commenced following the observed decline in CPUE for gizzard shad. This trend was evident in all three lakes, though the timing of the peak varied slightly by lake. This variation was due in part to the less frequent sampling on Lakes Apopka and Beauclair and possibly the unique features of each lake (e.g., mean lake depth and volume, which would influence water temperature [known to affect fish behavior] or basin morphology and orientation of a lake to prevailing winds) which influenced fish behavior indirectly. A composite length frequency for gizzard shad collected during peak season gill net catches illustrated the shift in the size structure of the Lake Denham gizzard shad population from a community dominated by large shad (38-cm mode in 1989) toward smaller-sized fish following haul seine operations (Figure 6). Average CPUE for gizzard shad during the entire year of 1991 (last complete year of data) was 20 percent below

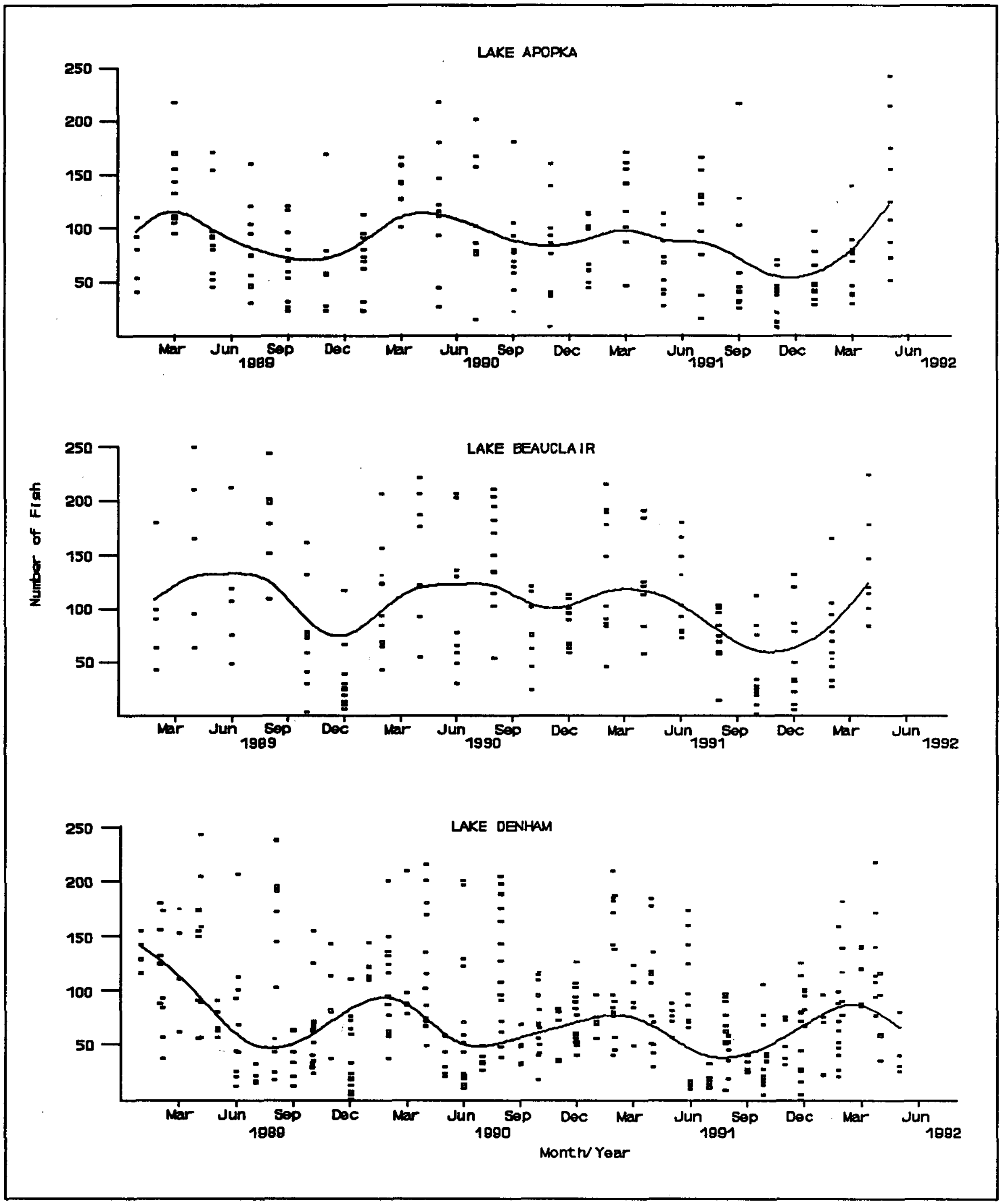

Figure 5. Gizzard shad catch in experimental gill net samples from Lakes Apopka, Beauclair, and Denham during January 1989 through May 1992. *The curve is the result of a locally weighted scatterplot smoothing function.*

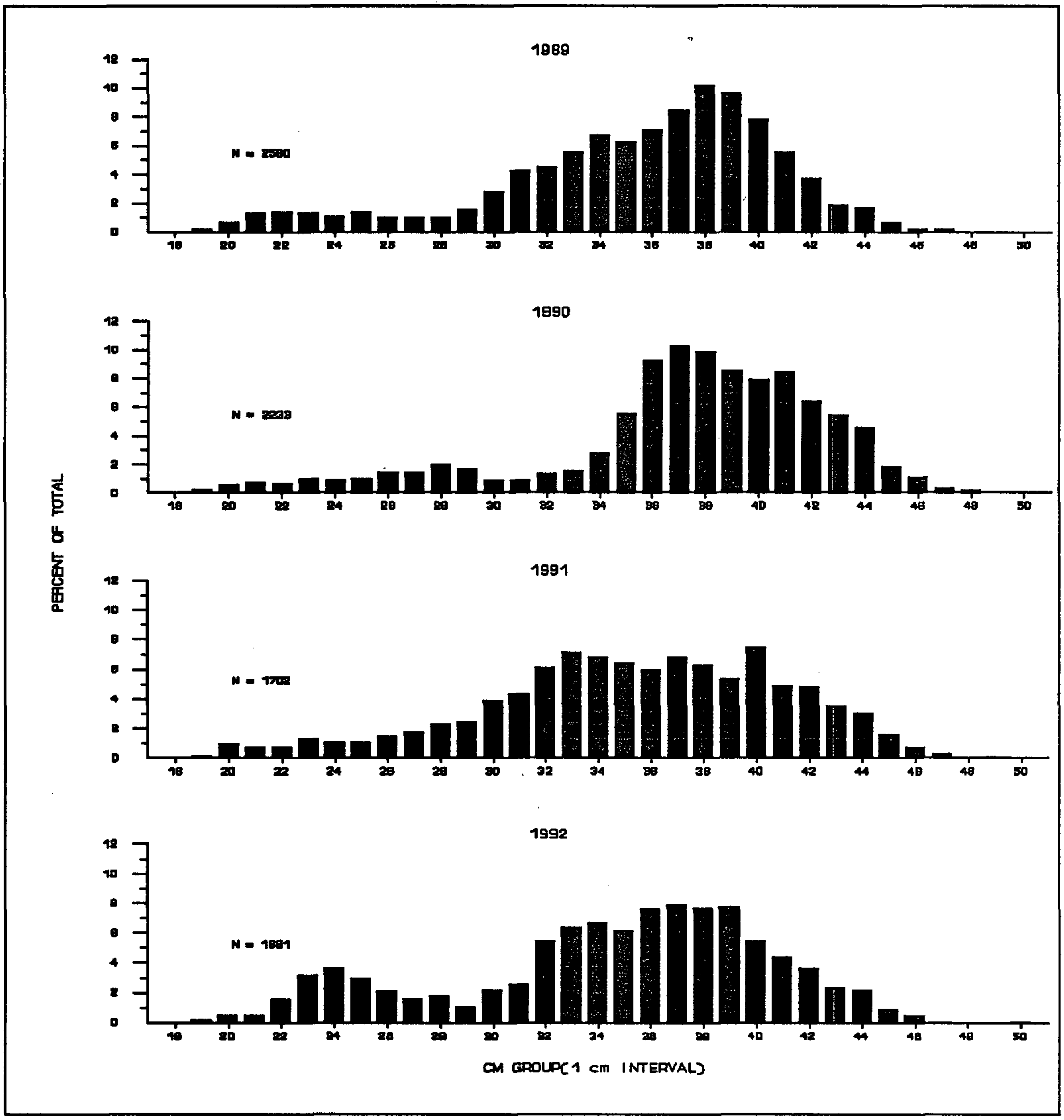

Figure 6. Composite length frequency of gizzard shad collected from experimental gill net samples in Lake Denham

Table 7. Experimental gill net monthly average CPUE (fish/hr/90 m) for gizzard shad collected from Lakes Apopka (N = 10), Beauclair (N = 10), and Denham (N = 5)

Month	Apopka		Beauclair		Denham	
	No.	Kg	No.	Kg	No.	Kg
January, 1989	*37.5	14.7	-	-	68.0	43.8
February	-	-	*47.5	25.7	69.1	41.6
March	70.4	28.0	-	-	57.33	4.2
April	-	-	78.4*	33.8	63.62	8.8
May	46.3	13.2	-	-	36.6	13.0
June	-	-	*56.3	14.1	20.3	11.8
July	40.4	14.3	-	-	12.5	7.2
August	-	-	109.9	33.1	19.6	11.5
September	33.8	11.1	-	-	18.0	9.2
October	-	-	36.4	13.2	20.4	10.7
November	30.1	11.1	-	-	46.6	26.1
December	-	-	17.5	6.1	32.7	21.9
January, 1990	37.4	15.1	-	-	61.2	45.0
February	-	-	51.9	25.8	59.2	37.0
March	92.2	41.5	-	-	57.0	34.2
April	-	-	97.5	41.0	45.9	25.6
May	72.3	29.6	-	-	18.3	9.4
June	-	-	61.2	21.4	9.0	5.1
July	48.0	16.9	-	-	19.0	8.6
August	-	-	75.8	23.8	32.0	13.0
September	39.6	16.3	-	-	24.0	11.1
October	-	-	39.9	13.0	36.6	16.2
November	38.8	17.6	-	-	31.5	16.7
December	-	-	42.7	18.8	35.4	17.3
January, 1991	40.5	18.7	-	-	37.6	20.8
February	-	-	66.5	31.3	52.7	31.8
March	70.6	36.2	-	-	46.3	22.8
April	-	-	96.4	34.2	33.6	17.3
May	33.6	10.7	-	-	38.3	18.7

Table 7. *Continued*

Month	Apopka		Beauclair		Denham	
	No.	Kg	No.	Kg	No.	Kg
June	-	-	56.4	17.8	7.2	4.1
July	52.8	19.7	-	-	10.0	5.3
August	-	-	36.2	12.0	21.8	11.3
September	36.0	12.3	-	-	16.0	7.2
October	-	-	20.5	7.1	20.2	10.5
November	17.5	7.3	-	-	27.3	12.1
December	-	-	28.5	13.4	45.4	18.6
January, 1992	26.0	12.0	-	-	29.4	17.2
February	-	-	36.4	17.5	61.5	37.4
March	34.2	14.8	-	-	58.3	29.4
April	-	-	73.0	25.8	37.4	18.0
May	65.2	21.0	-	-	25.1	10.3

Note: - = no sample
* = 5 nets per sample site

1990 estimates for both number and weight, and 26 percent below the 1989 complete year estimate for CPUE by number and 32 percent below CPUE by weight (Table 8).

