

RELATIONSHIPS BETWEEN HABITAT AND FISH  
POPULATIONS OF A NEW RESERVOIR

By

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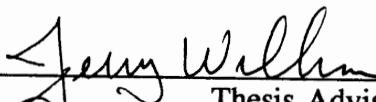
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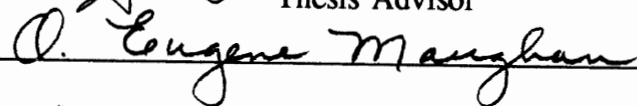
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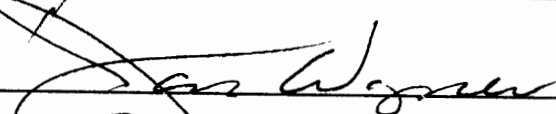
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## CHAPTER I

### INTRODUCTION

Historically, managers of recreational fisheries have attempted to maximize the sustained yield of individual species. The theory of maximum sustained yield (MSY) relies primarily on density-dependent population models (Murphy 1966, Everhart et al. 1975) and holds that more fish means better fishing (Anderson 1978). Density dependent population models are based on rates of recruitment, growth, and mortality which determine the apparent form and function of populations (Swingle 1950, Jenkins and Morais 1978). Management for maximum sustained yield usually involves manipulation or modification of the form and functions of individual fish populations to increase production (Anderson 1973). In reality, however, we must manage for a series of coexisting interrelated populations. This interrelated series of populations defines the structure of an ecosystem.

The structure of an ecosystem has been defined as the composition of the biological community including species, numbers, biomass, life history, and distribution in space. Consideration must be given to the quantity and distribution of abiotic materials and the range of conditions necessary for existence (Odum 1962). Traditional MSY theory could not be used in the management of ecosystems

because it ignored noncompensatory population regulation and other interactions caused by the coexistence of these interrelated series of populations. Inclusion of these interactive factors into management considerations has led to the recognition that a need exists to develop a new framework for fishery management objectives (Larkin 1977). The result was the optimum sustained yield theory in which emphasis was on improved fishing quality and favorable benefit-cost ratios and inclusion of an entire series of interactive factors (Anderson 1975, 1978). Successful application of optimum sustained yield (OSY) requires integration and application of ecological processes and socioeconomic perspectives during the development of management programs (Anderson 1980).

The need to include information on ecological processes in OSY efforts led initially to attempts to quantify the effects of density-independent factors such as habitat complexity (including water quality) on the rates of reproduction, growth, mortality, and distribution in space of individual species. Although the initial investigations and most of the subsequent studies have focused on the factors which govern density and biomass of individual species in streams, application of habitat modeling techniques to reservoir management exist (Summerfelt 1971, Regier 1972, Orth 1980, Henry 1986).

As mentioned above, more effort has been made to model stream fish habitats than model reservoir fish habitats. Although a wealth of information exists from stream habitats, few attempts have been made to adapt stream habitat assessment methodologies to reservoirs (Aggus and Morais 1979). My study was designed to

attempt to use habitat modeling techniques commonly used in stream systems to define habitat relationships on a new reservoir.

The objectives of this study were to: 1) determine habitat use patterns of numerically important fish species using habitat assessment procedures adapted from commonly used stream methodologies, 2) relate the relative abundance of fish species in a newly impounded reservoir to habitat conditions, and 3) relate attributes of population assemblages to the spatial variation in habitat structure found within the reservoir environment.



## CHAPTER II

### LITERATURE REVIEW

#### Habitat and Fish Community Structure

Currently two schools of thought exist concerning what controls populations of individual fish species and assemblages. The first hypothesis is that habitat structure is the controlling factor. The basis of this school of thought are studies that have shown that bird community diversity increases with increasing complexity of vegetation (MacArthur and MacArthur 1961, MacArthur 1964). These same processes have been found to operate in fish communities. Recent studies have documented the tendency of individual species of fishes and even assemblages of species to select specific habitat types (Zaret and Rand 1971, Mendelson 1975, Gorman and Karr 1978, Gorman 1988a; 1988b, James 1989). Over space, the distribution of stream fishes is characterized by large faunal changes (replacement of one assemblage by another) within relatively short distances (Shelford 1911). The changes in fish assemblages appear to be attributable to structural features of habitat including current velocity, substrate, and depth (Shelford and Eddy 1929, Winn 1958, Sheldon 1968, Gorman and Karr 1978) and may be initially manifested as species

additions, species replacements, or by changing relative abundances (Gorman and Karr 1978).

According to Grossman (1982), attributes of deterministic communities include: 1) limited morphological similarity among species; 2) species that segregate on the basis of habitat, microhabitat, and diet; 3) persistence of species through many generations; and 4) resiliency to perturbations. Stream fish assemblages believed to be organized by deterministic processes occur in relatively undisturbed environments where habitat specializations seemingly constitute evidence of coevolution, and assemblage structure is thought to be regulated by habitat selection, competition, or predation (Mendelson 1975, Gorman and Karr 1978, Gatz 1979, Grossman et al. 1982, Moyle and Vondracek 1985, Gorman 1987).

In contrast to this deterministic view some data sets indicate local stream fish assemblages represent nonequilibrium conditions that result from stochastic processes (Grossman et al. 1982, Schlosser 1982). For example, species predomination has been shown to be dependent on the degree of water level stability in Everglades marshes (Kushlan 1976). Communities structured by stochastic processes afford little opportunity to predict community structure (Nisbet and Gurney 1982).

In reality, both hypotheses may be true and the predictability of relationships between fish community composition and habitat structure may be dependent on where the system being studied occurs along the deterministic-stochastic continuum (Moyle and Vondracek 1985).

## Assessment of Fish Community Structure

Various indices such as species richness, diversity, and evenness have been related to habitat factors (Peet 1974). Species richness and evenness have been shown to be linearly related to habitat complexity and community complexity (Gorman and Karr 1978, Schlosser 1982). Community complexity is linearly related to longitudinal succession (Sheldon 1968). The latter relationship presumably arises because high faunal diversity occurs where environmental variability is low (Pianka 1966).

Several other procedures have been used to define community structure. Similarity indices and multivariate statistical procedures have been used to measure the mathematical relationships among samples for which information exists on two or more habitat variables (e.g., Mendelson 1975, Schlosser 1982, Gorman 1988a; 1988b). Similarity and dissimilarity indices compare the amount of overlap in species composition or the relative abundances between two samples (Fausch et al. 1990). Various similarity indices are discussed by Pielou (1984) along with their use in multivariate cluster analysis. Other multivariate procedures such as principal components analysis have been used to reveal previously unsuspected habitat relationships (Johnson and Wichern 1982).

## Habitat Evaluation for Single Species

Procedures to evaluate habitat preferences of single species and relationships

between fish communities and habitat structure rely on the assumption that both sets of data were taken with congruent sampling methodologies. Two of the most commonly used methods to relate habitat to the occurrence of single species are the instream flow incremental methodology and the aquatic habitat evaluation procedures. The instream flow incremental methodology (Stalnaker 1979, Bovee 1982) requires knowledge of microhabitat preferences for target species, usually expressed as habitat-suitability curves (Bovee and Cochnauer 1977). Whereas assumptions of habitat and stream fish community studies are typically derived from a poorly defined group of empirical generalizations based on the stream continuum concept (Schlosser 1982), the robustness of the incremental methodology is dependent on adherence to the following assumptions (Orth and Maughan 1982): 1) depth, velocity, and substrate are the most important habitat variables affecting fish distribution and abundance in flow regime considerations; 2) the stream channel is not altered by changes in flow regime; 3) depth, velocity, and substrate are independent in their influence on habitat selection by fishes; 4) the stream can be modeled on the basis of one or more representative sampling reaches; and 5) a positive, linear relationship exists between weighted usable area and fish standing stock or habitat use.

Several weaknesses have been suggested in the habitat suitability index models used in the instream flow incremental methodology. Habitat-suitability models are often based on incomplete data on species habitat requirements and suffer from the lack of a conceptual framework to guide the process of developing a composite habitat score from individual habitat ratings (Propst 1982, Hubert and Rahel 1989).

Variations of the habitat-suitability model development process are frequently used to

overcome these real or perceived weaknesses. For example, habitat-suitability index curves were developed for endangered fish species of the upper Colorado River basin using the Delphi Technique because of the belief that factors other than those measured controlled fish populations (Valdez et al. 1987). James (1989) reduced disadvantages inherent in the assumption of independence of habitat variables by using the summation of actual preferred habitat intervals in lieu of the weighted usable area scalar and by using multivariate statistical analyses. Despite the weaknesses addressed by the authors cited above, good correlations between a species distribution or standing stock and various physical-chemical features of the environment have been derived using standard statistical procedures (Matthews and Hill 1979, Layher and Maughan 1985, Layher et al. 1987, Hubert and Rahel 1989).

#### Inferential Assessments and the Reservoir Environment

In streams, the problems associated with relating abiotic factors to fish species distributions are reduced relative to reservoirs due to the linear configuration (Sheldon 1968). Unfortunately, many studies of stream fish communities have relied almost exclusively on seining surveys which effectively obliterate information on small-scale distributional relationships among species (Gorman 1987). Seining has provided some inferential assessments of habitat relationships in fish communities (e.g., Sheldon 1968, Gorman and Karr 1978, Schlosser 1982, Felley and Hill 1983). More recent studies have used in situ observations to provide detailed information on single species

habitat use patterns or analysis of habitat segregation of assemblages (e.g., Gorman 1983; 1987; 1988, Moyle and Vondracek 1985, Leon et al. 1987, James 1989).

Studies of fish species distributions and habitat preferences in turbid, windswept midwestern reservoirs cannot employ in situ observations and are limited to inferential assessments. The almost exclusive use of passive sampling required by the condition present in reservoirs increases the difficulty in differentiating between incidental use of habitats and active habitat selection. Despite these sampling limitations inherent to reservoirs, the vertical distribution of selected reservoir fishes has been related to specific physical-chemical factors (Dendy 1948, Borges 1950, Carter 1967) and to topographic features, depth of water, and sediment characteristics (Summerfelt 1971). For example, timbered areas of Bull Shoals Reservoir in Arkansas supported more fish and provided more fish to anglers than nontimbered areas (Burress 1961). In general, relative abundances of largemouth bass and bluegill increased in timbered areas of lakes, whereas crappie abundances increased in open areas (Davis and Hughes 1971) with localized cover (Hall et al. 1954, Goodson 1966).

Both deterministic and stochastic factors may govern the relationships between species and habitat that develop in reservoirs. Temperature and other physical-chemical characteristics are controlled by the amount of water stored, but the amount of water stored may be influenced by rainfall (Cross 1970). Dramatic changes in population density have been related to water level changes and concomitant changes in habitat and biota (Orth 1980). These changes can result from either direct effects or indirect effects such as altered plankton abundance (Taylor 1971), benthos abundance (Aggus 1971, Ison 1971, Benson and Hudson 1975), and abundance of

aquatic macrophytes (DeGruchy 1952, Boyd 1971). Several factors may complicate the establishment of community structure in reservoirs. Probably an adjustment period occurs in habitat definitions after a reservoir is filled (Terrell 1982). Fish populations which initially invade a new impoundment must restructure themselves as the environment changes. Presumably, ecological overlap or a greater similarity among syntopic species, can occur in unsaturated habitats where competition is reduced (Pianka 1983). This initial period of high productivity precedes the development of fish assemblages dominated by lower trophic levels (Buck and Cross 1951, Latta 1951, Jenkins and Leonard 1952, Carlander 1955, Jenkins 1958). Once the populations are structured, the addition of a competitor which is more effective in a given habitat can change the profitability ranking for a species so much that preferred habitats are abandoned (Zaret and Paine 1973, Werner and Hall 1979). Removal of fish can also cause profound changes and disrupt normal relationships among species (Keast 1978). Removal of fish can result from stochastic events. Summer flushing has been related to the loss of fish numbers, especially when flushing time was less than 7 days (Walburg 1977).

## CHAPTER III

### STUDY AREA

Copan Reservoir is located in northeastern Oklahoma, approximately 3 km west of Copan, Oklahoma in Washington County (Figure 1). The damsite is located at river km 11.9 on the Little Caney River, the primary stream feeding the reservoir. At conservation pool elevation 216 m above mean sea level, the reservoir has a surface area of approximately 1,962 ha and a shoreline of 48.3 km (Hauth et al. 1986). Mean depth at conservation pool is 2.7 m. Copan Reservoir is a multipurpose project used for flood control, water supply, water quality control, recreation, and fish and wildlife (Oklahoma Water Resources Board 1984).