Fall 1991 limnetic blocknet samples showed no statistically significant differences (P >0.1) among years in abundance of gizzard shad, even though numbers of fish in 1991 increased almost five-fold from 1990 (Table 9). Biomass estimates from limnetic blocknet samples also showed no significant difference (P >0.1) or trend among years and were far lower than estimates of gizzard biomass actually removed from Lake Denham in the haul seine program. The average weight for gizzard shad in fall limnetic blocknet samples has declined each year, from 362 g/fish in 1989, to 241 g/fish in 1990, to only 37 g/fish in the fall 1991 sample, which corroborated the trend documented in gill net samples.

Spring 1992 limnetic blocknet samples in Lake Denham showed no statistically significant (P >0.1) change in gizzard shad abundance among years (Table 10). The spring 1992 estimate of 251 fish/hectare was 73 percent below the average of 931 fish/hectare from the 1989 through 1991 data, while the 1992 average biomass of 46.2 kg/hectare was a 48 percent increase over the average estimate of 1989 through 1991 (31.3 kg/hectare). All blocknet samples showed great variability for gizzard shad standing stock. Biomass estimates ranged from 0.7 kg/hectare (fall 1989) to 58.8 kg/hectare (spring 1992) in individual samples from Lake Denham. Those values differed substantially from the 380 kg/hectare actually removed from the lake in 1990, 87.8 kg/hectare removed in 1991, and 30 kg/hectare removed in 1992. The variability in both gill net and blocknet samples contributed to uncertainty in measuring the gizzard shad population and highlighted the difficulty associated with sampling a schooling, pelagic species. While results of spring blocknet samples were inconclusive in resolving the question of whether gizzard shad abundance was different from the pre-haul seine values, the spring 1992 samples did point to a reduction in the abundance of YOY gizzard shad from previous years. In 1992, spring blocknets showed only an average of 95 YOY fish/hectare (as determined from the length frequency of the blocknet sample), compared to an average of 801 YOY fish/hectare in 1989, 466 YOY fish/hectare in 1990, and 1,117 YOY fish/hectare in 1991. However, all study lakes showed variation in YOY gizzard shad production, so this finding may prove to be important only if the trend is sustained in spring 1993 samples.

The weight per unit length relationship for gizzard shad collected in October through December gill net samples showed statistically significant (P <0.1) differences among years for all lakes; however, 1990 was the only sample year where a difference was visually apparent (Figure 7). For Lake Denham in 1990 (following the first and largest haul seine effort), smaller-sized shad were slightly heavier than in other sample years and the larger shad were relatively lighter since larger fish were selectively reduced by the haul seine program earlier in

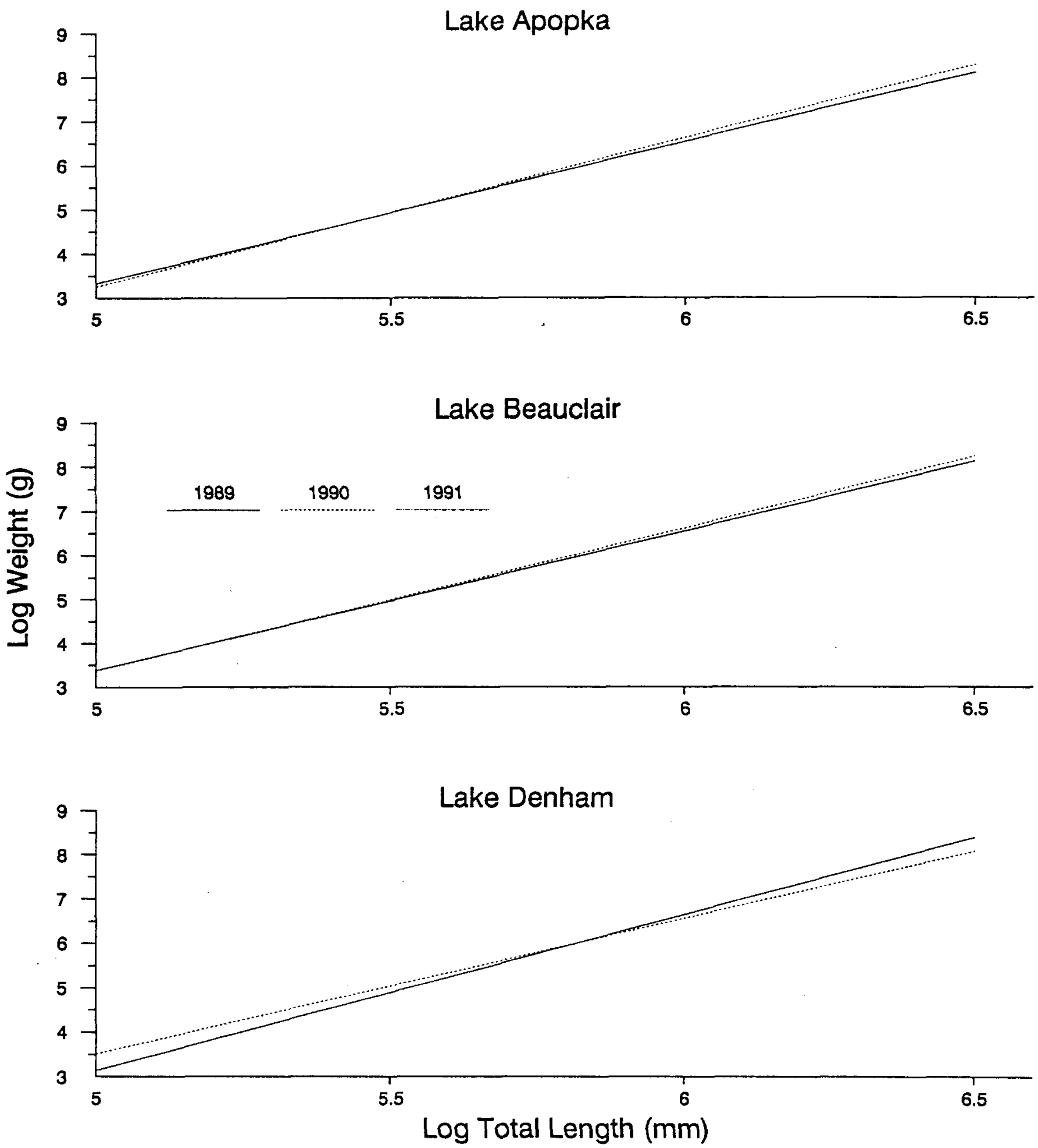

Figure 7. Natural log weight (g) vs. natural log total length (mm) for gizzard shad collected during 1989 through 1992 in spring electrofishing samples

Table 8. Average experimental gill net catch (fish/h and kg/h) for all species collected from Lake Denham in 1989 (N = 60), 1990 (N = 60), 1991 (N = 60), and 1992 (N = 25)

Species	1989		1990		1991		1992*	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Atlantic needlefish	-	-	-	-	<0.1	<0.01	-	-
Blue tilapia	0.1	0.02	0.1	0.04	<0.1	0.02	<0.1	0.01
Black crappie	1.8	0.42	1.1	0.29	0.6	0.16	0.2	0.04
Bluegill sunfish	0.2	0.05	0.7	0.15	0.2	0.03	0.1	0.02
Bowfin	0.1	0.10	0.1	0.19	0.1	0.17	0.3	0.52
Brown bullhead	0.1	0.04	0.1	0.09	<0.1	0.04	<0.1	0.02
Channel catfish	-	-	<0.1	0.01	-	-	-	-
Chain pickerel	<0.1	0.01	-	-	<0.1	0.01	-	-
Florida gar	0.2	0.13	0.3	0.13	0.2	0.08	0.2	0.10
Gizzard shad	38.7	21.66	35.8	19.94	29.7	15.04	42.3	22.48
Golden shiner	<0.1	0.01	<0.1	<0.01	<0.1	<0.01	-	-
Lake chubsucker	0.1	0.04	0.1	0.03	<0.1	<0.01	-	-
Largemouth bass	0.2	0.14	0.1	0.09	<0.1	0.04	<0.1	0.03
Longnose gar	0.5	0.63	0.3	0.37	0.2	0.33	0.1	0.13
Palmetto bass	0.1	0.06	<0.1	<0.01	0.1	0.07	<0.1	0.01
Redear sunfish	0.7	0.21	0.5	0.17	0.4	0.09	0.2	0.04
Threadfin shad	-	-	<0.1	<0.01	-	-	-	-
White catfish	-	-	<0.1	0.01	<0.1	0.02	<0.1	0.02
Yellow bullhead	-	-	-	-	-	16.1	-	-
Total	42.8	23.52	39.2	21.51	31.5	16.09	43.4	23.42

Note: - = no catch
* = incomplete sample year

Table 9. Mean number (fish/hectare) and weight (kg/hectare) of fish species collected from limnetic blocknet samples in Lake Denham in fall 1989 (N = 2), 1990 (N = 2), and 1991 (N = 2)

	1989		1990		1991	
	No.	Wt.	No.	Wt.	No.	Wt.
Atlantic needlefish	1	<0.1	-	-	6	0.4
Black crappie	837	37.3	1,244	29.0	2,009	35.3
Bluegill	61	1.4	514	4.2	1,396	34.5
Blue tilapia	-	-	1	2.6	2	3.9
Brown bullhead	4	2.2	16	11.1	6	4.5
Florida gar	1	0.5	5	2.2	4	1.9
Gizzard shad	37	13.4	101	24.4	493	18.3
Golden shiner	-	-	2	<0.1	22	0.5
Inland silverside	6	<0.1	5	<0.1	25	<0.1
Lake chubsucker	-	-	2	1.1	-	-
Largemouth bass	2	2.6	-	-	7	0.2
Longnose gar	4	4.0	1	1.5	-	-
Redear sunfish	33	11.7	133	31.2	590	51.4
Sailfin molly	-	-	1	<0.1	-	-
Seminole killifish	-	-	-	-	27	0.1
Tadpole madtom	-	-	2	<0.1	-	-
Taillight shiner	5,236	2.1	1,181	0.4	8,044	2.4
Threadfin shad	11,831	15.3	1,428	1.1	8,944	22.8
White catfish	-	-	5	6.6	5	1.7
Totals	18,053	90.5	4,641	115.4	21,580	177.9

Note: - = no catch

Table 10. Mean number (fish/hectare) and weight (kg/hectare) of fish species collected from limnetic blocknet samples in Lake Denham in spring 1989 (N = 4), 1990 (N = 4), 1991 (N = 4), and 1992 (N = 4)