The drainage area of the reservoir basin is about 1,347 km<sup>2</sup>, of which about 1,308 km<sup>2</sup> are above the damsite. The Little Caney River is a tributary of the Caney River in the Verdigris River Drainage of southeastern Kansas and northeastern Oklahoma. Elevation in the Verdigris River decreases 304 m, ranging from the 457 m elevation along the Flint Hills escarpment in the north to 153 m at the southern terminus of the basin, north of Muskogee, Oklahoma (Berg et al. 1972). The major physiographic region of the watershed is the Osage Plains, which include the Chautauqua Hills south of the Neosho River (Schoewe 1949). The Chautauqua Hills



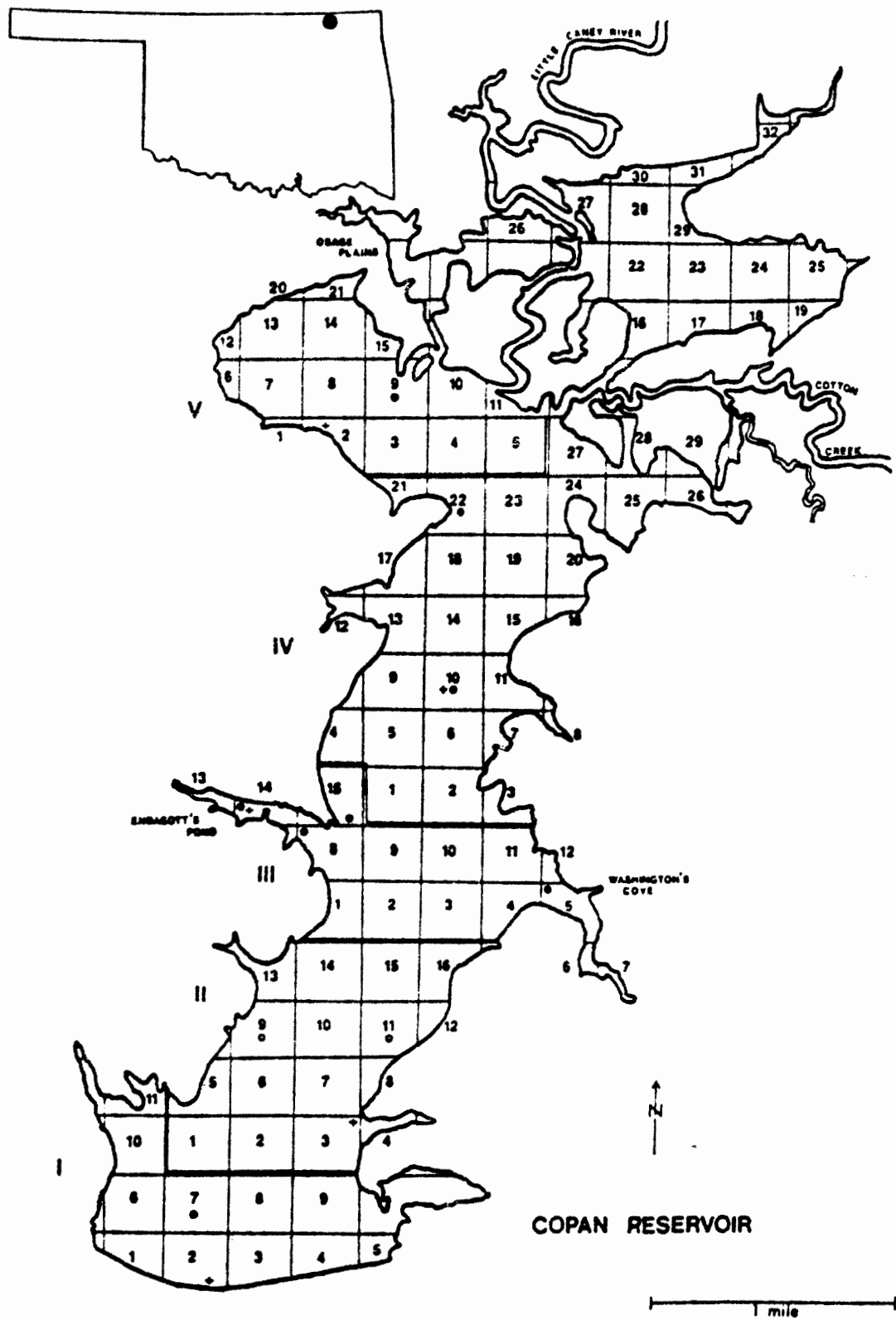


Figure 1. Copan Reservoir, Oklahoma.

are developed chiefly in the thick sandstones of the Douglas Group formed during the Pennsylvanian Period. As a result of erosion in the sandstone belt, the surface has been dissected into a range of low hills characteristically covered by oak-hickory forest. These hills differ in appearance from both the Caney River watershed in the west and the Verdigris River watershed in the east (Metcalf 1959). The gradient of the Little Caney River (=Middle Caney River; Metcalf 1959) in Chautauqua County, Kansas is 2.05 m/km.

The climate of the Verdigris Basin varies from a humid sub-tropical climate in the south and eastern portions of the basin to a humid continental climate in the western and northern portions (Berg et al. 1972). Winters are dry and mild with little precipitation falling as snow; summers are hot with precipitation falling predominately during spring and summer. Mean daily temperatures range from 27°C in July and August to about 0°C in January. Average annual precipitation ranges from 81.3 cm per year in the northeastern portion of the basin to 101.6 cm per year in the southern and eastern portions.

Stream density is high in the Verdigris River basin because of the relatively high precipitation (Berg et al. 1972). The entire division of the Chautauqua Sandstone Hills is intersected by many deeply incised streams (Metcalf 1959). Copan Reservoir is subject to rapid and dramatic changes in volume as a consequence of the physiography and climate of the drainage area. The interim flood control elevation of 216 m above mean sea level was achieved on 23 April 1983, a period of only 22 days following final impoundment on 1 April 1983. From 1 April 1983 to 31 May 1985 the reservoir volume was exchanged an estimated 9.5 times for an average exchange

rate of approximately once every 2.7 months. A maximum surface elevation of 221.2 m was reached on 7 March 1985, representing an increase of 134.4 hm<sup>3</sup> above conservation pool level. This excess volume was achieved in a 15-day interval following about 12.7 cm of rainfall within the drainage area.

Much of the vegetation within the flood pool of the reservoir was left intact prior to final impoundment. Dense stands of timber, formerly oak-hickory forest, persist in the northern half of Copan Reservoir. Passage through this standing timber from the main body of Copan Reservoir is via a "boat lane" to the northern-most extent of the reservoir. Travel is also aided by a series of "siltation lanes" which traverse the width of the reservoir through areas of standing timber.

Seasonally, Copan Reservoir has considerable spatial homogeneity in physical-chemical characteristics (Leon et al. 1986). This homogeneity occurs because the shallow mean depth and north-south orientation of the reservoir permits continuous physical mixing of the water column. Transition between seasonal conditions is gradual and the lake is holomictic.

## CHAPTER IV

### FISHES OF COPAN RESERVOIR

#### Introduction

Miller and Robison (1973) identified eighteen fish species native to the streams and rivers of Oklahoma that persist in impoundments and another 27 species that may be found in all major impoundments in the eastern half of the state. Prior to impoundment, the Caney River main stream contained 39 species (Metcalf 1959).

Twenty nine fish species were taken in Copan Reservoir. I quantified spatial and temporal variation in species richness and species relative abundances. Species richness was measured as the number of species occurring within samples. Relative abundances were derived from catch-per-unit effort (CPUE) estimates using frequency of occurrence and biomass data.

A few species decreased in abundance since 1984. I evaluated changes in fish community structure among seasons using the Percentage Similarity Coefficient (Whittaker 1952). Because there were no persistent changes in the physical characteristics of standard sampling locations, I attempted to relate the loss of fish numbers to periods of increased reservoir storage and discharge.

## Materials and Methods

### Collection of Fishes

Fishes were collected at least once each month using barrel nets, frame nets, and experimental gill nets. Barrel nets were 1.4 m in length, and 0.9 m in diameter with concave funnel ends terminating in apertures 0.2 m in diameter.

The frame nets were modified fyke nets with 1.25 cm mesh and an initial rectangular heart (two frames, each 1.83 m x 0.91 m) followed by a series of four hoops 0.76 m in diameter. A single 20-m lead net was used to direct fishes into the mouth of the net.

Frame nets were usually set in shallow water perpendicular to the shoreline in order to intercept fish moving parallel to shoreline. Combinations of frame nets and barrel nets were often used to sample near-shore habitats.

Experimental gill nets were multifilament nylon and were 45.72 m in length and 2.44 m in depth. Each net was comprised of five 9.14 m panels with mesh sizes of 1.91, 2.54, 3.18, 3.81 and 5.08 cm (square mesh). Gill nets were primarily used to sample off-shore habitats.

Fish captured were weighed to the nearest gram and total and standard lengths were measured to the nearest millimeter. Subsamples of 20 individuals per species were randomly selected for measurement when more than this number were taken. Biomass of these species was then estimated by extrapolating from the subsample.

Species were considered to be abundant if they were frequently represented in samples by large numbers of individuals. Species considered common were taken with regularity but in reduced numbers. Species considered rare occurred sporadically in samples and were represented by only a few individuals.

### Sampling Locations

Copan Reservoir was subdivided into five general areas based on differences in habitat (Figure 2). Sampling area I, the main body of the reservoir, was characterized as a wide, windswept pelagic region contiguous with the entire length of the rip-rapped earthen dam. Sampling area II was narrow relative to area I, with verticle sandstone cliffs forming abrupt shorelines. Area III was composed of two large coves; Endacott's Pond (local vernacular), a pre-impoundment water source for livestock whose dam had been breached, persisted at the terminus of the western cove. With the exception of the "boat lane" and the Little Caney River channel, dense stands of timber characterized sampling area IV. Sampling area V was a large areal expanse of shallow, windswept water where emergent linear arrangements of standing timber represented former wind-breaks between parcels of inundated agricultural land.

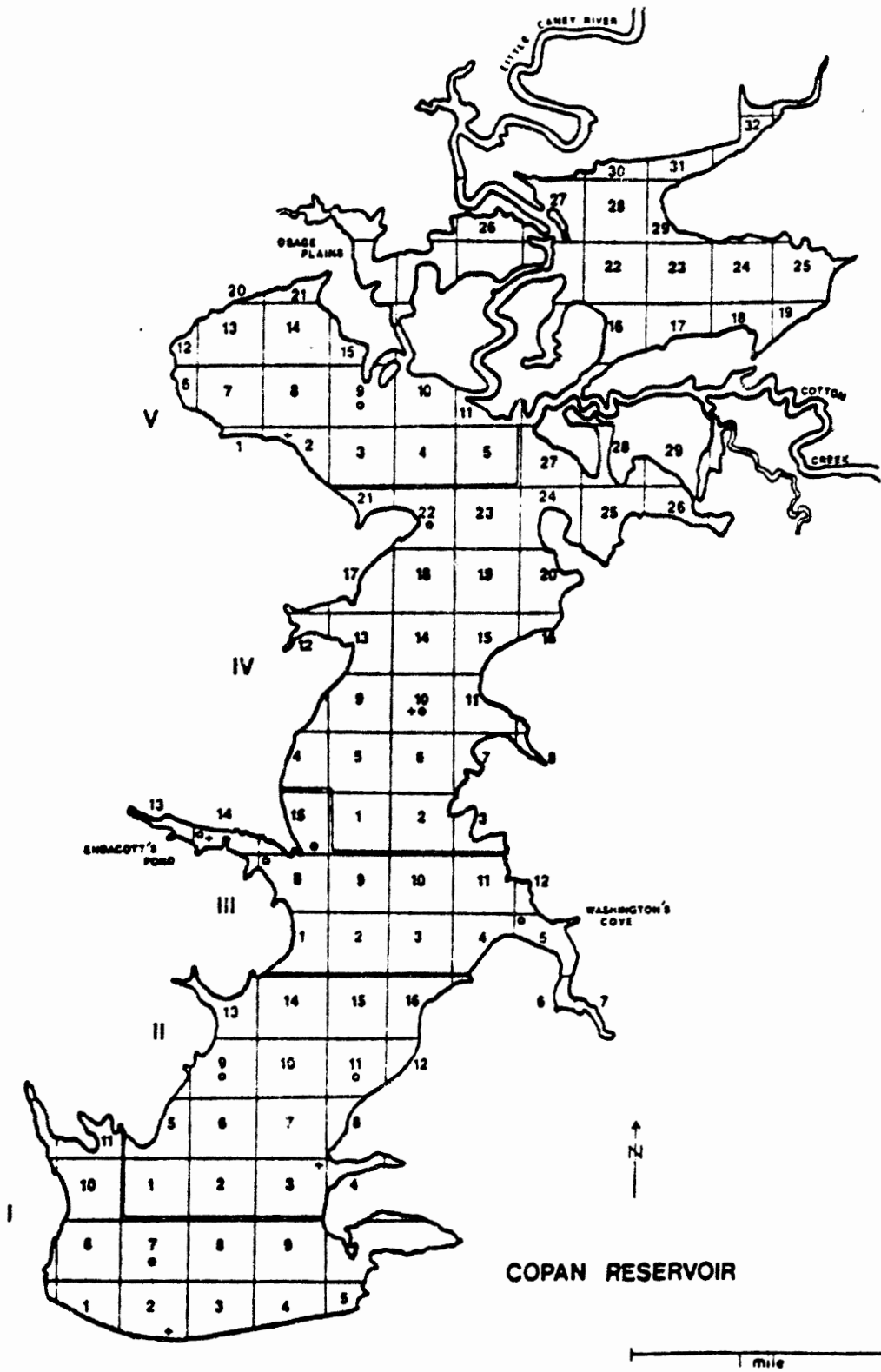


Figure 2. Five major study areas of Copan Reservoir, Oklahoma.

## Changes in Fish Community Structure

Whittaker's (1952) Percentage Similarity Coefficient (PSC) was used with relative abundance data to compare fish community structure among seasons. The equation used was  $PSC = 100 (1.0 - 0.5 \sum_{i=1}^s |p_{ix} - p_{iy}|)$ , where  $s$  is the number of species in a sample from the community,  $p_{ix}$  is the proportion of species  $i$  in the sample  $x$ , and  $p_{iy}$  is the proportion of species  $i$  in sample  $y$ . The degree of similarity between seasons was considered to be indicative of biological integrity.

## Results

### Sampling Effort

The cumulative sampling effort (inclusive of all gear types) for the entire study in Copan Reservoir was 4,568 hr (Table 1). Barrel nets were used a total of 915 hr and comprised 20% of the effort. Frame nets were used a total of 1,497 hr and represented 33% of the effort. Experimental gill nets were used a total of 2,156 hr for 47% of the effort.

In 1984, 58% (2,692 hr) of this effort was expended (Table 1). Frame nets accounted for 943 hr (35%), and experimental gill nets for 1,191 hr or 44% of the 1984 effort.

Seasonal effort among sections was consistent in 1984, except in winter (Table 2). During winter, ice cover caused sampling efforts to be concentrated in Section III



TABLE 1  
TOTAL YEARLY SAMPLING EFFORT (HR) BY SEASON OF  
BARREL NETS, FRAME NETS, AND GILL NETS

Gear/Season	Year		Total
	1984	1985	
<b>Barrel nets</b>			
Winter	57	116	173
Spring	387	0	387
Summer	114	0	114
Fall	0	241	241
Σ:	<u>558</u> (21%)	<u>357</u> (19%)	<u>915</u> (20%)
<b>Frame nets</b>			
Winter	0	0	0
Spring	470	77	547
Summer	244	236	480
Fall	229	241	470
Σ:	<u>943</u> (35%)	<u>554</u> (30%)	<u>1497</u> (33%)
<b>Gill nets</b>			
Winter	120	192	312
Spring	220	364	584
Summer	439	194	633
Fall	412	215	627
Σ:	<u>1191</u> (44%)	<u>965</u> (51%)	<u>2156</u> (47%)
Annual Total	<u>2692</u> (59%)	<u>1876</u> (41%)	<u>4568</u>

and restricted relative to gear; no frame nets were used due to the difficulty in placing them beneath ice (Table 14, 15, 16, 17; Appendix A). Low catch rates during all seasons in Section IV led to a reduction in effort in this section

Sampling in 1985 accounted for 41% (1,876 hr) of the cumulative effort expended during the study (Table 1). Barrel nets were used a total of 357 hr or 19% of the sampling effort. Barrel nets were not used during spring or summer seasons but frame nets and gill nets were used extensively (Table 2). Frame nets accounted for 30% (554 hr) and gill nets 51% (965 hr) of the effort.