Species	1989		1990		1991		1992	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Atlantic needlefish	1	<0.1	14	0.1	2	0.1	-	-
Black crappie	5,321	21.5	5845	29.3	3873	18.3	3813	28.3
Bluegill	1,188	21.5	112	8.1	245	2.5	122	2.6
Blue tilapia	-	-	1	0.5	-	-	-	-
Bowfin	-	-	-	-	-	-	1	0.7
Brook silverside	-	-	-	-	-	-	44	<0.1
Brown bullhead	79	0.6	6,206	38.3	680	1.1	20	8.8
Chain pickerel	1	<0.1	-	-	-	-	-	-
Eastern mosquitofish	15	<0.1	-	-	-	-	-	-
Eustis pupfish	6	<0.1	-	-	-	-	-	-
Florida gar	6	2.5	4	1.6	1	0.8	4	2.0
Gizzard shad	818	7.2	836	77.5	1139	9.1	251	46.2
Golden shiner	7	<0.1	3	0.2	-	-	1	<0.1
Inland silverside	264	0.1	62	<0.1	46	<0.1	3	<0.1
Lake chubsucker	1	0.2	1	0.2	-	-	-	-
Largemouth bass	177	2.3	7	3.3	114	0.4	6	<0.1
Least killifish	6	<0.1	-	-	-	-	-	-
Longnose gar	1	0.6	4	6.1	1	0.7	1	0.5
Pygmy sunfish	12	<0.1	-	-	-	-	-	-
Redear sunfish	1419	19.5	28	6.1	209	1.8	297	17.0
Tadpole madtom	-	-	-	-	1	<0.1	-	-
Taillight shiner	4,948	1.6	481	0.3	10,964	2.0	6,018	4.7
Threadfin shad	10,368	6.1	14,309	5.1	2294	1.7	4,516	3.1
Warmouth	-	-	237	0.1	-	-	-	-
White catfish	2	1.4	11	8.3	27	1.2	1	0.6
Totals	24,640	85.1	28,161	185.1	19,596	39.7	15,098	114.8

Note: - = no catch

1990, it was expected that the larger fish would be relatively heavier for their total length than the more abundant smaller-sized fish. In Lakes Apopka and Beauclair, larger gizzard shad were generally heavier in 1990 than in other sample years.

No significant difference (P >0.1) existed among years for threadfin shad abundance in Lake Denham, in either spring or fall samples, even though estimates from spring 1991 and 1992 limnetic samples were only 25 percent of the average of 1989 and 1990 (Tables 9 and 10). As was the case with gizzard shad, extreme sample variability limited the power of the tests to detect differences among years. Threadfin shad biomass ranged from 1.7 to 6.1 kg/hectare and averaged 4 kg/hectare in spring samples, which was comparable to an average of 5.6 kg/hectare in Lake Beauclair and 6.4 kg/hectare in Lake Apopka. The biomass estimates for threadfin shad from fall limnetic blocknet samples in Lake Denham were much higher in 1989 and 1991 (15.3 and 22.8 kg/hectare, respectively) when compared to the spring estimates. No comparable fall samples were collected from Lakes Apopka and Beauclair. The ability of smaller-bodied threadfin shad to produce the same magnitude of standing stock and plankton grazing effect as the gizzard shad removed from Lake Denham has not been documented.

The abundance of sport fish species relative to the total sample in Lake Denham spring limnetic blocknets averaged approximately 28 percent by number and 42 percent by weight. Black crappie remained the dominant sport fish and abundance was not significantly different (P >0.1) among years (Table 10). Fall limnetic blocknet samples indicated an increasing trend in black crappie abundance, which increased 49 percent in 1990 samples, and 61 percent in the 1991 estimate (Table 9); however, no statistically significant differences (P >0.1) were detected among sample years. Estimated black crappie biomass in 1991 increased 22 percent over the fall 1990 estimate to 35.3 kg/hectare, but was similar to the 1989 estimate of 37.3 kg/hectare. There was no significant difference (P >0.1) in black crappie abundance among years in spring blocknet samples. Both spring 1991 and 1992 estimates of abundance for black crappie were similar and were approximately 30 percent lower than the 1989 and 1990 estimates. The average biomass estimate in spring 1992 samples increased 55 percent from spring 1991, but was similar to the estimates of spring 1989 and 1990. The average biomass estimate of 24.4 kg/hectare for black crappie in Lake Denham spring blocknet samples was similar to Lake Beauclair at 23.2 kg/hectare (though the Beauclair estimate was more variable) and was six times the average estimate of 5.9 kg/hectare for Lake Apopka. Black crappie showed a decline in CPUE in gill net samples each year and averaged 1.1 fish/h/90 m of experimental gill net in Lake Denham during the completed sample years of 1989, 1990, and 1991, compared to 4.1 fish/h in Lake Beauclair and 1.1 fish/h/90 m of net in Lake Apopka. These data provided conflicting estimates of black crappie abundance between gear types in open waters of Lake Denham, but we detected no significant positive change in black crappie abundance as a result of the haul seine program in the lake.

Bluegill and redear sunfish were important components of the limnetic fish community in the Lake Denham fall blocknet samples, which is atypical of limnetic blocknet samples in the larger lakes of the Ocklawaha chain in the absence of submersed aquatic vegetation. These samples indicated that these two species increased in abundance for three consecutive years (Table 9). The 1991 biomass estimate of 34.5 kg/hectare of bluegill in fall 1991 limnetic blocknet samples was almost eight times the average of 1990. Redear sunfish numerical abundance also increased in fall 1991 limnetic blocknet samples, and the estimated weight of 51 kg/hectare was 65 percent greater than in 1990. These increases mirrored the increases in bluegill and redear abundance and biomass from 1990 to 1991 documented in fall littoral zone samples. Average CPUE for bluegill and redear sunfish in experimental gill net samples in Lake Denham was relatively low and not significantly different among years ($P > 0.1$), and also did not reflect the increasing trend in abundance seen in other sample methods. The CPUE averaged 0.4 fish/h/90 m of net for bluegill for the completed 1989, 1990, and 1991 sample years and 0.5 fish/h for redear sunfish (Table 8).

LAKE BEAUCLAIR LITTORAL ZONE ASSESSMENT

The electrofishing catch rate for harvestable largemouth bass from Lake Beauclair remained the highest of the three study lakes at an average of 2 fish/5 minutes in 1991–92, and the CPUE was not significantly different ($P > 0.1$) among years (Table 4). The electrofishing CPUE for subharvestable bass in Lake Beauclair was also not significantly different ($P > 0.1$) among years. The CPUE of subharvestable largemouth bass in Lake Beauclair was similar to Lake Denham during 1989–90 and 1990–91, but during 1991–92 the CPUE remained at 1 fish/5 minutes in Lake Beauclair, while the catch rate more than doubled in Lake Denham, to 2.2 fish/5 minutes. The lack of a second method of assessing the littoral zone fish community in Lake Beauclair limited the power of comparison with Lake Denham. Lakes Denham and Beauclair appeared to share more similarities in littoral zone fish community structure than did Lakes Denham and Apopka.

The electrofishing catch rate for harvestable bluegill remained high in Lake Beauclair, averaging almost 17 fish/5 minutes for the three study years (Table 4). The electrofishing CPUE for harvestable bluegill averaged less than 7 fish/5 minutes in Lake Denham and less than 2 fish 5/minutes in Lake Apopka. The CPUE estimates from 1989–90 and 1990–91 for subharvestable bluegill were very similar between Lakes Beauclair and Denham. The catch rate for subharvestable fish increased dramatically in 1991–92 in Lake Beauclair, as did the subharvestable bluegill CPUE in Lake Denham, increasing five-fold from an average of less than 5 fish/5 minutes to over 17 fish/5 minutes. Assessment of the causes for the apparent difference in production of subharvestable and harvestable bluegill between Lakes Beauclair and Denham during 1989–90 and 1990–91 was not possible and may have been influenced by nutrient loading, water temperatures, lake basin morphology, and sediment composition and distribution. Collection of these data were beyond the scope of work for this contract.

There was an increasing trend in electrofishing CPUE for redear sunfish in Lake Beauclair. Catch rates increased in 1991–92 for both harvestable and subharvestable fish compared to 1990–91 estimates. Catch per unit effort for harvestable redear increased 31 percent (from 3.9 to 5.1 fish/5 minutes), while CPUE for subharvestable fish increased significantly ($P < 0.1$), from an average of less than 0.5 fish/5 minutes during 1989–90 and 1990–91 to 2.6 fish/5 minutes in 1991–92 (Table 4).

Electrofishing CPUE for black crappie showed no statistically significant ($P > 0.1$) change among years in Lake Beauclair, either for harvestable or subharvestable fish (Table 4). Harvestable black crappie CPUE was always higher in Lake Apopka electrofishing samples than in samples from either Lakes Beauclair or Denham, while subharvestable fish CPUE was similar among all three lakes.

LAKE BEAUCLAIR LIMNETIC ZONE ASSESSMENT

For gizzard shad, there was no statistically significant difference ($P > 0.1$) in CPUE among sample years in terms of number or biomass caught per hour in 90 m of experimental gill net during the peak season (Table 6). The average peak season gizzard shad catch rate from Lake Beauclair in 1992 was almost 55 fish/h, the highest of all three study lakes. Lake Beauclair showed the highest peak season average CPUE for gizzard shad catch in each year except 1989, when the CPUE estimate was greatest in Lake Denham. Gizzard shad accounted for at least 86 percent of the average gill net catch by number and weight (Table 11).

An analysis of covariance indicated significant differences ($P < 0.1$) existed among 1989, 1990, and 1991 for the weight per unit length relationship of gizzard shad in Lake Beauclair. When the data were plotted, the 1990 sample year was the only visually different year, as was the case in both Lakes Apopka and Denham (Figure 7). Since this trend was also evident for both largemouth bass and bluegill in Lakes Denham and Apopka, some common factor that influenced condition may be involved.

Table 11. Average experimental gill net catch (fish/h and kg/h) for all species collected from Lake Beauclair in 1989 (N = 45), 1990 (N = 60), 1991 (N = 60), and 1992 (N = 20)

Species	1989		1990		1991		1992*	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Atlantic needlefish	<0.1	<0.01	-	-	-	-	-	-
Blue tilapia	0.8	0.31	0.5	0.28	1.7	1.08	2.9	1.93
Black crappie	3.8	1.00	4.2	1.30	4.3	1.29	2.5	0.84
Bluegill sunfish	0.1	0.02	0.2	0.03	0.2	0.02	0.2	0.01
Bowfin		-	-	-	-	-	-	-
Brown bullhead	0.4	0.14	0.3	0.12	0.2	0.09	0.1	0.04
Channel catfish	0.4	0.39	<0.1	0.05	<0.01	0.03	-	-
Chain pickerel	-	-	-	-	-	-	-	-
Florida gar	0.1	0.10	<0.1	0.06	0.1	0.09	-	-
Gizzard shad	56.6	19.83	61.5	23.96	50.7	19.29	54.7	21.64
Golden shiner	-	-	<0.1	<0.01	<0.1	<0.01	-	-
Lake chubsucker	-	-	-	-	-	-	-	-
Largemouth bass	0.1	0.07	<0.1	0.01	<0.1	0.02		
Longnose gar	0.1	0.18	<0.1	0.02	0.1	0.22	0.1	0.28
Palmetto bass	0.5	0.29	0.2	0.17	0.5	0.19	0.4	0.31
Redear sunfish	0.1	0.02	0.2	0.04	0.3	0.05	0.5	0.11
Threadfin shad	-	-	<0.1	<0.01	-	-	-	-
White catfish	0.1	0.04	0.3	0.16	0.1	0.05	<0.1	0.02
Yellow bullhead	<0.1	<0.01	-	-	-	-	-	-
Total	63.1	22.41	67.4	26.20	58.2	22.42	61.4	25.18

Note: - = no catch
* = incomplete sample year

Gizzard shad abundance in spring limnetic blocknet samples did not differ significantly (P >0.1) among years, either numerically or in biomass, even though the estimate of abundance declined 72 percent from the 1991 peak value of 9,402 fish/hectare (Table 12). The 1992 biomass estimate increased by approximately 70 percent from 1991, indicating fewer but larger fish were sampled. Blocknet estimates were extremely variable in Lake Beauclair. In one sample in 1989, over 8,000 gizzard shad (6,400 adults) were collected, while the other three nets combined produced only 166 fish, of which 26 were adults. This particular sample was excluded from analysis as an anomalous data point, but it illustrated the highly variable nature of gizzard shad stock estimates due to the schooling behavior of the fish.

Threadfin shad abundance was highest of all years in spring 1992 blocknet samples, increasing to 2.7 times the average of 1991 spring blocknet samples; however, even this increase did not meet the test of significance due to extreme sample variability (Table 12). Estimated threadfin shad biomass ranged from 4.0 to 7.1 kg/hectare and averaged 5.6 kg/hectare, which was 41 percent of the Lake Denham average of 13.1 kg/hectare.

Black crappie was the only sportfish species found in abundance in limnetic samples in Lake Beauclair, although there were increased numbers of bluegill and redear sampled in 1991. Gill net samples showed no statistically significant change (P >0.1) among years for black crappie CPUE, which averaged 4.1 fish/h/90 m of experimental net during the completed sample years of 1989, 1990, and 1991 (Table 11). This CPUE was nearly four times higher than the 1.2 fish/h/90 m of experimental nets observed in Lake Denham. Spring blocknet estimates of black crappie abundance and biomass declined from 1991, but 1992 estimates were similar to 1989 and 1990 sample values (Table 12). Analysis indicated that there was a significant difference (P <0.1) in black crappie abundance among years.

Lake Apopka Littoral Zone Assessment

Electrofishing CPUE for largemouth bass was the lowest in Lake Apopka for each year of the study, despite the stocking of over 1 million largemouth bass advanced fry during the spring of 1990 (Benton et al. 1991b). The average CPUE for harvestable bass was 0.5 fish/5 minutes or less, and less than 0.2 fish/5 minutes for subharvestable bass (Table 4). Largemouth bass were consistently collected by electrofishing or blocknet samples in the few areas of Lake Apopka that support suitable habitat (e.g., patches of *Scirpus californicus* or *Paspalidium geminatum*), but were rarely encountered elsewhere. The average number of 32 bass/hectare for the 3 years of littoral blocknet samples in Lake Apopka was similar to the estimates from Lake Denham during 1989 and 1990 (Tables 2 and 13). The size structure of the largemouth bass population in Lake

Table 12. Mean number (fish/h) and weight (kg/h) of fish species collected from limnetic blocknet samples in Lake Beauclair in spring 1989 (N = 3), 1990 (N = 4), 1991 (N = 4), and 1992 (N = 4)

Species	1989		1990		1991		1992	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Atlantic needlefish	3	<0.1	3	<0.1	3	0.2	7	<0.1
Black crappie	975	23.9	991	12.6	7,021	41.8	1,212	14.5
Bluegill	8	0.2	66	1.2	1,043	15.7	92	3.2
Blue tilapia	-	-	1	<0.1	601	125.4	47	0.8
Brown bullhead	7	2.1	99	6.4	157	5.3	64	3.1
Channel catfish	1	0.5	-	-	-	-	-	-
Florida gar	1	0.6	-	-	-	-	2	2.7
Gizzard shad	55	3.1	180	35.6	9,402	41.6	2,611	71.1
Golden shiner	1	<0.1	-	-	27	1.1	-	-
Inland silverside	7	<0.1	175	0.1	342	0.2	79	<0.1
Largemouth bass	-	-	3	<0.1	5	1.9	-	-
Longnose gar	-	-	-	-	-	-	1	0.1
Palmetto bass	1	0.1	4	<0.1	2	0.3	1	0.2
Redear sunfish	1	0.1	4	0.5	389	7.1	82	6.8
Seminole killifish	-	-	-	-	6	<0.1	-	-
Swamp darter	-	-	-	-	38	<0.1	-	-
Tadpole madtom	1	<0.1	-	-	52	<0.1	-	-
Taillight shiner	-	-	15	<0.1	82	0.1	31	<0.1
Threadfin shad	11,600	5.8	4,737	4.0	7,970	7.1	21,483	5.4
Warmouth	-	-	1	<0.1	1	0.1	-	-
White catfish	116	7.4	113	1.5	182	26.2	36	3.9
Totals	*12,777	43.8	6,392	61.9	27,323	274.1	25,748	111.8

Note: - = no catch
*1989 - excluding 4th net

Table 13. Mean number (fish/hectare) and weight (kg/hectare) of fish species collected from littoral blocknet samples in Lake Apopka in 1989 (N = 8), 1990 (N = 8), and 1991 (N = 8)

Species	1989		1990		1991	
	No.	Wt.	No.	Wt.	No.	Wt.
Atlantic needlefish	1	<0.1	-	-	7	<0.1
Black crappie	541	45.0	726	71.4	1,207	80.2
Bluegill	9,187	46.7	6,735	32.8	11,105	50.0
Blue tilapia	269	61.1	253	50.9	182	54.8
Bowfin	1	2.2	2	4.1	-	-
Brown bullhead	352	23.3	274	19.2	272	18.7
Eastern mosquitofish	1,133	0.2	1,233	0.3	1,018	0.3
Florida gar	5	5.8	10	8.8	0	6.0
Gizzard shad	368	28.4	907	10.9	1,103	117.1
Golden shiner	381	5.8	337	4.9	734	8.0
Inland silverside	9,086	1.6	366	0.11	106	<0.1
Largemouth bass	40	25.2	19	9.6	37	28.1
Longnose gar	1	0.3	1	<0.1	1	1.4
Palmetto bass	1	<0.1	-	-	2	0.2
Redear sunfish	571	14.9	510	14.9	1,681	21.7
Sailfin molly	16	<0.1	15	<0.1	67	<0.1
Seminole killifish	129	0.4	142	0.5	283	0.8
Spotted sunfish	-	-	-	-	2	<0.1
Tadpole madtom	656	0.6	250	0.4	315	0.9
Taillight shiner	765	0.5	1,352	0.9	1,901	1.4
Threadfin shad	2,275	2.0	208	0.4	5,943	6.3
Warmouth	2,434	14.7	598	11.4	2,029	12.3
White catfish	282	2.9	117	2.5	868	27.9
Yellow bullhead	30	3.4	20	3.4	15	1,6
Totals	28,524	285.0	14,075	247.4	28,878	437.7

Note: - = no catch

Apopka also was similar to Lake Denham for these years in that adults constituted the majority of the fish sampled and YOY fish were uncommon (Tables 3 and 13). Largemouth bass relative abundance in littoral blocknet samples did not change in 3 years, with bass constituting less than 1 percent of the sample by number and less than 9 percent by weight (Table 14). Largemouth bass have apparently increased in abundance since the early 1970s, but the population is still very low compared to other lakes of the chain (Benton et al. 1991a, 1992).

Bluegill CPUE for electrofishing samples showed no significant difference ($P > 0.1$) in the number of harvestable or subharvestable bluegill among years, averaging 1.7 harvestable and 4.5 subharvestable fish/5 minutes (Table 4). The average CPUE for harvestable bluegill in Lake Apopka electrofishing samples was only one-quarter of the Lake Denham average (6.8 fish/5 minutes) and only one-tenth that of Lake Beauclair (17 fish/5 minutes), yet the average CPUE for subharvestable bluegill of 4.5 fish/5 minutes was similar to both Lakes Denham and Beauclair during 1989-90 and 1990-91, which indicated a continuing recruitment problem in Lake Apopka. Fall littoral blocknet data showed no significant change ($P > 0.1$) or trend in the average abundance of bluegill from 1989 through 1991 (Table 13). Percent relative abundance of bluegill in littoral blocknet samples remained near the average of 40 percent by number and 14 percent by weight (Table 14), and subharvestable bluegill accounted for 98 percent of the sample by number (Table 3).

Redear sunfish also showed no significant change ($P > 0.1$) in CPUE for harvestable or subharvestable fish in electrofishing or blocknet samples in Lake Apopka. Electrofishing CPUE for harvestable-sized fish remained steady among years at 0.8 fish/5 minutes, while subharvestable redear CPUE showed an increasing trend, from the average of 0.5 fish/5 minutes in 1989–90 and 1990–91 to 1 fish/5 minutes in 1991–92 (Table 4). As with bluegill, the electrofishing CPUE for subharvestable fish was similar among all lakes during 1989–90 and 1990–91, and all three lakes showed an increase in subharvestable redear abundance during 1991–92. Recruitment of harvestable redear was lower in both Lakes Apopka and Denham when compared to Lake Beauclair. Fall 1991 littoral blocknet data showed that abundance of redear more than doubled (mostly subharvestable fish), and estimated littoral biomass increased 46 percent over the average of fall 1989 and 1990 (Table 13). This compared to a five-fold increase in abundance of redear in the Lake Denham littoral blocknet samples in fall 1991 over the average of 1989 and 1990 estimates (Table 2). Relative abundance for both harvestable and subharvestable fish in Lake Apopka showed no trend through the study period (Table 14).

Table 14. Percent relative abundance by number and weight for selected species from littoral blocknet samples (N = 8) in Lake Apopka in fall 1989, 1990, and 1991

Species	1989		1990		1991	
	No.	Wt.	No.	Wt.	No.	Wt.
Largemouth bass	0.1	8.8	0.1	3.9	0.1	6.4
Black crappie	1.9	15.8	5.2	28.9	4.1	18.3
Bluegill sunfish	33.2	16.4	47.9	13.3	37.8	11.4
Redear sunfish	2.0	5.2	3.6	6.0	5.7	5.0
Gizzard shad	1.3	10.0	6.4	4.4	3.8	26.7
Threadfin shad	8.0	0.7	1.5	0.2	20.2	1.4
Blue tilapia	0.9	21.4	1.8	20.6	0.6	12.5
Bowfin	<0.1	0.8	<0.1	1.7	(0)	(0)
Florida gar	<0.1	2.0	0.1	3.6	<0.1	1.4
Brown bullhead	1.2	8.2	1.9	7.8	0.9	4.3

LAKE APOPKA LIMNETIC ZONE ASSESSMENT

The catch rate of gizzard shad in January and March gill net samples from Lake Apopka fell in 1992, from an average of nearly 60 fish/h during 1989 through 1991 to 30 fish/h/90 m of net in 1992 (Table 6). The decline in the CPUE was statistically significant (P <0.1) and was 36 percent lower than the catch rate of nearly 47 fish/h from Lake Denham in 1992. Biomass also declined 50 percent from the average of 1989 through 1991, from an average of 26.4 kg/90 m net/h to 13.4 kg/90 m net/h, which was the lowest biomass recorded in any lake through the study period during the peak season. The length frequency of gizzard shad collected during January and March of 1992 was similar to that of 1991 (Figure 8) and also resembled the length frequency of Lake Denham in 1989 (Figure 6). The modal peak in the length-frequency histogram from Lake Apopka has shown a progression toward larger-sized fish with a larger percentage of fish included in the larger sizes, while the histogram of Lake Denham gizzard shad has shown the opposite trend. Gizzard shad constituted over 90 percent of the gill net catch on the average by both number and weight in Lake Apopka (Table 15).