Once again, severe winter weather (1985) restricted sampling to easily accessible areas of the reservoir. Sampling of Section III accounted for 92% of the effort during this season (Table 2). An attempt was made to maintain consistent effort among sections throughout the remaining seasons of 1985 (Table 2). However, low catch rates in Section IV caused the amount of effort expended in this section to be reduced.

#### Fish Species Relative Abundance

A total of 8,672 fishes of 29 species were taken from Copan Reservoir during the period 1 December 1983 to 31 November 1985 (Table 3). Seven species accounted for 83% of the total catch. These species were carp (*Carpiodes carpio*), gizzard shad (*Dorosoma cepedianum*), black bullhead (*Ictalurus melas*), bluegill (*Lepomis macrochirus*), spotted gar (*Lepisosteus oculatus*), white bass (*Morone chrysops*), and white crappie (*Pomoxis annularis*). Of the remaining species, river carpsucker (*Carpiodes carpio*), smallmouth buffalo (*Ictalurus bubalus*), bigmouth buffalo (*Ictiobus*

TABLE 2

1985 SAMPLING EFFORT (HR) OF BARREL NETS, FRAME NETS,  
AND GILL NETS WITHIN STANDARD SAMPLING SECTIONS

Gear/Month	Section					Total
	1	2	3	4	5	
<b>Barrel nets</b>						
Winter	0	0	116	0	0	116
Spring	0	0	0	0	0	0
Summer	0	0	0	0	0	0
Fall	48	48	48	48	49	241
$\Sigma$ :	<u>48</u>	<u>48</u>	<u>164</u>	<u>48</u>	<u>49</u>	<u>357 (19%)</u>
<b>Frame nets</b>						
Winter	0	0	0	0	0	0
Spring	18	18	20	0	21	77
Summer	46	46	48	48	48	236
Fall	48	48	48	48	49	241
$\Sigma$ :	<u>112</u>	<u>112</u>	<u>114</u>	<u>96</u>	<u>118</u>	<u>554 (30%)</u>
<b>Gill nets</b>						
Winter	0	0	168	0	24	192
Spring	91	77	76	48	72	364
Summer	49	49	48	0	48	194
Fall	47	48	48	24	48	215
$\Sigma$ :	<u>184</u>	<u>174</u>	<u>340</u>	<u>72</u>	<u>192</u>	<u>965 (51%)</u>
<b>Total</b>	347	334	618	216	359	1876

cyprinellus), yellow bullhead (Ictalurus natalis), channel catfish (I. punctatus), green sunfish (Lepomis cyanellus), longear sunfish (L. megalotis), redear (L. microlophus), shortnose gar (Lepisosteus platostomus), largemouth bass (Micropterus salmoides), and black crappie (Pomoxis nigromaculatus) were common. Freshwater drum (Aplodinotus grunniens), striped bass x white bass hybrids (Morone saxatilis x M. chrysops), blue catfish (Ictalurus furcatus), brook silverside (Labidesthes sicculus), warmouth (Lepomis gulosus), orangespotted sunfish (L. humilis), longnose gar (Lepisosteus osseus), river redhorse (Moxostoma erythrurum), golden shiner (Notemigonus crysoleucas), logperch (Percina caprodes), and flathead catfish (Pylodictus olivaris) were rare.

Gizzard shad and black bullhead were the most abundant species taken during this study; each represented 16% of the fishes collected (Table 3). The relative abundance of gizzard shad increased from 11% in 1984 to 27% in 1985 (Tables 18, 19; Appendix A.) Gizzard shad were most frequently taken in sections I, III, and V. The relative abundance of black bullhead decreased from 19% in 1984 to 11% in 1985. Black bullhead were most numerous in sections III and V but were commonly taken in all sections.

White crappie were also abundant in Copan Reservoir; 16% of all fishes collected (Table 3). The relative abundance of this species in the catch increased from 12% in 1984 to 24% in 1985 (Tables 18, 19; Appendix A). White crappie were abundant in sections III and V during 1984, but were frequent in catches from all sections in 1985. Forty two point nine percent of all fishes taken in the fall of 1985

were white crappie. Conversely, only 1% of the catch in winter 1983-1984 were white crappie.

Carp and bluegill each comprised 10% of all fishes collected during this study (Table 3). The relative abundance of carp decreased from 11% in 1984 to 9% in 1985, while that of bluegill increased from 9% to 13% during the same period (Table 18, 19; Appendix A). Carp were commonly taken in all sections of the reservoir; bluegill were most frequently taken in Section III.

White bass represented 9% of all fishes collected during the study (Table 3). In 1984, white bass made up 12% of the total catch (Tables 18, 19; Appendix A). However, in 1985 their relative abundance declined to 3% (Table 19; Appendix A). Sections I, II, and V consistently yielded relatively large numbers of white bass in 1984. The maximum relative abundance of approximately 24% was achieved in 1984 in Section I. In contrast, the maximum relative abundance in 1985 was 4% in Section V. A maximum seasonal relative abundance of 37% occurred in winter 1983-1984, but declined consistently throughout ensuing seasons until a minimum value of 1% was reached in summer 1985.

Spotted gar represented 5% of the total two-year catch (Table 3). The relative abundance of spotted gar decreased from 8% in 1984 to 0.3% in 1985 (Tables 18, 19; Appendix A). A preliminary study conducted during 1983 showed that spotted gar were primarily restricted to Section III; approximately 96% of all spotted gar taken during 1983 were from the area of Endacott's Pond. The population became

TABLE 3

TOTAL NUMBER OF FISHES IN EACH SPECIES COLLECTED BY ALL SAMPLING METHODS,  
WINTER 1984-FALL 1985

Species	Year and Season								Total	%
	1984				1985					
	Win	Spr	Sum	Fall	Win	Spr	Sum	Fall		
Drum	5	11	12	16	-	16	14	13	87	1.0
River carpsucker	10	67	51	55	1	13	1	2	200	2.3
Carp	7	323	231	67	4	151	86	24	893	10.3
Gizzard shad	34	121	121	319	18	240	144	397	1394	16.1
Hybrid bass	-	7	-	-	-	-	-	7	14	0.2
Smallmouth buffalo	-	2	2	37	2	38	8	9	98	1.1
Bigmouth buffalo	-	40	27	33	10	11	14	4	139	1.6
Blue catfish	-	4	30	2	-	20	15	21	92	1.1
Black bullhead	78	476	291	228	20	153	70	78	1394	16.1
Yellow bullhead	3	109	-	4	1	-	2	1	120	1.4

TABLE 3 (continued)

Species	Year and Season								Total	%
	1984				1985					
	Win	Spr	Sum	Fall	Win	Spr	Sum	Fall		
Channel catfish	18	40	67	33	-	17	13	10	198	2.3
Brook silverdale	-	1	-	-	-	-	1	-	2	0.02
Green sunfish	1	26	6	1	-	5	21	-	60	0.7
Warmouth	-	18	10	2	-	1	6	-	37	0.4
Orangespotted sunfish	-	1	-	1	-	-	10	1	13	0.1
Bluegill	29	328	93	53	1	13	347	23	887	10.2
Longear sunfish	-	33	6	-	-	1	31	1	72	0.8
Redear	-	20	4	3	5	1	23	3	59	0.7
Spotted gar	298	33	120	7	2	3	3	2	468	5.4
Longnose gar	-	-	4	-	-	0	1	-	5	0.1
Shortnose gar	-	6	80	4	1	3	7	-	101	1.2
Largemouth bass	1	28	73	8	-	7	10	2	129	1.5

TABLE 3 (continued)

Species	Year and Season								Total	%
	1984				1985					
	Win	Spr	Sum	Fall	Win	Spr	Sum	Fall		
White bass	293	194	134	64	9	29	9	35	767	8.8
River redhorse	-	-	-	-	-	-	-	1	1	0.01
Golden shiner	-	3	-	-	-	4	-	-	7	0.1
Logperch	-	1	-	-	-	-	-	-	1	0.01
White crappie	10	237	274	129	8	104	127	478	1367	15.8
Black crappie	1	29	8	11	2	5	7	2	65	0.7
Flathead catfish	-	1	1	-	-	-	-	-	2	0.02
Total	778	2159	1645	1077	84	835	970	1114	8672	
Relative Abundance (%)	7.1	19.5	14.8	9.7	0.8	7.5	8.7	10.0		



relatively evenly distributed throughout the reservoir in 1984 then nearly disappeared in 1985.

Other species were less abundant but were still frequently taken in samples. These species included freshwater drum, river carpsucker, smallmouth buffalo, bigmouth buffalo, blue catfish, yellow bullhead, channel catfish, and largemouth bass.

#### Catch-Per-Unit Effort (CPUE)

Catch-per-Unit Effort (fishes per net hr x 100) in frame nets and experimental gill nets generally exceeded that of barrel nets. The single exception was in winter 1984-1985, when barrel net CPUE was 34 and gillnet CPUE was 23. The most efficient gear type, based on CPUE, was experimental gill nets. These nets collected a seasonal maximum of 628 fishes per 100 hr in winter 1983-1984 and a minimum of 173 fishes per 100 hr in summer 1985. Frame nets exceeded the CPUE of experimental gill nets in only two instances, spring 1984 and summer 1985.

Mean annual CPUE for experimental gill nets decreased from 341.3 in 1984 to 156.3 in 1985. This decrease represented a 37% reduction in catch rates of offshore fish species. In contrast, cumulative CPUE values for barrel nets and frame nets exhibited a 2% reduction in catch rates of near-shore fish species during the same period.

Based on CPUE, seven species were abundant in the catch in 1984 (Table 4). These were carp, gizzard shad, black bullhead, bluegill, spotted gar, white bass, and

white crappie. These data agree with the relative abundance data presented in the previous section. Common species were river carpsucker, bigmouth buffalo, channel catfish, shortnose gar, and largemouth bass.

The maximum cumulative CPUE during 1984 was for black bullhead. This species was collected at the rate of about 40 individuals per 100 hr during 1984 and was consistently abundant each season (Table 4). The maximum seasonal CPUE was 44 in both winter and spring, with the seasonal minimum of about 36 in fall.

White bass were taken at the rate of 25 individuals per 100 hr during 1984 (Table 4). The seasonal CPUE of white bass declined from a maximum of about 166 in winter to about 10 in the fall.

The total 1984 CPUE of white crappie was approximately 24 per 100 hr (Table 4). Unlike white bass, the CPUE of white crappie increased from about 6 in winter to about 22 in spring and 34 in summer. In fall the CPUE of white crappie declined to about 20. This value was higher than that for all species except black bullhead and gizzard shad.

The total 1984 CPUE of gizzard shad was approximately 22 per 100 hr (Table 4) and increased each season. The seasonal minimum CPUE was about 1.9 in winter, increased to about 11 in spring, 15 in summer, and reached a seasonal maximum of about 50 in fall.

Carp were taken at a rate of approximately 19 fish per 100 hr (Table 4). Seasonal CPUE ranged from about 4 in winter to about 30 in spring.

The total CPUE for bluegill was approximately 19 per 100 hr (Table 4). Seasonal estimates of bluegill CPUE were greatest in spring when use of frame nets

and barrel nets was most extensive. Seasonal values ranged from about 8 in fall to about 30 in spring.

Spotted gar were collected at a rate of approximately 17 per 100 hr in 1984 (Table 4). Like white bass, seasonal CPUE values declined progressively. The maximum CPUE was about 168 in winter, but declined to about 3 in spring and 1 in fall. The CPUE increased to about 15 during summer when spotted gar were taken from all sections of the reservoir.

Shortnose gar were also a common component of the total catch in 1984. This species was collected at a rate of approximately 3 per 100 hr (Table 4). The maximum CPUE was about 10 in the summer. During this season shortnose gar were taken from all sections of the reservoir. Subsequently the CPUE for shortnose gar declined to less than 1 in the fall.

The CPUE of other common species (river carpsucker, bigmouth buffalo, channel catfish, and largemouth bass) varied little among seasons (Table 4). The 1984 cumulative CPUE for all species taken was approximately 210 per 100 hr (Table 4). The cumulative seasonal maximum was about 445 in winter. Thereafter, the cumulative seasonal CPUE values were about 200 in spring, 206 in summer, and 168 in fall.

Five species (carp, gizzard shad, black bullhead, bluegill, and white crappie) were abundant throughout 1985 (Table 4). Two previously abundant species were taken in very low numbers. Freshwater drum, smallmouth buffalo, bigmouth buffalo, blue catfish, channel catfish, longear sunfish, and redear were common in the 1985 catch.

Gizzard shad attained the maximum cumulative CPUE of any species in 1985 (Table 4). Approximately 43 per 100 hr were taken during the year. Seasonal CPUE values increased progressively from about 6 in winter to about 57 in fall. Gizzard shad continued to increase numerically in the catch throughout 1984 and 1985.

The total 1985 CPUE of white crappie was approximately 38 per 100 hr (Table 4) and increased each season. It was about 3 in winter, 24 in spring, 29 in summer, and 69 in fall.

Bluegill remained an important component of the 1985 catch, with a cumulative CPUE of approximately 20 per 100 hr (Table 4). The seasonal maximum CPUE of about 80 occurred in summer. The maximum CPUE corresponded to an increased use of barrel nets.

Black bullhead and carp were collected at a rate of about 17 and 14 per 100 hr, respectively (Table 4). Each species maintained consistent CPUE values throughout 1985.

The most significant change between the 1984 and the 1985 CPUE data was the extremely low catch rates of spotted gar, shortnose gar, and white bass in 1985. Total 1985 CPUE values of spotted gar and shortnose gar were less than 1 (Table 4). Although spotted gar were taken during each season, no shortnose gar were taken during fall. The seasonal maximum CPUE of shortnose gar occurred in the summer and was about 2.

The cumulative 1985 CPUE of white bass was approximately 4 per 100 hr (Table 4). The seasonal maximum CPUE was about 7 in the spring, and declined thereafter.