A statistically significant difference (P <0.1) among years was shown in an analysis of covariance for the weight per unit length relationship of gizzard shad in Lake Apopka; however, the only sample year that was visually different was

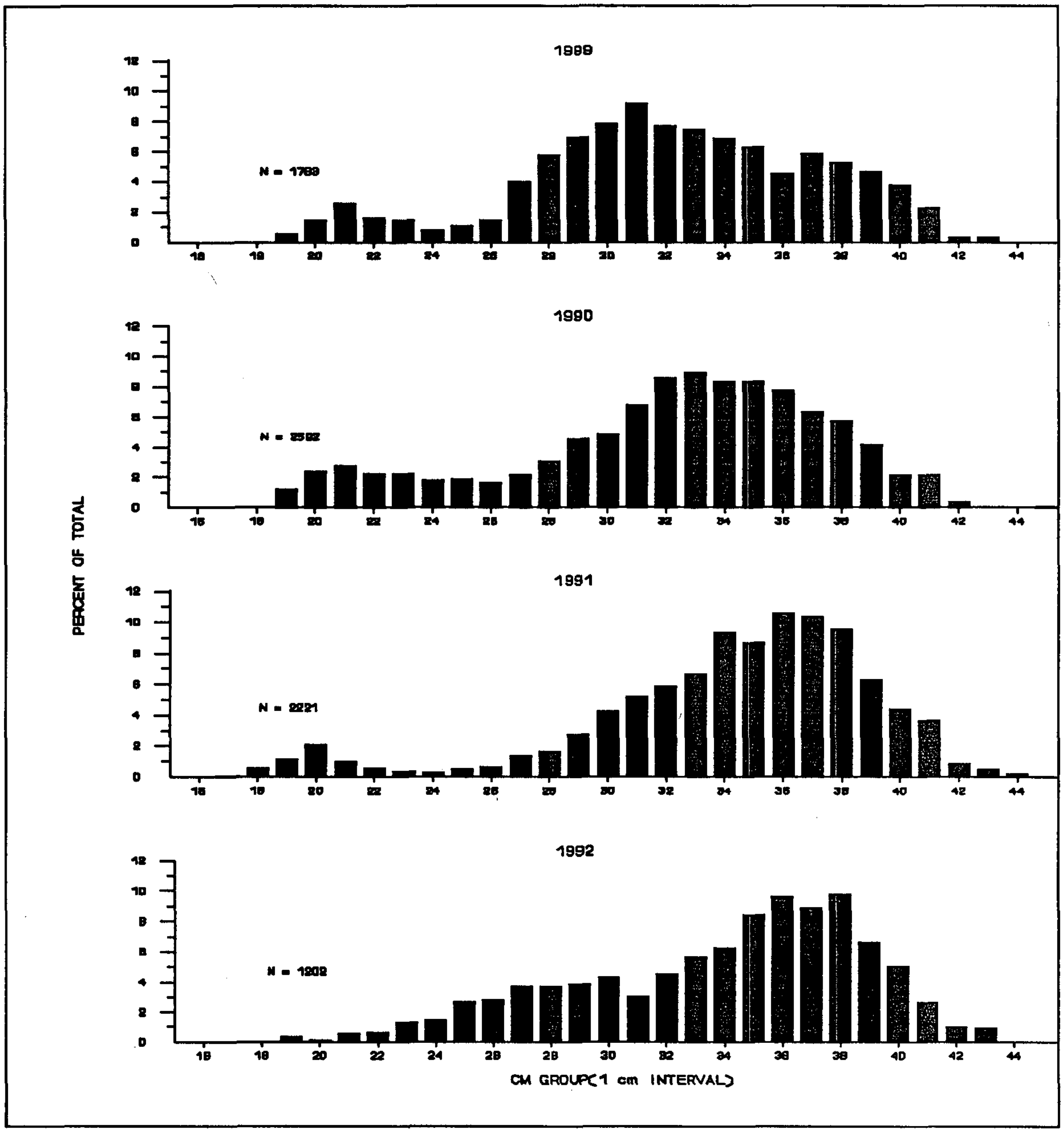

Figure 8. Composite length-frequency histograms for gizzard shad collected in experimental gill net samples from Lake Apopka from January through March of 1989 to 1992

Table 15. Average experimental gill net catch (fish/h and kg/h) for all species collected from Lake Apopka in 1989 (N = 55), 1990 (N = 60), 1991 (N = 60), and 1992 (N = 30)

Species	1989		1990		1991		1992*	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Atlantic needlefish	-	-	-	-	-	-	-	-
Blue tilapia	0.1	0.03	0.1	0.04	0.1	0.08	0.1	0.07
Black crappie	1.2	0.36	1.4	0.37	0.7	0.20	0.9	0.22
Bluegill sunfish	-	-	<0.1	<0.01	-	-	-	-
Bowfin	-	-	-	-	-	-	-	-
Brown bullhead	0.1	0.01	0.1	0.01	0.1	0.01	<0.1	<0.01
Channel catfish	-	-	-	-	-	-	-	-
Chain pickerel	-	-	-	-	-	-	-	-
Florida gar	0.1	0.12	0.1	0.15	<0.1	0.05	<0.1	0.08
Gizzard shad	43.6	15.47	54.7	22.83	41.8	17.50	41.8	15.96
Golden shiner	-	-	-	-	-	-	-	-
Lake chubsucker	-	-	-	-	-	-	-	-
Largemouth bass	-	-	-	-	-	-	<0.1	0.02
Longnose gar	0.2	0.37	0.1	0.32	0.1	0.24	0.2	0.19
Palmetto bass	0.7	0.41	0.4	0.30	0.2	0.04	0.5	0.23
Redear sunfish	<0.1	<0.01	-	-	-	-	-	-
Threadfin shad	<0.1	<0.01	<0.1	<0.01	<0.1	<0.01	<0.1	<0.01
White catfish	-	-	<0.1	<0.01	0.1	0.02	<0.1	0.02
Yellow bullhead	-	-	-	-	-	-	-	-
Total	46.0	16.77	56.9	24.02	43.1	18.14	43.5	16.79

Note: - = no catch
* = incomplete sample year

the 1990 sample year (Figure 7). Larger gizzard shad tended to have a greater weight for a given unit of length during 1990 in both Lakes Apopka and Beauclair, while the opposite trend was evident in Lake Denham. Since 1990 was also a unique year for largemouth bass and bluegill weight-length relationships in Lake Denham and for largemouth bass in Lake Beauclair, other factors beyond the scope of work for this contract would need to be analyzed to assess the relevance of that observation (e.g., nutrient loading, plankton communities, and water quality data). Apopka during spring 1992, 767 (91 percent) were less than 12 cm in length (YOY), compared to an estimate of 95 YOY fish/hectare (27 percent) out of 346 total fish in Lake Denham and 1,729 YOY fish/hectare (66 percent) out of 2,611 total fish in Lake Beauclair. Due to the extreme inter-annual variability in the data, the trend toward increased abundance of small gizzard shad in Lake Apopka would have to be sustained for several years to be found a statistically significant population change.

Limnetic blocknet samples collected from Lake Apopka in the spring of 1992 had significantly (P <0.1) more gizzard shad than previous years, while estimated biomass declined for the fourth successive year and was the lowest of the three lakes in 1992 (Table 16). Of an estimated 839 gizzard shad/hectare in LakeApopka during spring 1992, 767 (91 percent) were less than 12 cm in length (YOY), compared to an estimate of 95 YOY fish/hectare (27 percent) out of 346 total fish in Lake Denham and 1,729 YOY fish/hectare (66 percent) out of 2,611 total fish in Lake Beauclair. Due to the extreme inter-annual variability in the data, the trend toward increased abundance of small gizzard shad in Lake Apopka would have to be sustained for several years to be found a statistically significant population change.

The abundance of threadfin shad in spring limnetic blocknet samples increased over four-fold from the 1991 estimate and were higher than estimates from previous years, yet there was no statistically significant (P >0.1) increase among years (Table 16). Abundance estimates for threadfin shad in Lake Apopka ranged from 837 fish/hectare to 3,423 fish/hectare, which were the lowest of the three lakes. Lake Beauclair had the highest range (from 4,737 to 21,483 fish/hectare). In spring 1992 blocknet samples from Lake Apopka, threadfin shad constituted 50 percent of the total limnetic blocknet sample by number and 33 percent of the total weight (Table 16).

Brown bullhead abundance in spring limnetic blocknets in Lake Apopka has decreased each year, particularly during the spring of 1991, when brown bullhead abundance decreased 90 percent compared to 1990 (Table 16). Brown bullhead abundance also dropped in fall littoral blocknet samples, decreasing 22 percent from 1989 to 1990 and remaining unchanged in 1991 (Table 13). The CPUE for brown bullhead in experimental gill nets was not large enough to evaluate population trends (Table 15).

Table 16. Mean number (fish/hectare) and weight (kg/hectare) of fish species collected from limnetic blocknet samples in Lake Apopka in spring 1989 (N = 6), 1990 (N = 6), 1991 (N = 6), and 1992 (N = 6)

Species	1989		1990		1991		1992	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Atlantic needlefish	1	<0.1	<1	0.1	<1	<0.1	4	0.4
Black crappie	169	6.9	262	7.9	413	1.7	2,272	7.1
Bluegill	22	0.2	19	0.2	5	<0.1	62	0.5
Blue tilapia	<1	<0.1	2	<0.1	6	<0.1	2	<0.1
Brown bullhead	389	20.4	260	17.3	175	6.9	17	1.5
Eastern mosquitofish	<1	<0.1	-	-	-	-	-	-
Florida gar	-	-	-	-	<1	<0.1	-	-
Gizzard shad	262	38.5	222	30.5	358	16.4	839	13.7
Golden shiner	5	0.2	-	-	-	-	-	-
Inland silverside	71	<0.1	107	<0.1	41	<0.1	70	<0.1
Least killifish	-	-	-	-	-	-	2	<0.1
Longnose gar	<1	0.8	-	-	-	-	-	-
Palmetto bass	<1	0.2	-	-	-	-	<1	0.2
Redear sunfish	7	0.4	4	0.4	<1	<0.1	2	<0.1
Seminole killifish	1	<0.1	-	-	1	<0.1	-	-
Tadpole madtom	<1	<0.1	6	<0.1	-	-	-	-
Taillight shiner	24	<0.1	27	<0.1	33	0.1	94	0.1
Threadfin shad	1,572	3.6	1,435	6.9	837	3.5	3,423	11.7
Yellow bullhead	-	-	2	0.1	-	-	-	-
White catfish	54	1.2	78	1.8	63	1.4	13	0.7
Totals	2,577	72.4	2,420	65.2	1,932	30.0	6,800	35.9

Black crappie was the only sport fish species present in substantial numbers in spring blocknet samples in the limnetic zone of Lake Apopka. Numerical abundance increased slightly each year, but increased five-fold in 1992 over 1991 (from 413 to 2,272 fish/hectare) because of a large number of juvenile fish in the samples. Numerical estimates were below those from Lake Denham (which ranged from 3,813 to 5,845 fish/hectare) and Lake Beauclair (which ranged from 975 to 7,021 fish/hectare) (Tables 10 and 12). Biomass also increased in 1992 and was similar to the biomass estimate for 1989 and 1990. Catch rates for black crappie in gill net samples (whole year averages) from Lake Apopka showed no inter-annual trend and averaged 1 fish/h/90 m of gill net (Table 15).