TABLE 4  
SEASONAL CPUE (NO. FISHES PER 100 HR SAMPLING) IN  
COPAN RESERVOIR

Species	Season				Total
	Winter	Spring	Summer	Fall	
Drum					
1984	2.82	1.02	1.51	2.50	1.63
1985	-	3.63	3.23	1.87	2.29
River carpsucker					
1984	5.65	6.20	6.40	8.58	6.79
1985	0.32	2.95	0.23	0.29	0.90
Carp					
1984	3.95	29.91	28.98	10.45	23.30
1985	1.30	34.24	19.82	3.44	14.10
Gizzard shad					
1984	19.21	11.20	15.18	49.77	22.08
1985	5.84	54.42	33.18	56.96	42.50
Hybrid bass					
1984	-	0.65	-	-	0.26
1985	-	-	-	1.00	0.37
Smallmouth buffalo					
1984	-	0.19	0.25	5.77	1.52
1985	0.65	8.62	1.84	1.29	3.03
Bigmouth buffalo					
1984	-	3.70	3.39	5.15	3.71
1985	3.25	2.49	3.23	0.57	2.07
Blue catfish					
1984	-	0.37	3.76	0.31	1.34
1985	-	4.54	3.46	3.01	2.98
Black bullhead					
1984	44.07	44.07	36.51	35.57	39.81
1985	6.49	34.69	16.13	11.19	17.07

TABLE 4 (Continued)

Species	Season				Total
	Winter	Spring	Summer	Fall	
<b>Yellow bullhead</b>					
1984	1.69	10.09	-	0.62	4.30
1985	0.32	-	0.46	0.14	0.21
<b>Channel catfish</b>					
1984	10.17	3.70	8.41	5.15	5.86
1985	-	3.85	3.00	1.43	2.13
<b>Brook silverdale</b>					
1984	-	0.09	-	-	0.04
1985	-	-	0.23	-	0.05
<b>Green sunfish</b>					
1984	0.56	2.41	0.75	0.16	1.26
1985	-	1.13	4.84	-	1.38
<b>Warmouth</b>					
1984	-	1.67	1.25	0.31	1.11
1985	-	0.23	1.38	-	0.37
<b>Orangespotted sunfish</b>					
1984	-	0.09	-	0.16	0.07
1985	-	-	2.30	0.14	0.59
<b>Bluegill</b>					
1984	16.38	30.37	11.67	8.27	18.66
1985	0.32	2.95	79.95	3.30	20.43
<b>Longear sunfish</b>					
1984	-	3.06	0.75	-	1.45
1985	-	0.23	7.14	0.14	1.76
<b>Redear</b>					
1984	-	1.85	0.50	0.47	1.00
1985	1.62	0.23	5.30	0.43	1.70
<b>Spotted gar</b>					
1984	168.36	3.06	15.06	1.09	16.99
1985	0.65	0.68	0.69	0.29	0.53

TABLE 4 (Continued)

Species	Season				Total
	Winter	Spring	Summer	Fall	
<b>Longnose gar</b>					
1984	-	-	0.50	-	0.15
1985	-	-	0.23	-	0.05
<b>Shortnose gar</b>					
1984	-	0.56	10.04	0.62	3.34
1985	0.32	0.68	1.61	-	0.59
<b>Largemouth bass</b>					
1984	0.56	2.59	9.16	1.25	4.08
1985	-	1.59	2.30	0.29	1.01
<b>White bass</b>					
1984	165.54	17.96	16.81	9.98	25.42
1985	2.92	6.58	2.07	5.02	4.36
<b>River redhorse</b>					
1984	-	-	-	-	-
1985	-	-	0.14	-	0.05
<b>Golden shiner</b>					
1984	-	0.28	-	-	0.11
1985	-	0.91	-	-	0.21
<b>Logperch</b>					
1984	-	0.09	-	-	0.04
1985	-	-	-	-	-
<b>White crappie</b>					
1984	5.65	21.94	34.38	20.12	24.12
1985	2.60	23.58	29.26	68.58	38.14
<b>Black crappie</b>					
1984	0.56	2.69	1.00	1.72	1.82
1985	0.65	1.13	1.61	0.29	0.85
<b>Flathead catfish</b>					
1984	-	0.09	0.13	-	0.07
1985	-	-	-	-	-

### Biomass (CPUE)

The total fish biomass taken in all gear types was approximately 1,293,627 g, or about 28.3 kg/100 hr. Based on biomass, carp, spotted gar, white crappie, black bullhead, and white bass were important components of the Copan Reservoir fish community. Other species which contributed substantially to biomass included river carpsucker, gizzard shad, channel catfish, bluegill, shortnose gar, largemouth bass, and black crappie.

The cumulative biomass CPUE of carp was about 4.7 kg/100 hr. About 5.3 kg/100 hr occurred in 1984 compared to about 4.0 kg/100 hr in 1985. Maximum values of about 6.7 and 10.6 kg/100 hr occurred in the spring of 1984 and 1985, respectively (Table 5).

Spotted gar accounted for approximately 4.1 kg/100 hr of the biomass during this study. The maximum yearly value was about 6.6 kg/100 hr in 1984. The following year, the species accounted for only about 0.3 kg/100 hr. The maximum seasonal biomass was about 60.0 kg/100 hr in winter 1983-1984 (Table 5). Thereafter, spotted gar biomass declined progressively until it reached a low of about 0.2 kg/100 hr in fall 1985.

The cumulative biomass CPUE of white bass was approximately 3.3 kg/100 hr during the study. The maximum yearly CPUE of about 4.9 kg/100 hr was attained in 1984. Like spotted gar, the maximum seasonal biomass (approximately 31.2 kg/100 hr) occurred in winter 1983-1984 (Table 5). The minimum biomass CPUE was in summer 1985, when the species accounted for only about 0.4 kg/100 hr.



TABLE 5  
SEASONAL CPUE BIOMASS (GRAMS PER 100 HR SAMPLING) OF SPECIES  
COLLECTED IN COPAN RESERVOIR

Species	Year and Season							
	1984				1985			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
River carpsucker	477	402	969	1,227	60	836	39	52
Carp	458	6,764	6,589	2,526	263	10,587	4,843	797
Gizzard shad	3,927	842	1,852	4,355	167	4,991	1,822	2,394
Black bullhead	9,258	2,932	4,284	4,404	738	4,022	1,877	1,600
Channel catfish	2,864	527	3,079	2,024	-	1,697	839	406
Bluegill	1,351	2,089	428	475	39	234	3,000	75
Spotted gar	60,002	1,349	6,738	701	461	443	379	187
Shortnose gar	-	78	6,904	598	360	768	1,792	-

TABLE 5 (Continued)

Species	Year and Season							
	1984				1985			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Largemouth bass	58	674	1,202	335	-	125	459	23
White bass	31,167	3,316	3,439	1,982	781	1,321	388	1,127
White crappie	1,786	5,656	2,628	1,648	146	2,140	1,832	5,193
Black crappie	11	192	42	134	37	105	122	17
Other	627	1,964	2,283	3,324	1,830	3,541	2,890	1,444

Black bullhead contributed approximately 3.3 kg/100 hr of the biomass during this study. The maximum yearly biomass CPUE was about 4.1 kg/100 hr in 1984, with a seasonal maximum of about 9.3 kg/100 hr in winter 1983-1984 (Table 5). The minimum biomass CPUE of about 0.7 kg/100 hr occurred in winter 1985.

White crappie accounted for approximately 3.3 kg/100 hr of the catch during this study. The maximum annual biomass of about 3.5 kg/100 hr was taken in 1984. The greatest seasonal biomass CPUE of about 5.6 kg/100 hr was taken in spring 1984; the minimum of about 0.1 kg/100 hr occurred in winter 1984-1985 (Table 5). White crappie maintained substantial biomass CPUE levels throughout the study. In contrast, few black crappie were represented in catches.

The biomass CPUE of gizzard shad increased from approximately 2.2 kg/100 hr in 1984 to about 2.5 kg/100 hr in 1985. Seasonal levels fluctuated widely but generally increased over time (Table 5).

#### Changes in Fish Community Structure

Many species declined or increased in abundance in Copan Reservoir. The relative abundances and biomass estimates of spotted gar and white bass declined precipitously in spring 1984 and continued to decline thereafter (Figure 3). Combined predator biomass, in excess of forage biomass early in the study, decreased below forage biomass in fall 1984. Forage biomass, including centrarchid species and gizzard shad, remained stable throughout this same period.

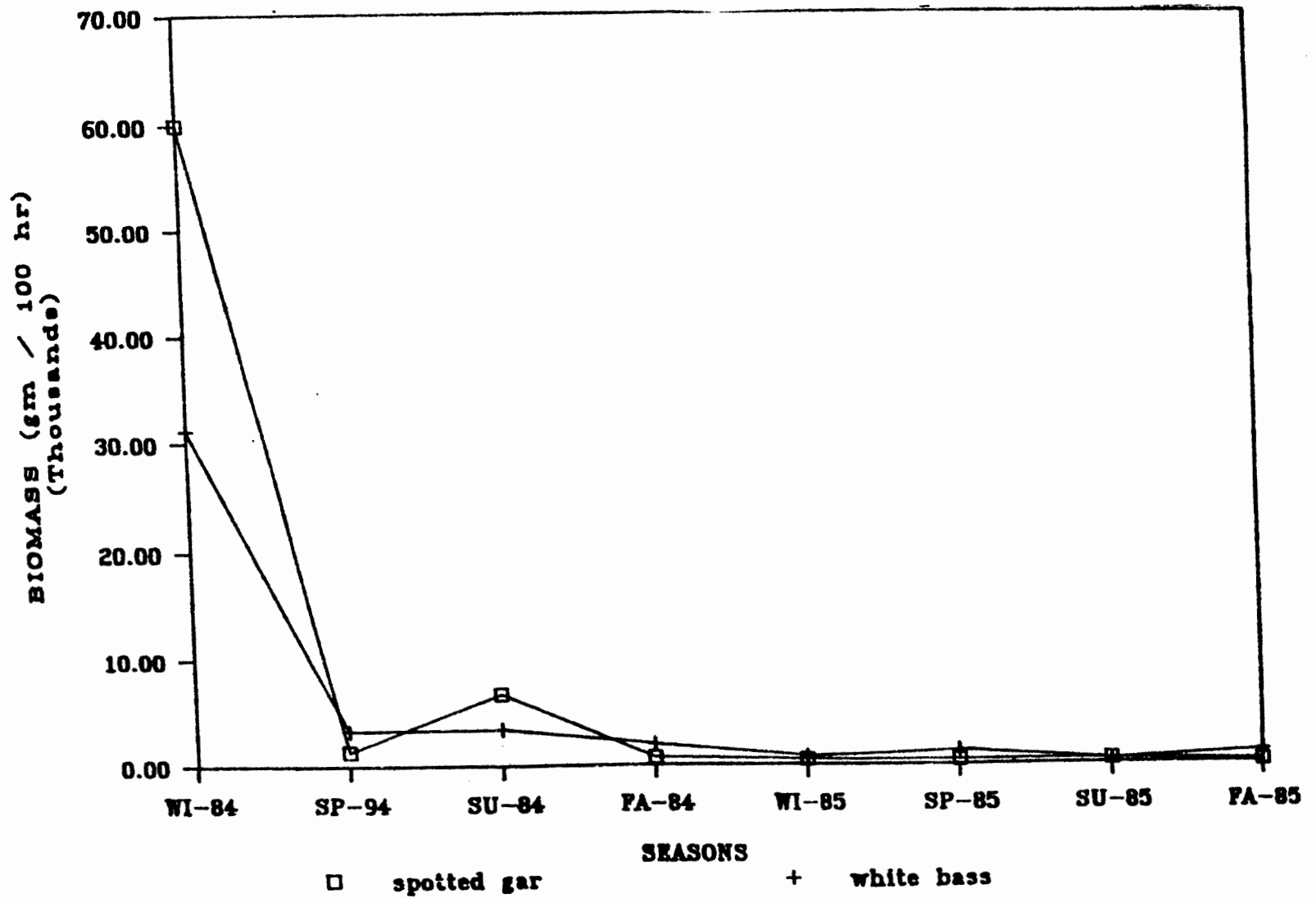


Figure 3. Seasonal biomass Catch-Per-Unit-Effort of spotted gar and white bass, Copan Reservoir.

Seasonal comparisons of fish community structure using Percentage Similarity Coefficients (PSC) showed the reservoir fish community to be continually changing (Table 6). In general, the trend was toward decreasing similarity with time; the fish community in 1985 was different from the community sampled in 1984. The fall 1985 fish community shared only about 21% of the winter 1984 community characteristics.

### Discussion

Evaluation of relative abundance, CPUE, and biomass data indicated that seven of 29 fish species were initially abundant in Copan Reservoir. The tendency of species to decline or increase in relative abundances caused progressively disparate PSC values over time. Abundant species which declined included shortnose gar, white bass, and black bullhead. Relative abundance of white crappie, bluegill, and gizzard shad increased.

Biotic factors have been hypothesized to control the survival of animals, while abiotic conditions primarily influence distribution (Ivlev 1961). Conditions of feeding may provide greater control of survival than other synecological factors. Therefore, forage limitations were investigated as a contributing factor in the precipitous decline in spotted gar and white bass biomass in spring 1984. The expectation that biomass of forage species would respond positively to declines in piscivore biomass was not substantiated by the data. Biomass estimates of some forage species increased slightly and continued to vary seasonally thereafter; gizzard shad biomass decreased in spring 1984 simultaneous with declines in piscivore biomass.

TABLE 6

SEASONAL PERCENTAGE SIMILARITY COEFFICIENT (WHITTAKER 1952)  
 COMPARISONS OF THE COPAN RESERVOIR FISH COMMUNITY  
 USING RELATIVE ABUNDANCE DATA

		1985			
		WINTER	SPRING	SUMMER	FALL
1984	WINTER	32.35	26.07	21.24	20.96
	SPRING	60.52	63.58	59.35	34.57
	SUMMER	55.92	66.92	52.60	43.40
	FALL	73.35	82.70	54.42	60.58

No persistent changes in the substrate characteristics of sampled habitats occurred during this study. However, rapid and dramatic fluctuations in depths did occur during periods of increased reservoir storage. A period of increased storage followed by increased reservoir discharge in spring 1984 (Figure 4) coincided with declines in spotted gar, white bass, black bullhead, and gizzard shad biomass. Dramatic changes in population densities have been related to water level changes (Orth 1980) and reservoir flushing has been related to loss of fish numbers (Walburg 1977). In addition, removal of fish may reduce populations to the extent where normal relationships between species are disrupted (Keast 1978).

The data from this study support the assertion that periods of high productivity in new reservoirs precede the development of fish assemblages dominated by lower trophic levels (Buck and Cross 1951, Latta 1951, Jenkins and Leonard 1962, Carlander 1955, Jenkins 1958). Rapid and dramatic changes in reservoir discharge probably allowed vagile riverine species to redistribute upstream or downstream of the reservoir. Following their decline in Copan Reservoir, white bass were taken in substantial numbers by anglers in the Little Caney River in Kansas and below the spillway downstream of Copan Dam. The effect of short volume retention time on site-specific or less vagile populations was negligible.

Fishery management programs developed for Copan Reservoir should be responsive to the stochastic processes which limit some fish populations. Multiple surveys may be necessary to assess annual trends in fish population abundances in reservoir environments subject to rapid changes in discharge.