Assessment of Haul Seine Activities in Lake Denham

From January 18, 1990, to April 6, 1990, a total of 39,524 kg (380 kg/hectare) of gizzard shad was removed from Lake Denham by 35 haul seine "pulls" (Table 17). An estimated 45,719 kg (440 kg/hectare) of gizzard shad were

Table 17. Summary of total catches of gizzard shad, gar (both longnose and Florida), and blue tilapia from haul seine operations in Lake Denham in 1990, 1991, and 1992

	1990		1991		1992	
	No.	Kg	No.	Kg	No.	Kg
	35 Pulls		13 Pulls		8 Pulls	
Gizzard shad	62,897*	39,524	20,409*	9,098	8,982*	3,124
Gar		829		388		363
Blue tilapia		22		23		25

*Estimated from subsample data

available to capture by haul seine, as calculated from catch-and-effort data (area swept by the seine) using a Leslie regression equation (Ricker 1975) (Figure 9). The 90 percent confidence limits for the estimate were 39,370 kg for the lower limit and 56,209 kg for the upper limit. These data indicated an 87 percent reduction in the biomass of gizzard shad available to the haul seine. A second method of assessing the biomass of gizzard shad that was available to be caught by the haul seine was employed by fitting a curve of cumulative catch (kg) upon cumulative effort (area fished by the seine). This method gave an estimate of 48,217 kg of gizzard shad of catchable size. The total catch of

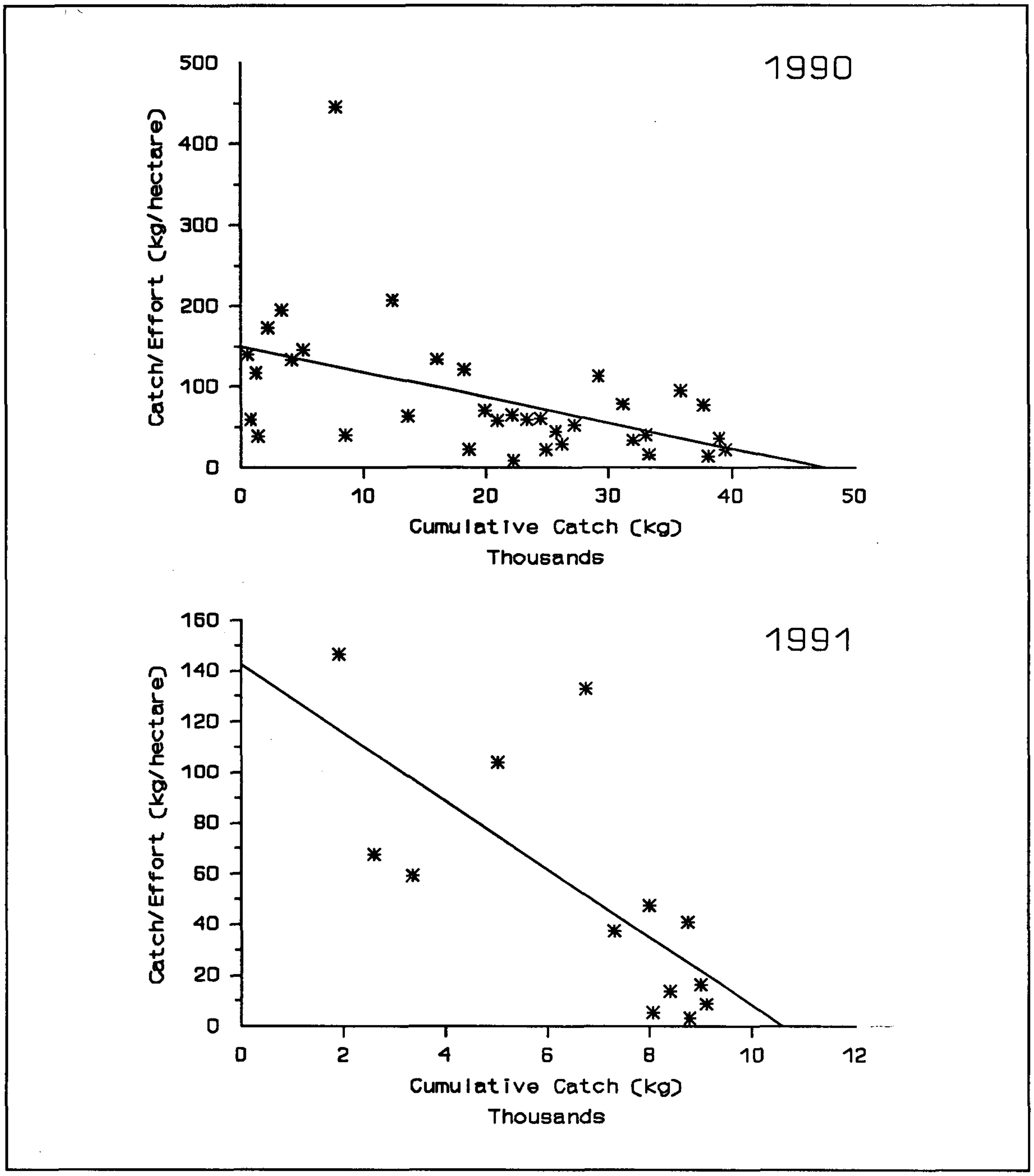

Figure 9. **Plot of haul seine catch per unit effort on cumulative catch to derive an estimate of the original weight of gizzard shad available to be caught in the haul seine during 1990**

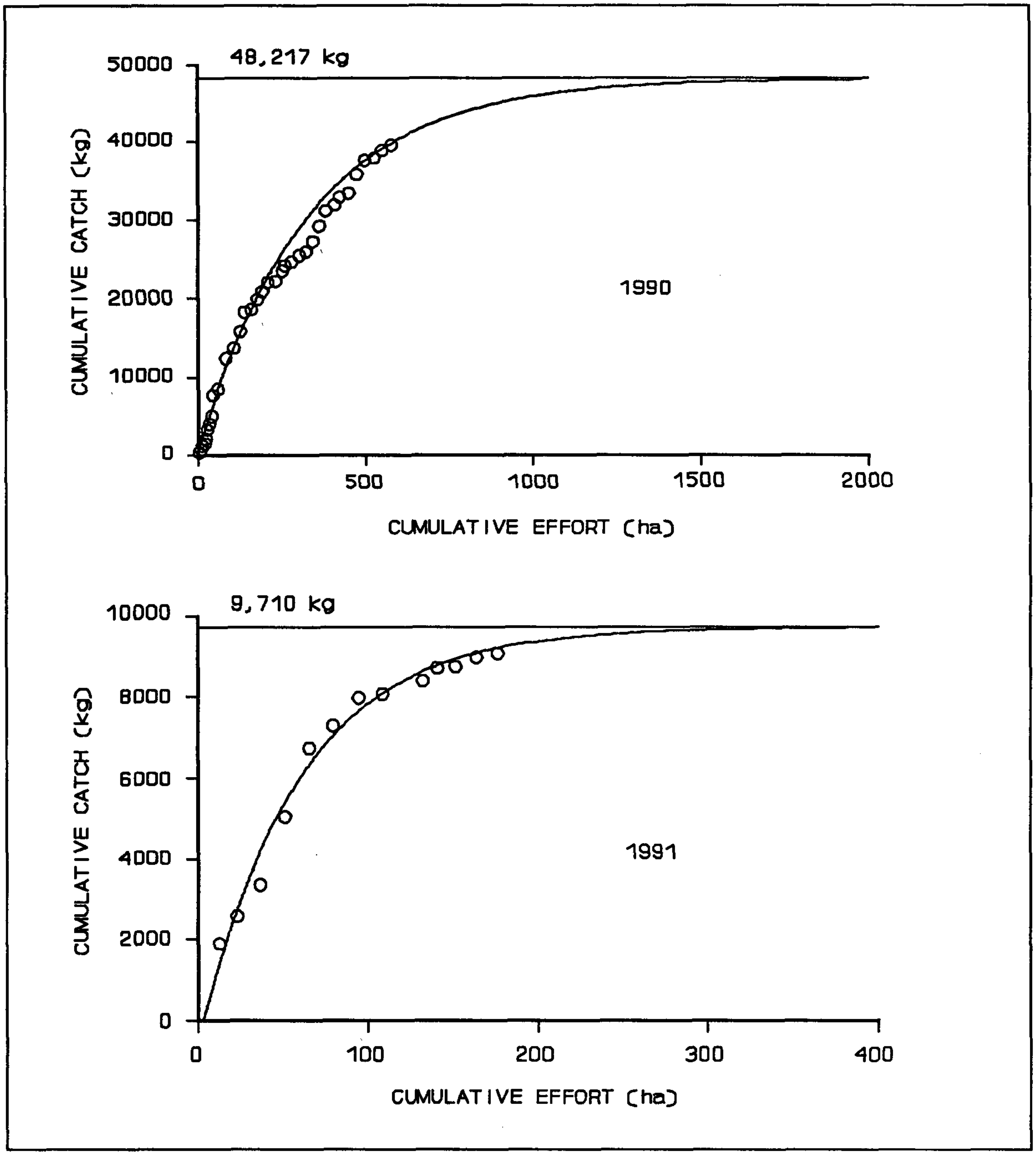

Figure 10. Plot of haul seine cumulative catch on cumulative effort to derive an estimate of the original weight of gizzard shad available to be caught in the haul seine during 1990

39,524 kg of shad would represent a reduction of 82 percent using the second method.

A second haul seine program was conducted in Lake Denham in May 1991. Thirteen seine hauls resulted in a total catch of 9,098 kg of gizzard shad (87.8 kg/hectare). Results of the Leslie regression indicated that 10,287 kg (99 kg/hectare) of gizzard shad were available to the haul seine (90 percent confidence interval, 9,595–11,195 kg). The gizzard shad catch of 9,098 kg represented an 88 percent reduction in available biomass from the initial 1991 estimate calculated using the Leslie regression. The alternative method to estimate catchable gizzard shad biomass by cumulative catch-and-effort predicted 9,710 kg of gizzard shad were present prior to the May 1991 haul seine effort (Figure 10). The catch of 9,098 kg of gizzard shad would represent a 93 percent reduction in the catchable stock.