Abundance levels of highly mobile, pelagic fish populations will probably remain low in the absence of intensive stocking efforts. Most notable among these populations are white bass and white bass x striped bass hybrids. Gizzard shad, a species requisite to the successful establishment of white bass in reservoirs of the southern plains region (Cross 1967), also tended to decrease simultaneous to periods of increased storage and discharge. Continued escapement of these populations will impact native fishes within the Verdigris River system and should be considered in management decisions.

Some species within Copan Reservoir may be successfully managed. White crappie, bluegill, and largemouth bass were consistently taken in samples and remained relatively stable over time. Harvest of these populations may be effectively offset with supplemental stockings.

Fluctuating water levels favor the continued prevalence of carp. Large areal expanses of shallow water and frequent inundation of surrounding grasslands facilitate successful reproduction and recruitment of this highly fecund species. Since carp undoubtedly compete for food with many kinds of native fish and alter habitats in ways detrimental to other species (Cross 1967), they must necessarily be considered in the development of fishery management goals for Copan Reservoir.



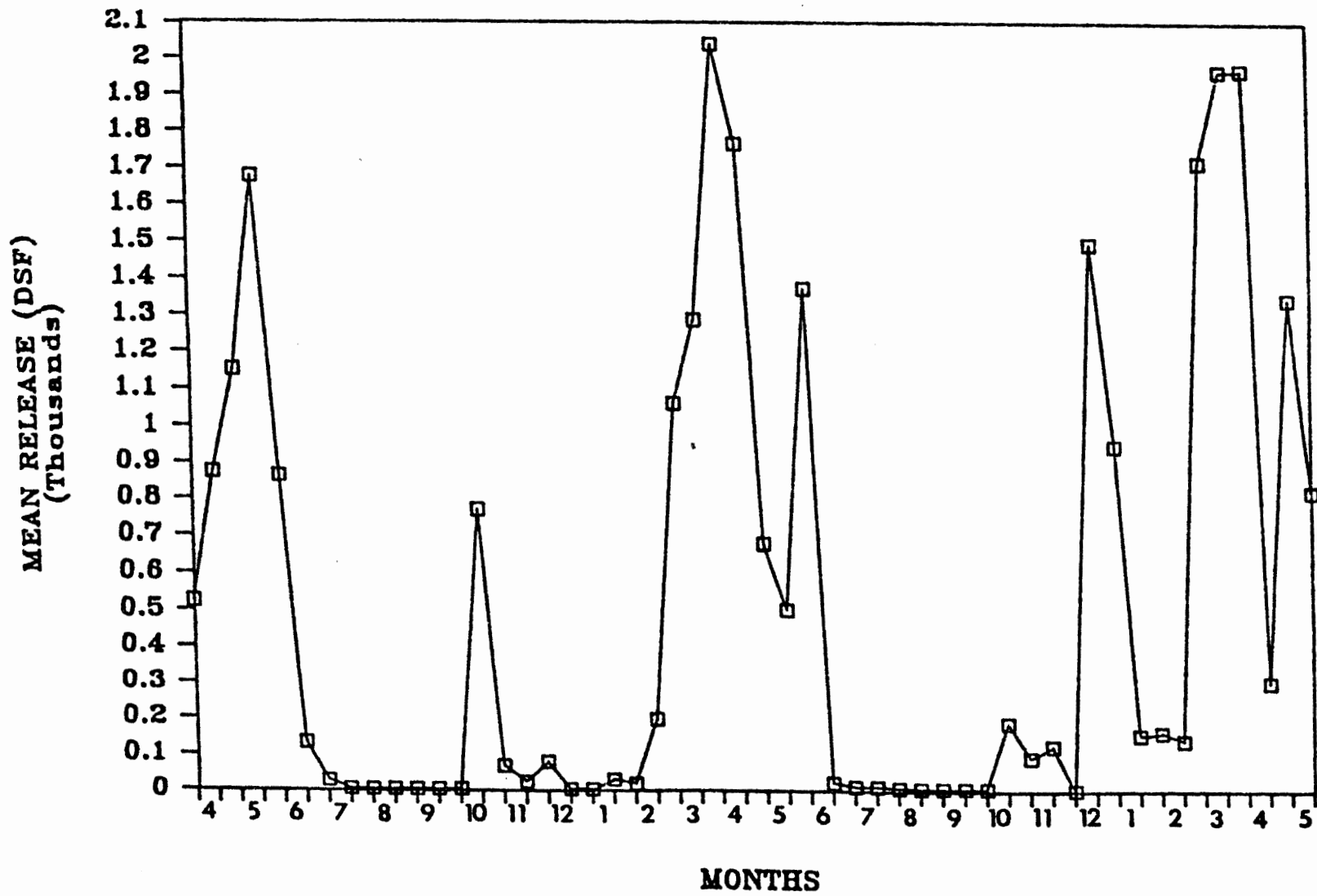


Figure 4. Mean biweekly water release rates from Copan Reservoir, April 1983 - May 1985.

## CHAPTER V

### HABITAT PREFERENCES OF COMMON FISH SPECIES

#### Introduction

The relative abundance of six species varied seasonally among sampled habitats in Copan Reservoir. These species were gizzard shad (*Dorosoma cepedianum*), black bullhead (*Ictalurus melas*), carp (*Carpiodes carpio*), spotted gar (*Lepisosteus oculatus*), white bass (*Morone chrysops*), and white crappie (*Pomoxis annularis*). An attempt was made to quantify seasonal habitat preferences of these species along the dimensions of depth and substrate using habitat assessment procedures adapted from commonly used stream methodologies.

The frequency of capture of these species also appeared to be positively or negatively correlated to localized physical, chemical, and biological characteristics of the reservoir. Using multidimensional data sets, an attempt was made to relate the occurrence of species to measurable physical, chemical, and biological attributes of sampled habitats.

## Materials and Methods

### Seasonal Habitat Preferences

Habitat preferences of numerically important species were determined from measurements of depths and substrates made at capture locations in each sampling site. Depths were measured to the nearest cm using one or more sections of 1.27 cm diameter aluminum-alloy conduit. Bottom types were classified in relation to increasing structural features (Table 7). To ease the interpretation of the heterogeneity component hidden in the calculation of mean substrate scalars, and to represent more accurately the horizontal complexity of reservoir habitats, similar mean substrate values were pooled into bottom complexity intervals. The bottom complexity intervals and their respective descriptions included: 0 - 2, even and uninterrupted; 2 - 4, coarse and occasionally interrupted; 4 - 6, broken and interrupted; 6 - 8, substantially heterogeneous; > 8, greatly dissected.

Habitat availability was determined at each sampling location by measuring water depth and substrate at 5-m intervals along transects within point measurement grid systems. Grids were constructed to conform specifically to each of the various types of passive sampling equipment because of the differing assumptions underlying fish capture by each type of equipment.

Experimental gill nets were considered to provide the most accurate inferences about habitat use because of the increased probability of accidental entanglement

TABLE 7

CLASSIFICATION OF BOTTOM TYPES IN RELATION TO INCREASING  
STRUCTURAL FEATURES

Code	Substrate	Approximate particle size (mm)
1	Silt	$\leq 0.45$
2	Silt-sand	-
3	Sand	.600-4
4	Sand-gravel	-
5	Gravel	4-25
6	Gravel-rubble	-
7	Rubble	$> 25$
8	Wood	-
9	Flooded vegetation	-

during active use of sampled habitats. Point measurements associated with experimental gill nets were taken along five transects located at 5-m intervals parallel to the axis of the net with the center transect immediately juxtapositioned to the net. Experimental gill net grids yielded mean depth and substrate values for an area of 625 m<sup>2</sup>.

Frame nets, or modified fyke nets, were considered to provide inferences of satisfactory accuracy relative to the use of near-shore habitats by reservoir fishes. Point measurement grids associated with frame nets were based on the assumption that active habitat selection was intercepted and redirected by the single lead net connecting the frame net to the shoreline. As a result, four point measurements were taken along a series of five transects located at 5-m intervals parallel to the lead net with the center transect located along the axis of the lead. Frame net grids yielded mean depth and substrate values for an area of 500 m<sup>2</sup>.

Barrel nets were considered to provide marginal inferences of habitat preferences based on the assumption that certain species were more apt to be captured as a result of deliberate entry. However, because proximity to the net was assumed to be necessary before successful capture, point measurement grids were constructed to measure the habitat immediately surrounding each barrel net. Point measurements were taken at 5-m intervals along two 20-m axes of an X - Y coordinate plane with the center representing the point of capture. Barrel net grids yielded mean depth and substrate values for an area of 225 m<sup>2</sup>. Although bluegill (*Lepomis macrochirus*) were an important numerical component of the reservoir fish community, the species was not included in the habitat analysis because of its ease of capture in barrel nets.

Sampled habitats with similar mean depth and bottom complexity values were pooled within each season. The Chi-Square goodness of fit test (Conover 1980) was used to test the hypothesis that fish distributions were uniform relative to habitat availability. Nonuniform distributions were equated with preference for specific depths and substrates.

#### Habitat Structure and Fish Population Assemblages

Summer (June-August) and fall (September-November) 1984 habitat data from the five standard sampling locations were used to relate the occurrence of species and the form of populations to the physical, chemical, and biological attributes of the reservoir. Other seasons were excluded from the analysis because the sampling regimes were interrupted by prolonged ice-cover or normal relationships among fish populations were disrupted by increased reservoir storage. Physical habitat characteristics at each sampling locality were determined by point measurements along transects arranged in the grid patterns discussed in the previous section. Chemical and other environmental characteristics of sampled habitats were derived from averages of verticle profile measurements or single measurements taken at one location central to the point of fish capture. These measurements were then generalized to represent the entire grid. Biological characteristics included standardized (by effort) measures of species richness and total number of individual fishes taken. Numbers of each numerically important species occurring in samples were also standardized by effort and included in the biological characteristics data set.

Estimates of plankton biomass were derived from sampling ten vertical meters of the water column with a number 20 Wisconsin plankton net at the same locations where chemical characteristics were determined. Each concentrated plankton sample of approximately 100 ml was immediately preserved in 1% Lugol's solution to delay decomposition (Pennak 1978). Biomass estimates were derived using the gravimetric method (Standard Methods 1971). Samples were filtered using Millipore filters and pre-dried and weighed on 50 um filter paper. Filtered samples were then dried for 12 hr at 50°C and placed in desiccators until each cooled to room temperature. Samples were then weighed to the nearest thousandth gram, and actual weight calculated as the difference between filtered sample weight and filter paper weight. Biomass estimates were derived using 113.11 as the volume of reservoir represented by each sample.

Initial data matrices were constructed to evaluate which physical, chemical, and biological characteristics best explained the variation among sampled habitats and which characteristics were predictive of the seasonal species richness and total number of fish collected. The following variables were included in the initial matrices:

SP = species richness/net hour	AL = alkalinity (ppm)
NO = number fishes/net hour	AM = ambient air temperature (°C)
PB = plankton biomass (g)	WT = average temperature of water column (°C)
MD = mean depth (m)	PH = pH
SD = standard deviation of depth	DO = average dissolved oxygen of water column (°C)
MS = mean substrate value	NTU = average turbidity from surface, mid-depth, bottom
SS = standard deviation of substrate value	CON = average conductivity from surface, mid-depth, bottom
HD = MD x MS	
SH = SD x SS	
SC = Secchi reading (cm)	

The data matrices were evaluated using principal components analysis (BMDP 1985). The use of principal components analysis is purely descriptive and

computation requires no assumptions about multivariate normality, the variance-covariance matrix or matrices, or any other structure of the data (Harris 1975). An assumption implicit in principal component analysis is that important phenomena will be represented most clearly by the components in the directions of greatest variance, thereby permitting generalized inferences (Neff and Smith 1979). The resultant orthogonal rotation causes the principal axes to be uncorrelated with one another (Pielou 1984). Therefore, the rotated data matrix meets the assumptions of multiple regression analysis (Johnson and Wichern 1982). To determine which of the physical, chemical, and biological attributes measured in Copan Reservoir were the best predictors of population form, the rotated data matrix was transposed and re-evaluated using stepwise multiple regression analysis (Wilkinson 1988).

The same procedures were used to relate the occurrence of each numerically important species to the attributes of habitats measured. The following variables were added to the existing data matrices for this analysis:

LO = spotted gar/net hour  
DC = gizzard shad/net hour  
CC = carp/net hour

BB = black bullhead/net hour  
WB = white bass/net hour  
WC = white crappie/net hour

The assumption underlying this portion of the analysis was that the realized niche (Hutchinson 1957) of any species is ultimately defined by the subset of environmental variables common to multiple co-occurring species. Stepwise multiple regression analyses were performed to evaluate the physical, chemical, or biological attributes that were predictive of single species occurrences.



## Results

### Seasonal Habitat Preferences

The general tendency of species to occupy specific depth and substrate intervals was indicated by observed frequencies within seasons and estimates of fish numbers per unit area of sampled habitat intervals (Tables 8, 9). Further analysis showed that seasonal distributions often differed significantly from expected uniformity.

White crappie were collected exclusively in winter from habitats having even, uninterrupted substrates. They were uniformly distributed in the water column during this period ( $P > 0.259$ , (Table 20, Appendix B). The largest individuals (mean TL = 268.0 mm) were taken from a depth of 2-3 m (Figure 5, Appendix C).

In spring, the distribution of white crappie was nonuniform across sampled substrates ( $P < 0.001$ ), (Table 21, Appendix B). Relative frequencies were greatest in broken, heterogeneous habitats (Figure 6, Appendix C). However, individuals taken from preferred habitats were small compared to those taken from less diverse habitats. The depth distribution of fish during this period was also nonuniform ( $P < 0.001$ ), (Table 22, Appendix B). The greatest relative frequency occurred in the 2-3 m depth interval (Figure 7, Appendix C), but larger individuals were collected at 1-2 m depths.