During June 1992, a third year of haul seine removal of gizzard shad was attempted. Although the 1992 haul seine operation fell beyond the time frame of this report, these data were included to give a comprehensive view of the planktivore removal in Lake Denham. The contractor reported removal of 3,124 kg of gizzard shad (30 kg/hectare) with 8 "pulls." The catch of gizzard shad in the haul seine did not show the decline necessary to generate an estimate of standing stock available to the haul seine, as was done in 1989 and 1990. The contractor experienced equipment failure, coupled with low gizzard shad catch, making it unprofitable for the effort to continue. Gizzard shad constituted approximately 90 percent of the total fish biomass removed from Lake Denham in 1992. The contractor also removed 363 kg of gar (both longnose gar and Florida gar), and 25 kg of blue tilapia. Gamefish were a minor component of the haul seine catch in 1992 and, in previous years, averaged less than 10 percent of the total catch by number. Redear sunfish, black crappie, and bluegill were the major components of the bycatch, with bullhead and white catfish (*Ameiurus catus*) representing the balance of the typical bycatch.

The length-frequency histograms derived from haul seine subsamples in 1990, 1991, and 1992 showed dramatic shifts toward smaller-sized individuals in each year (Figure 11). In 1990, almost 90 percent of the fish in the haul seine samples were 36 cm or larger; however, by 1992 the case was almost exactly reversed. The lower limit for efficient gizzard shad capture by the haul seine occurred at approximately the 26-cm size class.

The length frequency of gizzard shad measured in the haul seine subsamples differed from the length frequency generated from combined May and June 1992 experimental gill net samples (Figure 12), while the length-frequency histogram of the haul seine and limnetic blocknet samples collected during May 1992 showed much better agreement. Although the mesh sizes chosen for experimental gill net

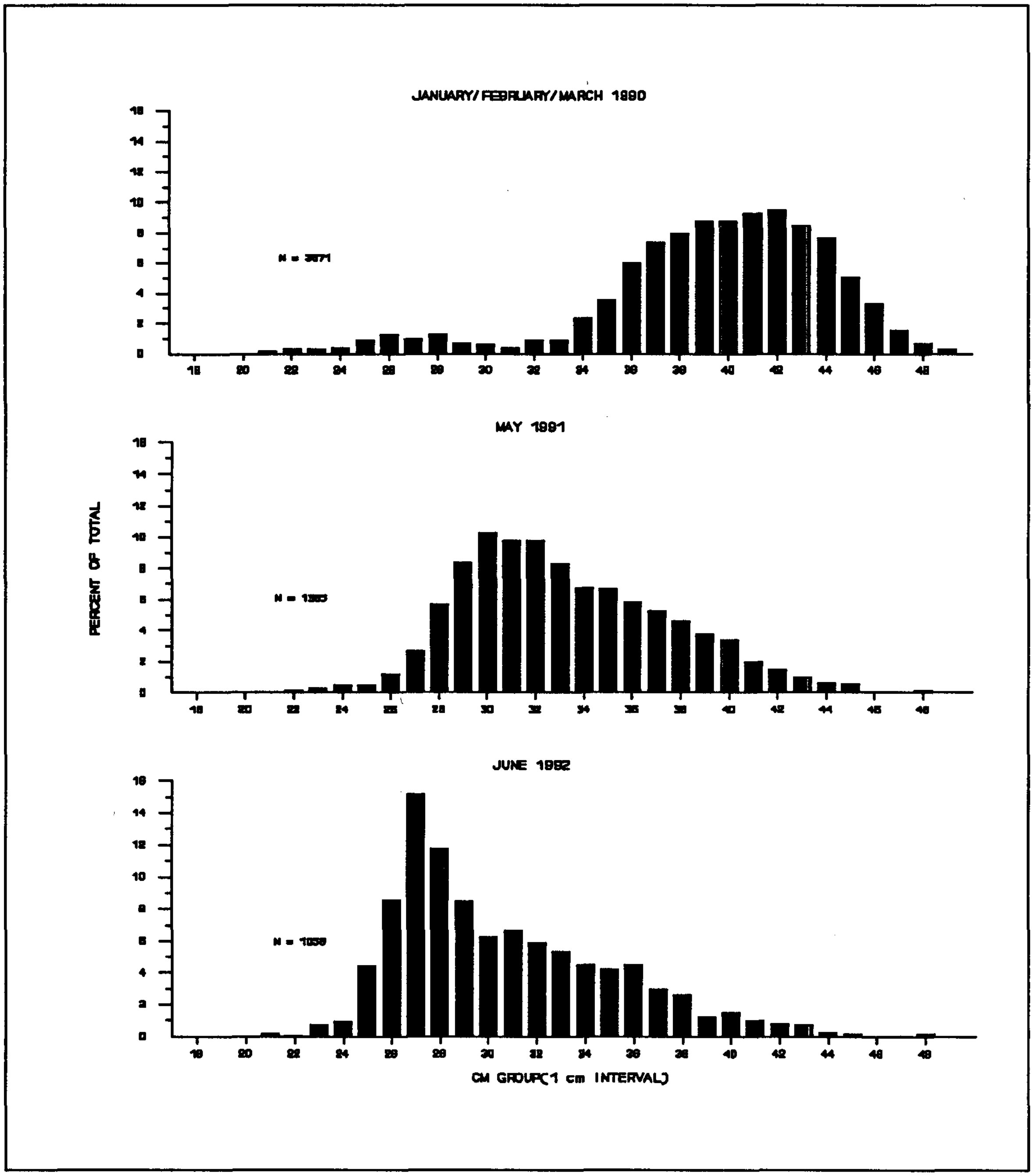

Figure 11. Composite length frequency of gizzard shad collected from haul seine subsamples in Lake Denham during 1990, 1991, and 1992

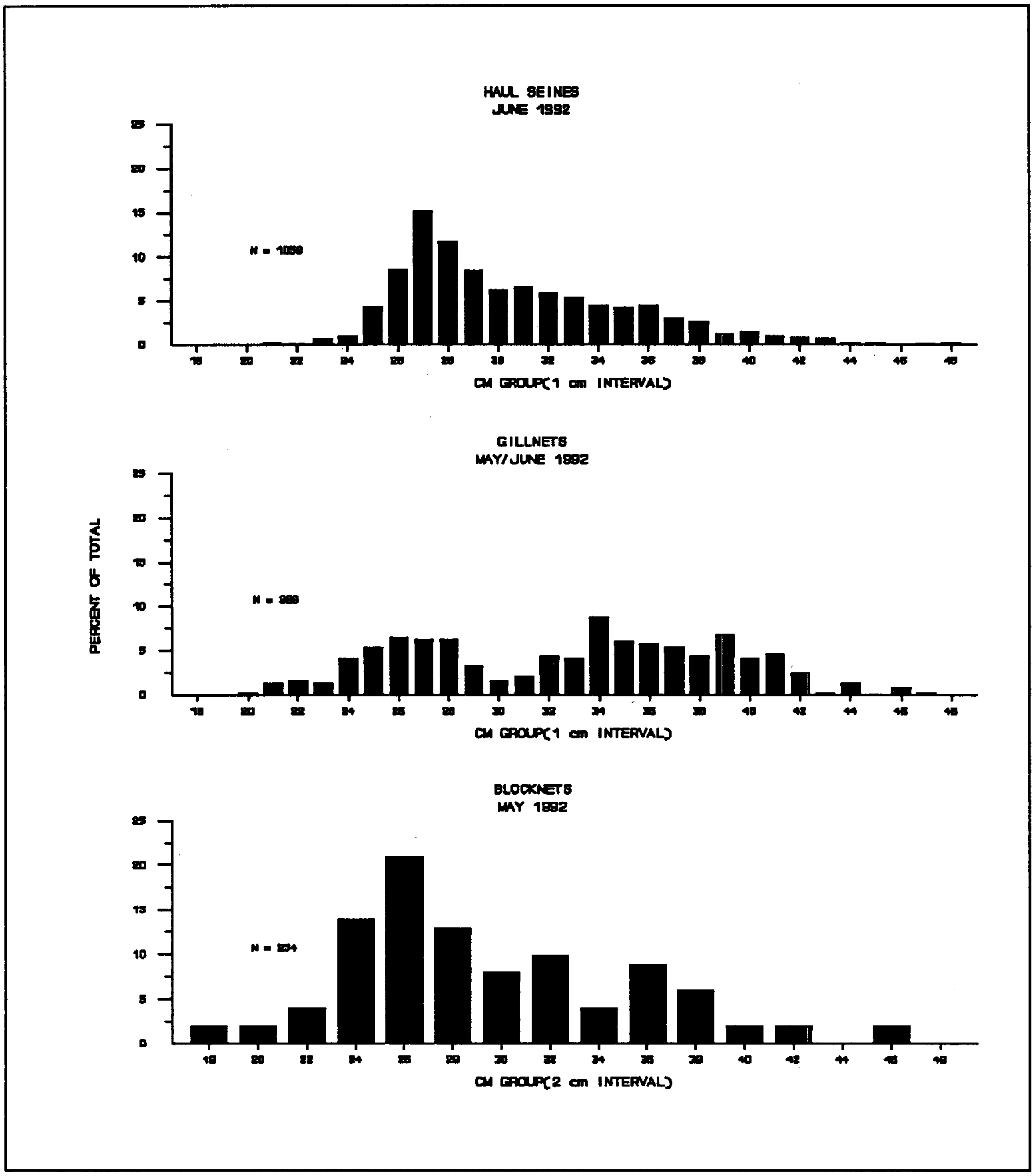

Figure 12. Comparative length frequency for gizzard shad sampled by haul seine, gill net, and blocknet in Lake Denham during spring 1992

panels apparently favored the capture of a higher proportion of larger-sized gizzard shad, length-frequency histograms generated from both haul seine and gill net data demonstrated a trend toward smaller-sized individuals in Lake Denham following removal of gizzard shad (Figures 6 and 11).

Assessment of Gill Nets as a Gizzard Shad Population Sampling Tool

The decline of gizzard shad CPUE in experimental gill net samples in Lake Denham in the months following winter and spring haul seine operations could not be attributed exclusively to exploitation by the haul seine. All lakes showed a seasonal increase and decrease in gizzard shad CPUE (Figure 5). Other factors apparently influenced gizzard shad catch; therefore, population differences among years were evaluated using pooled data from January through April, when shad gill net catch was apparently most efficient (Table 6).

The effect of gear saturation on gill nets was evaluated in March 1990 and January 1991 in Lake Denham. Gear saturation may cause underestimation of the true catch rate through fish physically occupying available net holes and by captured fish making the net more visible to uncaptured fish. In these 2 months, five 1-hour samples were made to compare with standard 2-hour samples. The 1-hour catch rate of 33.2 gizzard shad/h in January 1991 was not significantly different (P >0.1) from the 37.6 gizzard shad/h calculated from the 2-hour sets. However, the 1-hour catch rate in March 1990 (80.4 shad/h) was significantly different and was 1.4 times higher than the 57.0 shad/hour from the 2-hour sets. These tests suggested that some saturation occurred in 2-hour gill net samples at catch rates of more than 38 shad/h.