Distributions of white crappie were nonuniform with respect to substrates ( $P < 0.005$ ) and depths ( $P < 0.005$ ) in summer (Tables 23, 24; Appendix B). Relative frequencies were greatest in broken, interrupted habitats at depths of 4-5 m (Figures

TABLE 8

DISTRIBUTION OF FISHES COLLECTED BY DEPTH FROM  
SPRING 1984 TO FALL 1984 IN COPAN RESERVOIR

Species	Depth (m)							
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
White crappie								
Win	-	2	2	-	4	0	-	-
Spr	12	17	30	0	8	0	0	-
Sum	4	2	30	27	49	-	2	-
Fall	8	11	40	1	38	16	-	1
$\Sigma/\text{Area}(\text{m}^2)$	0.012	0.005	0.013	0.007	0.009	0.004	0.001	0.002
White bass								
Win	-	0	167	-	56	0	-	-
Spr	0	3	34	5	28	0	0	-
Sum	2	0	29	81	109	-	9	-
Fall	0	30	11	0	19	13	-	0
$\Sigma/\text{Area}(\text{m}^2)$	0.001	0.005	0.031	0.021	0.020	0.003	0.004	0
Spotted gar								
Win	-	0	0	-	244	45	-	-
Spr	17	1	3	0	2	0	1	-
Sum	2	0	37	31	29	-	19	-
Fall	0	3	2	0	3	2	-	0
$\Sigma/\text{Area}(\text{m}^2)$	0.010	0.001	0.005	0.008	0.026	0.013	0.008	0
Gizzard shad								
Win	-	1	23	-	7	0	-	-
Spr	9	28	5	0	1	0	0	-
Sum	46	0	39	14	80	-	1	-
Fall	1	18	39	0	201	67	-	3
$\Sigma/\text{Area}(\text{m}^2)$	0.028	0.007	0.013	0.003	0.027	0.018	<0.001	0.005

TABLE 8 (continued)

Species	Depth (m)							
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
<b>Carp</b>								
Win	-	0	2	-	5	0	-	-
Spr	15	6	86	-	65	0	0	-
Sum	0	2	50	89	99	-	8	-
Fall	6	13	10	0	26	9	-	0
$\Sigma/\text{Area(m}^2\text{)}$	0.011	0.003	0.019	0.022	0.018	0.002	0.003	0
<b>Black bullhead</b>								
Win	-	1	54	-	24	0	-	-
Spr	11	46	79	-	14	4	0	-
Sum	0	0	60	118	90	-	16	-
Fall	15	56	65	0	46	54	-	1
$\Sigma/\text{Area(m}^2\text{)}$	0.013	0.015	0.033	0.029	0.016	0.015	0.006	0.002

TABLE 9

DISTRIBUTION OF FISHES COLLECTED BY SUBSTRATE FROM  
 SPRING 1984 TO FALL 1984 IN COPAN RESERVOIR

Species	Substrates				
	0-2	2-4	4-6	6-8	>8
<b>White crappie</b>					
Spr	15	22	15	15	0
Sum	36	14	37	17	-
Fall	29	12	22	10	-
$\Sigma/\text{Area}(\text{m}^2)$	0.007	0.007	0.013	0.008	0
<b>White bass</b>					
Spr	4	9	27	25	5
Sum	125	10	62	31	-
Fall	22	5	3	28	-
$\Sigma/\text{Area}(\text{m}^2)$	0.014	0.004	0.016	0.015	0.008
<b>Spotted gar</b>					
Spr	2	17	3	2	0
Sum	22	5	50	39	-
Fall	2	0	3	7	-
$\Sigma/\text{Area}(\text{m}^2)$	0.002	0.003	0.010	0.009	0
<b>Gizzard shad</b>					
Spr	5	25	8	5	0
Sum	46	34	39	15	-
Fall	204	67	19	27	-
$\Sigma/\text{Area}(\text{m}^2)$	0.023	0.019	0.011	0.009	0
<b>Carp</b>					
Spr	62	34	44	32	35
Sum	58	25	115	47	-
Fall	17	19	4	15	-
$\Sigma/\text{Area}(\text{m}^2)$	0.013	0.012	0.028	0.017	0.056

TABLE 9 (continued)

Species	Substrates				
	0-2	2-4	4-6	6-8	> 8
<b>Black bullhead</b>					
Spr	61	43	11	35	14
Sum	140	60	37	53	-
Fall	106	35	2	55	-
$\Sigma/\text{Area(m}^2\text{)}$	0.028	0.021	0.009	0.026	0.022

8-9, Appendix C). During this period, the largest individuals were taken from preferred habitats.

In fall, the distribution of white crappie was nonuniform relative to substrate availability ( $P < 0.005$ ), (Table 25, Appendix B). The greatest relative frequency occurred in habitats having broken, interrupted substrates (Figure 10, Appendix C). No difference existed in the sizes of white crappie collected over different substrate categories. White crappie depth distribution was also nonuniform during this period ( $P < 0.001$ ), (Table 26, Appendix B). Relative frequencies were greatest above 3 m and concentrated in the 0 - 1 m depth interval (Figure 11, Appendix C). Again, no difference in mean lengths of fish was found among depth categories.

White bass were associated exclusively with even, uninterrupted substrates in winter. The distribution across sampled depths was nonuniform ( $P < 0.001$ ), (Table 27, Appendix B). The greatest relative frequency occurred in the 2 - 3 m depth interval (Figure 12, Appendix C). Individual sizes did not differ between depth categories.

The spring distribution of white bass was nonuniform across substrates ( $P < 0.001$ ), (Table 28, Appendix B). Relative frequencies were greatest in heterogeneous habitats (Figure 13, Appendix C). No differences existed in mean lengths of fish among available substrate categories. Depth distributions of fish were also nonuniform ( $P < 0.001$ ), (Table 29, Appendix B). Relative frequencies were greatest in the 2 - 3 m and 4 - 5 m depth intervals, and no difference existed in the size of individuals among depths (Figure 14, Appendix C). Nonuniform distributions of white bass occurred across substrates ( $P < 0.001$ ) and depths ( $P < 0.001$ ) in

summer (Tables 30, 31; Appendix B). The greatest relative frequency of fishes occurred in even, uninterrupted habitats at the depth of 4 - 5 m (Figures 15-16, Appendix C). The smallest individuals were taken in association with preferred substrates; larger individuals occurred at preferred depths.

In fall, white bass were again distributed irregularly relative to substrates ( $P < 0.001$ ), (Table 32, Appendix B). The greatest frequency of white bass occurred in habitats having broken, heterogeneous substrates (Figure 17, Appendix C). No significant disparity existed in mean lengths of fish among substrate categories. During this period, the depth distribution of white bass was nonuniform ( $P < 0.001$ ), (Table 33, Appendix B). The greatest frequency occurred in 1 -2 m depth intervals (Figure 18, Appendix C). No differences existed in the sizes of individuals among depths.

Spotted gar were taken only from habitats having even, uninterrupted substrates in winter. The distribution relative to depth was nonuniform ( $P < 0.001$ ), (Table 34, Appendix B). Spotted gar were taken only from depths exceeding 4 m, with the greatest frequency occurring in the 4 - 5 m depth interval (Figure 19, Appendix C). Similar size individuals were collected at all depths.

Spring distribution of spotted gar was nonuniform across available substrates ( $P < 0.001$ ), (Table 35, Appendix B). The greatest relative frequency was observed over coarse, uninterrupted habitats (Figure 20, Appendix C). Although sizes were similar across substrate categories, the largest individuals (mean TL = 460.8 mm) were taken from areas of preferred substrate. During this period, spotted gar

preferred the 0 - 1 m depth interval ( $P < 0.001$ ), (Table 36, Appendix B; Figure 21, Appendix C).

The distribution of spotted gar was nonuniform across substrate ( $P < 0.001$ ) and depths ( $P < 0.05$ ) in summer (Tables 37, 38; Appendix B). Relative frequencies were greatest in broken, interrupted habitats at depths exceeding 2 m (Figures 22-23, Appendix C). Smaller individuals were found in less complex habitats in shallow water less than 2 m deep.

In fall, the distribution of spotted gar was uniform across substrates ( $P < 0.005$ ), (Table 39, Appendix B). The greatest relative frequencies occurred in habitats with complex substrates, especially those areas that were broken and interrupted and substantially heterogeneous (Figure 24, Appendix C). Spotted gar were uniformly distributed across depths during fall ( $P > 0.25$ ), (Table 40, Appendix B) but greatest relative frequency occurred in the 1 - 2 m depth interval (Figure 25, Appendix C).

Gizzard shad were associated exclusively with even, uninterrupted substrates in winter. The distribution was nonuniform across sampled depths ( $P < 0.001$ ), (Table 41, Appendix B), with the greatest relative frequency occurring in the 2 - 3 m depth interval (Figure 26, Appendix C). The largest individuals (mean TL = 282.5 mm) were associated with the preferred depth interval.

Distributions of gizzard shad were nonuniform across substrates ( $P < 0.001$ ) and depths ( $P < 0.001$ ) in spring (Tables 42, 43; Appendix B). Relative frequencies were greatest in coarse, uninterrupted habitats at a depth of 0 - 1 m; the depth interval 1 - 2 m was nearly equally preferred (Figures 27-28, Appendix C).



However, the larger individuals were taken in broken and interrupted habitats at 2 - 3 m depth.

In summer, the distribution of gizzard shad was nonuniform across sampled substrates ( $P < 0.001$ ), (Table 44, Appendix B). Relative frequencies were highest in coarse, occasionally interrupted habitats and lower in complex, substantially heterogeneous habitats (Figure 29, Appendix C). Large individuals were collected from each substrate category. Gizzard shad were also irregularly distributed across depths ( $P < 0.001$ ) during this period (Table 45, Appendix B). The preferred depth was 0 - 1 m, but the largest individuals occurred at greater depth (Figure 30, Appendix C).

Gizzard shad distributions were nonuniform across sampled substrates in fall ( $P < 0.001$ ), (Table 46, Appendix B). The greatest relative frequency of gizzard shad occurred in habitats having even, uninterrupted substrates (Figure 31, Appendix C). As in spring, larger individuals occurred in more complex habitats. Distributions were also nonuniform across depths ( $P < 0.001$ ), (Table 47, Appendix B). The preferred depth interval was 4 - 5 m, but larger individuals were taken from the 2 - 3 depth interval (Figure 32, Appendix C).

Carp were collected exclusively from even, uninterrupted habitats in winter. The distribution across sampled depths was uniform ( $P < 0.25$ ), (Table 48, Appendix B). However, carp were taken only from the 2 - 3 m depth interval (Figure 33, Appendix C).

Carp distributions were nonuniform across substrates ( $P < 0.001$ ) and depths ( $P < 0.001$ ) during spring (Tables 49, 50; Appendix B). The greatest relative frequency

was observed in greatly dissected habitats (Figure 34, Appendix C), and was correlated with increased reservoir storage allowing carp to move into newly inundated vegetation. Carp preferred the 2 - 3 m depth interval, although depth between 3 - 5 m were also used extensively (Figure 35, Appendix C). No size-related differences existed in habitat selection.

The distribution of carp was nonuniform across substrates in summer ( $P < 0.001$ ), (Table 51, Appendix B). The greatest relative density of carp occurred in broken, interrupted habitats (Figure 36, Appendix C). The largest individuals were found in substantially heterogeneous habitats. The depth distribution of carp was also nonuniform during this period ( $P < 0.001$ ), (Table 52, Appendix B). Carp preferred the 3 - 4 m depth interval, and secondarily the 4 - 5 m interval (Figure 37, Appendix C). A few extremely large individuals (mean TL = 423.2 mm) were taken at depths below 6 m.

Fall distribution of carp across substrates was uniform ( $P > 0.10$ ), (Table 53, Appendix B). Relative frequencies were nearly equal between habitats having uninterrupted substrates and those having interrupted or heterogeneous substrates (Figure 38, Appendix C). The depth distribution was nonuniform ( $P < 0.01$ ) during this period (Table 54, Appendix B). Relative density was greatest in the 0 - 1 m depth interval (Figure 39, Appendix C). No differences in habitat preferences were apparent.

Black bullhead were entirely restricted to even, uninterrupted substrates in winter. Depth distribution during this period was nonuniform ( $P < 0.001$ ), (Table 55, Appendix B); black bullhead preferred the 2 - 3 m depth interval (Figure 40,

Appendix C). Smaller individuals were collected in shallow water, whereas larger individuals were taken in depths exceeding 4 m.

Distribution of black bullhead was nonuniform across substrates ( $P < 0.001$ ) and depths ( $P < 0.001$ ) in spring (Tables 56, 57; Appendix B). Relative frequencies were greatest in heterogeneous habitats at a depth interval of 2 - 3 m (Figure 41-42, Appendix C).

Use of substrates by black bullhead was nonuniform during summer ( $P < 0.001$ ), (Table 58, Appendix B). Relative frequencies were greatest in even and uninterrupted habitats, although larger individuals were taken from broken, interrupted areas (Figure 43, Appendix C). The distribution across depths were also nonuniform during this period ( $P < 0.001$ ), (Table 59, Appendix B). Black bullhead preferred the 3 - 4 m depth interval; no individuals were taken from depths less than 2 m (Figure 44, Appendix C).

The distribution of black bullhead across sampled substrates was nonuniform in fall ( $P < 0.001$ ), (Table 60, Appendix B). Increased relative frequencies occurred in even, uninterrupted habitats and substantially heterogeneous habitats (Figure 45, Appendix C). The fall depth distribution was also nonuniform ( $P < 0.001$ ), (Table 61, Appendix B). Relative densities were greatest in shallow water, particularly the 0 - 1 m depth interval (Figure 46, Appendix C).

#### Habitat Structure and Fish Population Assemblages

By convention, seven of nine possible factor arrays were interpreted because their

respective eigenvalues exceeded 1.0. Factor one of the principal components analysis showed much of the variance (35.4%) among sampled habitats in summer 1984 was explained by deep areas of the reservoir with heterogeneous substrates. These areas were further characterized by reductions in mean dissolved oxygen concentrations, mean water temperature, and total numbers of fishes taken per net hour (Table 10).

Pelagic habitats characterized by moderate depths and relatively homogenous substrates were identified in the second factor array and explained 18.1% of the variance among sampled habitats. These open, pelagic habitats also had an inverse relationship between turbidity and depths of Secchi disk readings.

Habitats with structurally simple substrate, reduced mean water temperature, and surface pH values were correlated with standardized species richness on factor three. Factor four loaded habitats with increased plankton biomass and were open, pelagic areas with reduced mean water temperatures relative to other areas. The fifth factor array represented the positive association between elevated dissolved oxygen concentrations and increased standardized species richness and total numbers of fishes taken. Factors six and seven are probably representative of shallow, shoreline areas because of the association with elevated water temperatures, stable dissolved oxygen concentrations, high air temperatures, and reduced species richness.

Stepwise multiple regression analysis of the transposed data matrix successfully generated equations predictive of standardized species richness and total numbers of fishes from a subset of measurable environmental attributes (Table 11). Variables used to predict species richness included air temperature, conductivity, pH, plankton biomass, and turbidity. The largest coefficients were for air temperature,

conductivity, and pH, and suggested that the effects of all three were variously reduced in the presence of multiple species. Variables used to define total numbers of fishes included dissolved oxygen, conductivity, water temperature, turbidity, and substrate heterogeneity. Coefficients of dissolved oxygen, water temperature, and turbidity were positive; coefficients for conductivity and substrate heterogeneity were negative.

Following addition of numerically important species to the initial data matrix, nine factors with eigenvalues exceeding 1.0 existed. Deep areas with heterogeneous substrates again loaded on factor one and explained approximately 28.2% of the variation among sampled habitats (Table 12). Mean dissolved oxygen was low with corresponding low numbers of white crappie and total numbers of fishes; however, spotted gar were positively associated with these habitats.

Gizzard shad loaded with open, pelagic habitats on factor two. This factor explained approximately 16.5% of the matrix variance. Factor three represented pelagic habitats with reduced turbidities and relatively homogenous substrates. Gizzard shad were negatively associated with these pelagic areas.

On factor four, spotted gar were positively associated with shallow mean depths, reduced air temperatures, the presence of other species, and total numbers of fishes. Habitats depicted by factor five had relatively heterogeneous substrates, reduced turbidities and alkalinities, and increased numbers of carp negatively associated with black bullhead. Factor six was habitats where white crappie and black bullhead co-occur and are each represented in significant numbers. Of the remaining factor

TABLE 10  
 SORTED ROTATED FACTOR LOADINGS OF SUMMER 1984 HABITAT DATA,  
 COPAN RESERVOIR  
 (LOADINGS LESS THAN 0.25 NOT SHOWN)

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
SH	0.980	-	-	-	-	-	-
SD	0.966	-	-	-	-	-	-
HD	0.950	-	-	-	-	-	-
DO	-0.766	-	-	-	0.339	0.296	-
NTU	0.686	-0.609	-	-	-	-	-
MD	0.659	0.328	-	0.361	-	-	-
MS	0.637	-0.401	-0.315	-0.409	-	-	-
SC	-	0.931	-	-	-	-	-
SS	0.555	-0.665	-	-0.352	-	-	-
AL	-	-	0.949	-	-	-	-
PB	-	-	-	0.984	-	-	-
NO	-0.373	-	-	-	0.913	-	-
SP	-	-	0.517	-	0.669	-	-0.367
CON	-	-	0.304	-	-	0.896	-0.262
WT	-0.320	0.265	-0.440	-0.445	-	0.525	-
AM	-	-	-	-	-	-	0.916
PH	-	0.486	-0.544	-	-	-	-
Eigenvalues	5.349	2.384	1.971	1.683	1.538	1.444	1.194

TABLE 11

STEPWISE MULTIPLE REGRESSIONS OF SPECIES RICHNESS  
AND TOTAL NUMBERS OF FISHES, STANDARDIZED FOR  
EFFORT, COPAN RESERVOIR, SUMMER 1984

Dependent	Regression	F	P	R <sup>2</sup>
SP	0.420 - 1.159(AM) - 0.959(CON) - 0.527(PH) - 0.245(PB) + 0.033(NTU)	78,063.76	0.003	1.00
NO	0.168 + 1.834(DO) - 1.365(CON) + 1.120(WT) + 3.178(NTU) - 1.786(SS)	1,853.74	0.018	1.00

arrays, substantial numbers of white bass were associated with gizzard shad in areas of reduced conductivity and alkalinity.

Variables chosen as predictors of the capture of spotted gar per net hour included turbidity, mean substrate, standard deviation of the substrate, air temperature, standard deviation of the habitat scalar, mean depth, and dissolved oxygen (Table 13). The signs of the various coefficients implied spotted gar were more frequently taken during cooler portions of the day in turbid, near-shore habitats containing coarse substrates with low horizontal heterogeneity.

Predictor variables for gizzard shad per net hour included mean substrate, Secchi disk transparency, plankton biomass, dissolved oxygen, standardized species richness, and spotted gar. Consideration of the coefficient terms indicates that capture of gizzard shad is related to pelagic areas of low mean substrate size, decreased depths of Secchi disk readings, and reduced plankton biomass, where dissolved oxygen is not limiting and other species are present but reduced numbers of spotted gar exist.

The regression model for carp explains relatively less of the variation in numbers per net hour than do the models for other species. Variables selected for inclusion in this model were mean depth and conductivity with the implication of an association with shallow habitats.

Variables chosen as important predictors of black bullhead capture per net hour included mean substrate, alkalinity, plankton biomass, and the presence of spotted gar, carp, and white crappie. Coefficients were negative for numbers of spotted gar and carp and positive for numbers of white crappie.



TABLE 12

SORTED ROTATED FACTOR LOADINGS OF SUMMER 1984 HABITAT  
DATA WITH NUMERICALLY IMPORTANT SPECIES  
(LOADINGS LESS THAN 0.25 NOT SHOWN)

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
HD	0.969	-	-	-	-	-	-	-	-
SH	0.951	-	-	-	-	-	-	-	-
SD	0.919	-	-	-	-	-	-	-	-
DO	-0.795	-	-	-	-	-	-	-	0.297
NTU	0.704	-	-0.498	-	-0.255	-	-	-	-0.261
MD	0.700	-	0.297	-0.366	-	-	-	0.368	-
MS	0.648	-0.268	-0.405	-	0.302	-	-	-0.375	0.255
AL	-	0.807	-	-	-0.285	-	-0.271	-	-
SP	-	0.799	-	0.341	0.278	-	-	-	-
PH	-	-0.728	0.478	-	-	-	-	-	-
DC	-	0.694	-0.462	-	-	-	0.300	-	-
SC	-	-	0.945	-	-	-	-	-	-
SS	0.605	-	-0.621	-	-	-	-	-0.365	-
LO	0.339	-	-	0.888	-	-	-	-	-
AM	0.416	-0.271	-	-0.687	-	0.351	-	-	-
CC	-	-	-	-	0.909	-	-	-	-
CON	-	0.345	0.251	0.345	-0.572	-	-0.371	-	0.448

TABLE 12 (continued)

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
WC	-0.265	-	-	-	-	0.893	-	-	-
BB	-	0.266	-	-	-0.485	0.771	-	-	-
WB	-	-	-	-	-	-	0.859	-	-
NO	-0.338	0.284	-	0.370	0.300	0.292	0.699	-	-
PB	-	-	-	-	-	-	-	0.945	-
WT	-0.345	-0.364	-	-	-	-	-	-0.329	0.726
Eigenvalues	5.880	3.015	2.582	2.063	2.022	1.877	1.860	1.589	1.200

TABLE 13

STEPWISE MULTIPLE REGRESSION OF FREQUENCIES OF OCCURRENCE  
OF NUMERICALLY ABUNDANT SPECIES, STANDARDIZED FOR  
EFFORT, COPAN RESERVOIR, SUMMER 1984

Dependent	Regression	F	P	R <sup>2</sup>
LO	0.188 + 1.969(NTU) + 2.051(MS) - 2.394(SS) - 0.225(AM) - 0.244(SH) - 0.378(MD) + 0.658(DO)	148.17	0.063	1.00
DC	0.259 - 0.485(MS) - 1.056(SC) - 0.283(PB) + 0.024(DO) + 0.350(SP) - 0.173(LO)	191.97	0.005	1.00
CC	0.247 - 0.500(MD) - 0.662(CON)	5.98	0.037	0.67
BB	0.192 - 0.260(MS) + 0.093(AL) - 0.519(PB) - 0.135(LO) - 0.849(CC) + 0.745(WC)	2,542.08	< 0.001	1.00
WB	-0.031 - 0.071(HD) + 0.620(DO) + 1.121(MD) + 1.265(ND) + 0.446(AL) - 0.675(BB) - 1.135(SP)	1,594,475.72	0.001	1.00
WC	-0.257 + 0.349(MS) - 0.125(AL) + 0.696(PB) + 0.181(LO) + 1.139(CC) + 1.342 (BB)	1,240.86	0.001	1.00

Seven variables predict the numbers of white bass captured per net hour, habitat scalar, dissolved oxygen, mean depth, total numbers of fishes taken, alkalinity, the presence of black bullhead, and species richness. Negative coefficients included habitat scalar, the presence of black bullhead, and species richness.

The regression model for white crappie included the variables mean substrate, alkalinity, plankton biomass, and the presence of spotted gar, carp, and black bullhead. Alkalinity was the single negative coefficient in this linear model.

Seven of nine possible factor arrays in the fall 1984 data matrix were interpreted. Factor one showed much of the variance among sampled habitats was explained by deep, heterogeneous areas. These areas explained 32.7% of the total variation within the data matrix and were again characterized by reductions in mean dissolved oxygen (Table 62, Appendix B).

Habitats with increased plankton biomass, conductivity, and mean water temperature were correlated with standardized species richness and total numbers of fishes in factor two. This factor explained 26.3% of the variance among sampled habitats and included the inverse relationship between turbidity and depths of Secchi disk readings.

The third factor represented habitats with reduced mean dissolved oxygen and turbidity relative to increases in mean water temperature, pH, and total numbers of fishes. Habitats with structurally complex substrates, reduced turbidity, and reduced total fish numbers per hour loaded on factor four. Habitats with reduced mean substrate sizes but with corresponding increases in turbidity, mean dissolved oxygen, plankton biomass, and increased depths of Secchi disk readings were identified by

factor five. Factor six represented habitats with increased mean water temperatures, air temperatures, mean conductivities, and standardized species richness. Habitats with increased alkalinities were associated with reduced mean substrate sizes and increased depths of Secchi disk readings on factor seven.

Variables in the transposed data matrix that predicted species richness during the stepwise procedure included plankton biomass, mean depth, turbidity, water temperature, and total numbers of fishes taken per net hour (Table 63, Appendix B). The coefficient terms indicated that the relationship had been constructed based on samples in relatively shallow habitats that were warm and turbid. Variables used to define total numbers of fishes included standard deviation of depth, turbidity, and mean water temperatures. The single negative coefficient was associated with depth heterogeneity.

Following addition of numerically important species to the initial fall data matrix, nine factors were available for interpretation (Table 64, Appendix B). Spotted gar, white bass, carp, and white crappie numbers per net hour increased in habitats with increased plankton biomass, conductivity, water temperature and decreased turbidity. Factor one explained 32.7% of the matrix variance.

Factor two represented deep areas of the reservoir with heterogeneous substrates and reduced dissolved oxygen concentrations and explained 21.2% of the total variance. Carp loaded negatively on this array.

Habitats with increased substrate sizes, substrate heterogeneities, mean water temperatures, and pH, and reduced levels of mean dissolved oxygen and turbidity

were represented on factor three. Numbers of carp per net hour varied positively with these habitats.

On factor four, gizzard shad and white crappie numbers per net hour contributed to an increased total number of fishes taken in warmer habitats with uniformly low substrate complexity and reduced oxygen concentrations.

Factor five represented habitats with high alkalinity and decreased mean substrate sizes. White crappie numbers were positively correlated to these habitats while numbers of white bass were negatively correlated.

Habitats with high Secchi disk transparencies, alkalinities, and increased mean dissolved oxygen levels were represented by loadings on factor six. These habitats also had increased levels of plankton biomass and reduced mean substrate sizes.

Factor seven represented habitats with increased numbers of black bullhead, carp, and white crappie. Numbers of white bass in these habitats were relatively low. Substrate heterogeneities and alkalinities were also reduced.

Habitats with increased substrate complexities, substrate heterogeneities, mean water temperatures, and pH values were represented on factor eight. These habitats were also represented by a greater number of species per net hour and increased numbers of spotted gar.

Factor nine represented pelagic habitats with increased mean depths and decreased substrate sizes and reduced mean water temperature. White bass were negatively associated with these habitats.

Variables used in stepwise multiple regression analysis to predict spotted gar numbers per net hour included mean substrate size, conductivity, mean water

temperatures, Secchi disk transparencies, pH, and number of white crappie per net hour (Table 65, Appendix B). The coefficients of water temperatures and pH values were negative.

The variables mean depth, substrate heterogeneity, dissolved oxygen, alkalinity, Secchi disk transparency, number of spotted gar, and total numbers of fishes were used to predict numbers of gizzard shad. Negative coefficients were dissolved oxygen and spotted gar.

The transposed factor matrix failed to provide a clear linear relationship between the occurrence of carp and any independent variables other than mean depth. However, the regression is sufficient to infer carp were generally taken in shallow habitats.

Variables used to predict numbers of black bullhead per net hour included the habitat scalar and alkalinity. Coefficients of both variables were negative.

Numbers of white bass were predicted by dissolved oxygen, plankton biomass, and standardized species richness. The single negative coefficient was dissolved oxygen.

Variables used to predict numbers of white crappie per net hour included alkalinity, water temperature, and the presence of white bass. White crappie were negatively associated with white bass.

## Discussion

Point measurements of depths and substrates along transects associated with

locations of fish capture provided assessments of preferred seasonal habitats of numerically abundant species. White crappie densities were greatest in shallow areas during all seasons except summer when the species was taken predominately from depths exceeding 2 m. The winter distribution was associated entirely with even and uninterrupted habitats (low complexity). Spring distributions indicated a preference for more heterogeneous habitats. Spawning occurred along shoreline expanses characterized by broken, interrupted substrates. Crappie densities remained high in areas of moderate substrate complexity during summer and fall.

Densities of white bass were greatest in depths of 2-5 m during winter, spring, and summer. In fall, white bass preferred the 1-2 m depth interval. Spring and fall distributions were associated with broken, interrupted and substantially heterogeneous habitats. Even, uninterrupted pelagic areas and broken, interrupted shoreline expanses were preferred during summer. White bass were distributed in areas of low complexity during winter.

Spring distributions of spotted gar and gizzard shad were similar; both species preferred low complexity habitats and the 0-1 m depth interval. During summer and fall the densities of spotted gar increased in substantially heterogeneous habitats, whereas gizzard shad remained in low complexity pelagic areas. Gizzard shad preferred depths exceeding 4 m during fall.

Gizzard shad are the predominant food item of white bass in lakes and reservoirs (Hubbs and Lagler 1958, Tatum 1958, Greene 1962, Cross 1967, Moser 1968, Webb and Moss 1968, Pflieger 1975, Trautman 1981). However, distributions of white bass and gizzard shad in Copan Reservoir were dissimilar in all seasons except winter



when both species preferred the 2-3 m depth interval in low complexity habitats. Thereafter, these species occupied different depth intervals and areas of different substrate complexity. Summerfelt (1971) found that gizzard shad fed in deeper water than white bass during early fall. It remains unclear whether gizzard shad distributions defined in this study were the result of predator-avoidance behavior.

Carp were collected predominantly from depths ranging from 2-5 m in areas of varying complexity. During spring, and coincident to increased surface elevation of the reservoir, carp preferred newly inundated, greatly dissected habitats. Large expanses of flooded vegetation were common in the northern-most extent of the reservoir during spring.

Densities of black bullhead also increased in areas of flooded vegetation during spring. In summer, black bullhead were taken predominantly from low complexity areas in depths exceeding 2 m. Black bullhead were distributed among a variety of available habitats during fall.