The amount of variation in monthly gizzard shad CPUE estimates from gill nets was examined by using coefficient of variation (C.V.) values for each study lake. Values were examined by month or pooled into seasons of warm and cool water periods. No seasonal trends were evident, and no significant differences were found among sample periods. A plot of monthly C.V. values for Lake Denham (Figure 13) suggested that gill net saturation occurred during the early months of the study (January and February 1989), as shown by low C.V. at high-catch values. However, C.V. values increased in March and April 1989 in spite of a high CPUE. No significant correlation (P >0.1) between gill net catch rate and coefficient of variation was found for any of the study lakes.

Gizzard shad in Lake Denham attained total lengths of 25 cm and became fully vulnerable to experimental gill nets during their second year of life (Table 18). Although large seasonal fluctuations in CPUE values were observed, gizzard shad larger than 25 cm and ranging in age from 1–4 years were well represented in gill net catches during the peak season sample period of January through March (Figure 6). It would be unreasonable to conclude that annual

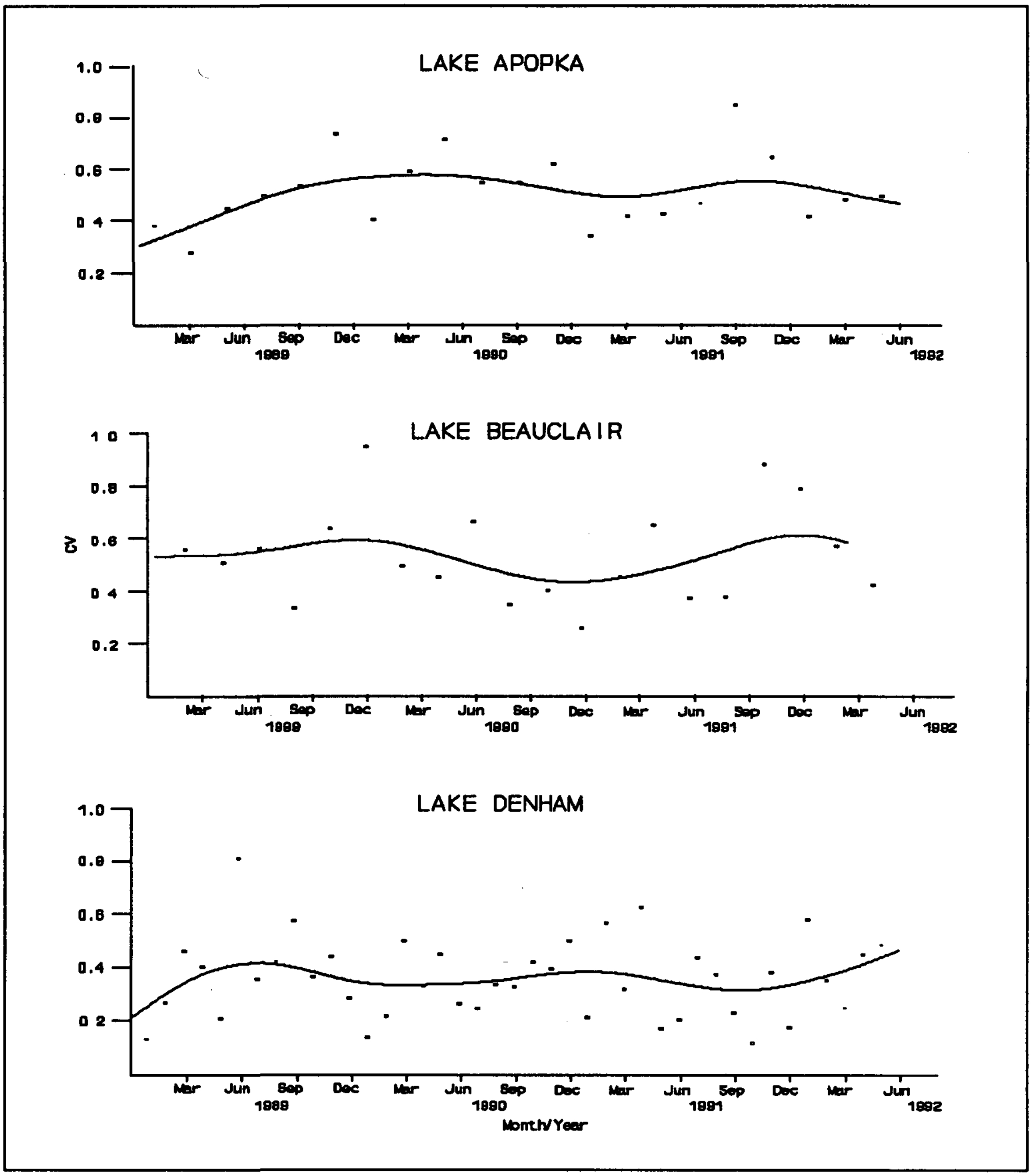

Figure 13. Coefficient of variation (C.V.) in gizzard shad catch in experimental gill nets from Lakes Apopka, Beauclair, and Denham from January 1989 through May 1992. *The curve is a distance-weighted least-squares function.*

declines in CPUE of 84 percent or greater over the course of 2 months in Lake Denham (and the control lakes) were exclusively the result of natural mortality or removal by haul seine. These declines more likely were the result of behavior and activity levels which affected the catchability of the fish. This seasonal decrease in CPUE for gizzard shad was demonstrated in Lake Denham during 1989 (the year before the haul seine removal) and was demonstrated in each year in the other study lakes. Thus comparisons of catch rates that were made for the same period in each study year had the confounding effect of new fish that were recruited to the gear during the summer and fall interim period, limiting the utility of gill nets in assessing the standing stock of gizzard shad in any quantitative form. This question could be largely resolved through the incorporation of catch by age class data, which would require a thorough study using otoliths.

Table 18. Mean length at age for gizzard shad collected November 1990, using whole otoliths

Age	Male			Female		
	No.	Mean	Range	No.	Mean	Range
0	19	201	169-220	16	200	174-247
1	105	302	226-358	90	311	244-389
2	25	349	317-400	18	382	300-438
3	26	375	343-398	26	411	365-451
4	5	385	347-404	9	428	402-462
5	1	414	414	2	434	424-444
6	0	-	-	1	440	440

Note: - = no fish of this age

Conclusions

Subharvestable largemouth bass, bluegill, and redear sunfish in Lake Denham demonstrated significant ($P < 0.1$) increases in CPUE for electrofishing samples during 1991–92, and littoral blocknet samples indicated the same result for juvenile largemouth bass and redear sunfish. Lake Beauclair also demonstrated significant increases ($P < 0.1$) in CPUE for both bluegill and redear sunfish in electrofishing samples from the same time period. An increasing trend in numbers of subharvestable redear was also evident in littoral zone samples from Lake Apopka, though the increases were not statistically significant. Therefore, it is not possible at this time to conclude that the manipulation of the fish population in Lake Denham by haul seine was the stimulus for increased abundance of juvenile centrarchids of those three species. The first positive response that centrarchids would exhibit, following release from competitive interaction by gizzard shad, should be increased production. That apparently happened in Lake Denham during late 1991 and 1992; however, the increases noted in Lake Beauclair, and to a lesser degree in Lake Apopka, could not be explained. The role of climatic variables and such factors as changing quality and quantity of water flowing into Lake Beauclair via the Apopka-Beauclair canal were not explored in the scope of this report.

There has been no statistically significant ($P > 0.1$) increase in the abundance of harvestable-sized largemouth bass, bluegill, or redear in any of the study lakes as measured through electrofishing or blocknet samples. During 1989–90 and 1990–91, the abundance of juvenile bluegill and redear was similar among the three lakes as measured by electrofishing, and between Lakes Apopka and Denham as shown by littoral blocknet samples; yet Lake Beauclair had a much higher population of harvestable-sized bluegill and redear. If the increased abundance of juvenile fish in Lake Denham does not recruit to larger size classes within the 1992–93 sample year, then other mechanisms must be limiting the production of harvestable-sized fish. Increased abundance of submersed aquatic vegetation in large hypereutrophic lakes that typically support only a limited littoral zone plant community has proven to facilitate recruitment of harvestable-sized largemouth bass, bluegill, and redear sunfish. The amount and types of habitat within the three lakes was similar among years, but was not quantified in this study.

Gizzard shad abundance was difficult to measure with any great degree of confidence. Gill net samples were subject to factors such as gear saturation at high population densities, seasonal CPUE value variation, and possible selection for larger-sized individuals that limited their value in measuring population parameters. Limnetic blocknet results were also quite variable, and their ability to accurately sample a schooling, randomly dispersed pelagic species such as gizzard shad is questionable. In spite of sample methodology limitations, sufficient data were gathered from all limnetic samples and haul seine data to support the conclusion that a significant portion of the gizzard shad population was removed from Lake Denham by successive haul seine operations, and that gizzard shad abundance has remained below the pre-manipulation estimate during 1990, 1991, and 1992. This study should be continued for another season to determine if the increased abundance of juvenile sport fish produce increased numbers of adult fish.

LITERATURE CITED

Benton, J., and D. Douglas. 1992. *Annual Report for Ocklawaha Chain of Lakes Largemouth Bass Population Dynamics Study.* Florida Game and Fresh Water Fish Commission. Tallahassee, Florida. 10p.

Benton, J., D. Douglas, and L. Prevatt. 1991a. *Completion Report for Fisheries Studies of the Oklawaha Chain of Lakes.* Florida Game and Fresh Water Fish Commission. Tallahassee, Florida. 38p.

Benton, J., D. Douglas, and L. Prevatt. 1991b. *Completion Report for Apopka Fisheries Studies.* Florida Game and Fresh Water Fish Commission. Tallahassee, Florida. 41p.

Chapman, P., and W. Fish. 1991. *Final Report for Tenoroc Reserve Management Area: Management by Regulation Study, Lakes 3 and 5.* Florida Game and Fresh Water Fish Commission. Tallahassee, Florida. 30p.

Crisman, T., and J. Beaver. 1988. *Lake Apopka Trophic Structure Manipulation: Phase I Final Project Report.* St. Johns River Water Management District. Palatka, Florida. 127p.

Jearld, A. 1983. Age Determination. L.A. Nielsen and D.L. Johnson, eds., p. 301–324. *Fisheries Techniques.* American Fisheries Society. Bethesda, Maryland.

Kautz, R.S. 1981. *Effects of Eutrophication on the Fish Communities of Florida Lakes.* Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, 34:67–80.

McQueen, D.J. 1990. Manipulating Lake Community Structure: Where Do We Go From Here? *Freshwater Biology,* 23:613–620.

Ricker, W.E. 1975. *Computation and Interpretation of Biological Statistics of Fish Populations.* Bulletin of the Fisheries Resources Board of Canada. Bulletin Number 191. Ottawa. 382p.

Steele, R.G.D., and J.H. Torrie. 1980. *Principles and Procedures of Statistics.* 2nd Ed. McGraw-Hill, Inc. New York. 633p.

Ware, F.J. 1971. *Lake Management Research: Haul Seine Study.* Job Completion Report for Project F–12–15. Florida Game and Fresh Water Fish Commission. Tallahassee, Florida. 31p.

Wilkinson, L. 1990. *SYSTAT: The System for Statistics.* Systat, Inc. Evanston, Illinois.