Principal components analysis of measurable physical, chemical, and biological characteristics of sampled habitats indicated that dissolved oxygen and water temperature were important factors limiting the distribution of fish populations during summer and fall 1984. Although structural complexity explained the greatest proportion of the variance among sampled habitats, no predictable relationships existed between the physical characteristics of habitat and the apparent form of fish population assemblages. Variation in species richness and numbers of fishes was most effectively explained by a combination of physical, chemical, and biological characteristics.

Divergence from linear relationships between physical habitat structure and fish community diversity occurs in environments which become uninhabitable by fishes, ecosystems which do not approach evolutionary equilibrium, and when disequilibria result from natural stochastic events or the effects of human activities (Gorman and Karr 1978). All of these explanations for divergence may be applicable to perceived patterns of habitat use by Copan Reservoir fish populations. The newly created reservoir environment represents a condition of protracted disequilibria which may cause deterioration of relationships between habitat and fish populations. Historic and recent species introductions and harvest pressures directed at only a few species may alter antecedent relationships and cause the reservoir fish community to diverge further from evolutionary equilibrium. Finally, reduced dissolved oxygen levels caused the most diverse habitats in Copan Reservoir to become less habitable during summer and fall.

Decisions to retain large areal expanses of timber within reservoir basins must be predicated, at least partially, on the assumption that predictable relationships exist between habitat structure and fish community diversity. The findings of this study do not substantiate this assumption. Physical-chemical constraints occurring within the vast timbered area of Copan Reservoir essentially made elements of the environmental matrix inaccessible to fishes. Hutchinson (1957) referred to these areas as homogeneously diverse and suggested that the ratio of total number of individuals to total number of species would remain constant within these environmental subdivisions. In Copan Reservoir, this ratio remained constant and low. The consequent management implications are of considerable importance. The inundated

forest did not increase fish community diversity or the numeric strength of desirable sport fish populations. In addition, angler opportunity was not enhanced.

Plans to retain large areas of timber within reservoir basins should involve consideration of environmental characteristics of the post-impoundment period. The unit of area that would become homogeneously diverse may be modified into a more desirable heterogeneously diverse area with numerous patches of standing timber separated by open pelagic areas. Species that initially occupy these patches should be faced with the constant pressure of high immigration and species attempting to colonize should find it harder to do so because of the greater diversity of resident competitors opposing them at any given moment (MacArthur and Wilson 1967). In the absence of physical-chemical constraints, patches within heterogeneously diverse areas would likely increase local fish community diversity, increase the numeric strength of some fish populations, and enhance angler opportunity.

## CHAPTER VI

### SUMMARY AND CONCLUSIONS

Twenty nine species were taken by passive capture in Copan Reservoir. Spotted gar (Lepisosteus oculatus), carp (Carpoides carpio), black bullhead (Ictalurus melas), white bass (Morone chrysops), white crappie (Pomoxis annularis), bluegill (Lepomis macrochirus), and gizzard shad (Dorosoma cepedianum) were shown to be initially abundant, accounting for about 83% of the total 2-year capture. These species declined or increased in relative abundances and caused seasonal comparisons of Percentage Similarity Coefficient (Whittaker 1952) values to become progressively disparate over time. A period of high productivity in Copan Reservoir preceded the development of a fish assemblage dominated by lower trophic levels. Combined predator biomass, in excess of forage biomass early in 1984, decreased below forage biomass in fall 1984.

Attributes associated with deterministic communities (Grossman 1982) were inconsistent with the structure of the Copan Reservoir fish community. Reservoir fish populations were susceptible to stochastic perturbations. Rapid and dramatic changes in reservoir volume and increased reservoir discharges altered population densities by facilitating emigration of vagile riverine species. Shifts in population densities could not be explained by feeding relationships.

The abundance of white bass and striped bass x white bass hybrids in Copan Reservoir is dependent on continued intensive stocking efforts. Biomass of gizzard shad decreased simultaneous to periods of increased storage and discharge. However, fluctuating water levels favor the continued prevalence of carp and have negligible impact on populations of crappie, bluegill, and largemouth bass.

A point measurement system was adapted from the stream methodology of Gorman and Karr (1978) to evaluate depths and substrates relative to locations of fish capture. Frequency distributions that were nonuniform relative to habitat availability were equated with preference for specific depth and substrate intervals. Inferential assessments of seasonal habitat preferences for spotted gar, gizzard shad, black bullhead, carp, white crappie, and white bass were successfully developed.

Measures of species richness and equivalencies were not linearly related to increased structural complexity of habitats in Copan Reservoir. In this study, variation in species richness and numbers of fishes was explained by a combination of physical, chemical, and biological characteristics of sampled habitats.

Analyses of multidimensional data sets supported and expanded the inferential assessments of seasonal habitat preferences. Principal components analysis indicated that dissolved oxygen and water temperature were important factors limiting the distribution of fish populations during summer and fall 1984. Further evaluation by stepwise multiple regression analysis indicated that frequency of occurrence was often positively or negatively correlated with the occurrence or absence of other species.

Fish community diversity and the numeric strength of sport fish populations did not increase in the vast timbered area of Copan Reservoir. In the absence of

physical-chemical constraints, patchy habitats within heterogeneously diverse areas would likely increase local fish community diversity, increase the numeric strength of some fish populations, and enhance angler opportunity.

Future attempts to assess the distribution of species occupying reservoir environments should be conducted following the initial period of high productivity characteristic of new impoundments, specifically evaluate impacts of stochastic events on fish populations, and use various physical, chemical, and biological measurements to discern patterns of habitat use.

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**APPENDIX A**

**SAMPLING EFFORT AND CATCH DATA FOR  
COPAN RESERVOIR**



TABLE 14

WINTER 1983-1984 SAMPLING EFFORT (HR) OF BARREL NETS,  
FRAME NETS, AND GILL NETS WITHIN STANDARD  
SAMPLING SECTIONS

Gear/Month	Section					Total
	1	2	3	4	5	
Barrel nets						
Jan	0	0	57	0	0	57
Feb	0	0	0	0	0	0
Σ:	0	0	57	0	0	57 (32.20%)
Frame nets						
Jan	0	0	0	0	0	0
Feb	0	0	0	0	0	0
Gill nets						
Jan	0	0	12	0	0	12
Feb	12	12	36	24	24	108
Σ:	12	12	48	24	24	120 (67.80%)
Total	12	12	105	24	24	177

TABLE 15

SPRING 1984 SAMPLING EFFORT (HR) OF BARREL NETS, FRAME  
NETS, AND GILL NETS WITHIN STANDARD SAMPLING SECTIONS

Gear/Month	Section					Total
	1	2	3	4	5	
<b>Barrel nets</b>						
Mar	54	84	69	41	48	323
Apr	0	0	6	0	0	0
May	0	12	46	0	0	58
$\Sigma$ :	<u>54</u>	<u>96</u>	<u>148</u>	<u>41</u>	<u>48</u>	<u>387 (35.93%)</u>
<b>Frame nets</b>						
Mar	27	36	12	24	31	130
Apr	25	25	24	0	82	156
May	43	99	0	0	42	184
$\Sigma$ :	<u>95</u>	<u>160</u>	<u>36</u>	<u>24</u>	<u>155</u>	<u>470 (43.52%)</u>
<b>Gill nets</b>						
Mar	0	6	17	0	6	29
Apr	24	8	8	0	8	48
May	46	24	24	0	49	143
$\Sigma$ :	<u>70</u>	<u>38</u>	<u>49</u>	<u>0</u>	<u>63</u>	<u>220 (20.37%)</u>
<b>Total</b>	219	294	233	65	266	1077

TABLE 16

SUMMER 1984 SAMPLING EFFORT (HR) OF BARREL NETS, FRAME NETS, AND GILL NETS WITHIN STANDARD SAMPLING SECTIONS

Gear/Month	Section					Total
	1	2	3	4	5	
<b>Barrel nets</b>						
Jun	0	0	0	0	0	0
Jul	0	0	0	0	0	0
Aug	38	38	38	0	0	114
Σ:	<u>38</u>	<u>38</u>	<u>38</u>	<u>0</u>	<u>0</u>	<u>114</u> (14.30%)
<b>Frame nets</b>						
Jun	0	19	0	0	0	19
Jul	24	31	24	0	24	103
Aug	29	29	35	0	29	122
Σ:	<u>53</u>	<u>79</u>	<u>59</u>	<u>0</u>	<u>53</u>	<u>244</u> (30.62%)
<b>Gill nets</b>						
Jun	36	44	52	21	41	194
Jul	30	30	30	30	30	150
Aug	24	24	24	0	23	95
Σ:	<u>90</u>	<u>98</u>	<u>106</u>	<u>51</u>	<u>94</u>	<u>439</u> (55.08%)
<b>Total</b>	181	215	203	51	147	797

TABLE 17

FALL 1984 SAMPLING EFFORT (HR) OF BARREL NETS, FRAME NETS,  
AND GILL NETS WITHIN STANDARD SAMPLING SECTIONS

Gear/Month	Section					Total
	1	2	3	4	5	
<b>Barrel nets</b>						
Sep	0	0	0	0	0	0
Oct	0	0	0	0	0	0
Nov	0	0	0	0	0	0
<b>Frame nets</b>						
Sep	0	0	0	0	0	0
Oct	24	24	25	24	0	97
Nov	25	30	25	26	26	132
Σ:	<u>49</u>	<u>54</u>	<u>50</u>	<u>50</u>	<u>26</u>	<u>229</u> (35.73%)
<b>Gill nets</b>						
Sep	25	26	19	22	23	115
Oct	24	24	57	0	28	133
Nov	23	24	24	45	48	164
Σ:	<u>72</u>	<u>74</u>	<u>100</u>	<u>67</u>	<u>99</u>	<u>412</u> (64.27%)
<b>Total</b>	121	128	150	117	125	641

TABLE 18

TOTAL NUMBER OF FISHES IN EACH SPECIES COLLECTED IN  
EACH SECTION OF COPAN RESERVOIR BY ALL SAMPLING  
METHODS, DECEMBER 1983 - NOVEMBER 1984

Species	Section					Total	%
	1	2	3	4	5		
Drum	19	10	6	8	1	44	0.8
River carpsucker	30	35	25	6	87	183	3.2
Carp	128	189	67	19	225	628	11.1
Gizzard shad	177	95	158	28	137	595	10.5
Hybrid bass	4	-	-	-	3	7	0.1
Smallmouth buffalo	20	5	7	-	9	41	0.7
Bigmouth buffalo	11	5	10	8	66	100	1.8
Blue catfish	23	2	4	1	6	36	0.6
Black bullhead	83	145	322	68	455	1,073	18.9
Yellow bullhead	4	17	31	6	58	116	2.1
Channel catfish	26	45	17	15	55	158	2.8
Brook silverdale	1	-	-	-	-	1	0.02
Green sunfish	2	10	7	-	15	34	0.6
Warmouth	-	17	11	-	15	34	0.5
Orangespotted sunfish	-	1	-	-	1	2	0.04
Bluegill	23	91	285	12	92	503	8.9
Longear sunfish	8	26	4	-	1	39	0.7
Redear	-	7	19	-	1	27	0.5
Spotted gar	14	33	319	17	75	458	8.1

TABLE 18 (Continued)

Species	Section					Total	%
	1	2	3	4	5		
Longnose gar	-	-	1	-	3	4	0.07
Shortnose gar	2	25	13	11	39	90	1.6
Largemouth bass	29	21	13	2	45	110	1.9
White bass	222	110	9	10	334	685	12.1
Riverredhorse	-	-	-	-	-	-	-
Golden shiner	-	1	-	-	2	3	0.05
Logperch	-	-	-	1	-	1	0.02
White crappie	94	94	241	19	202	650	11.50
Black crappie	7	6	14	4	18	49	0.9
Flathead catfish	-	1	-	1	-	2	0.04
Total	926	992	1,583	236	1,932	5,669	
Relative Abundance (%)	16.3	17.5	27.9	4.2	34.1		

TABLE 19

TOTAL NUMBER OF FISHES IN EACH SPECIES COLLECTED IN  
EACH SECTION OF COPAN RESERVOIR BY ALL SAMPLING  
METHODS, DECEMBER 1984 - NOVEMBER 1985

Species	Section					Total	%
	1	2	3	4	5		
Drum	15	19	2	1	6	43	1.4
River carpsucker	2	1	1	-	13	17	0.6
Carp	59	91	43	7	65	265	8.8
Gizzard shad	122	25	182	157	313	799	26.6
Hybrid bass	-	1	-	4	2	7	0.2
Smallmouth buffalo	10	28	4	3	12	57	1.9
Bigmouth buffalo	-	-	10	-	29	39	1.3
Blue catfish	29	7	3	-	17	56	1.9
Black bullhead	56	37	150	16	62	321	10.7
Yellow bullhead	-	-	3	1	-	4	0.1
Channel catfish	17	8	7	1	7	40	1.3
Brook silverdale	-	1	-	-	-	1	0.03
Green sunfish	7	3	8	3	5	26	0.9
Warmouth	2	1	3	-	1	7	0.2
Orangespotted sunfish	1	1	8	1	-	11	0.4
Bluegill	24	40	251	43	26	384	12.8
Longear sunfish	4	1	6	1	21	33	1.1
Redear	-	1	15	1	15	32	1.1
Spotted gar	-	-	4	2	4	10	0.3

TABLE 19 (Continued)

Species	Section					Total	%
	1	2	3	4	5		
Longnose gar	-	-	1	-	-	1	0.03
Shortnose gar	-	1	2	-	8	11	0.4
Largemouth bass	7	3	5	-	4	19	0.6
White bass	16	8	21	2	35	82	2.7
River herring	-	-	-	1	-	1	0.03
Golden shiner	-	-	-	-	4	4	0.1
Logperch	-	-	-	-	-	-	-
White crappie	138	102	147	143	187	717	23.9
Black crappie	1	1	6	-	8	16	0.5
Flathead catfish	-	-	-	-	-	-	-
Total	<u>510</u>	<u>380</u>	<u>882</u>	<u>387</u>	<u>844</u>	<u>3003</u>	
Relative Abundance (%)	17.0	12.7	29.4	12.9	28.1		



**APPENDIX B**

**DISTRIBUTION OF SPECIES RELATIVE TO  
DEPTHS AND SUBSTRATES,  
COPAN RESERVOIR**

TABLE 20

DISTRIBUTION OF WHITE CRAPPIE RELATIVE TO DEPTHS  
 SAMPLED DURING WINTER 1983-1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	675	2	1.42
2 - 3	625	2	1.32
4 - 5	1,875	4	1.32
5 - 6	625	0	1.32
Total	<u>3,800</u>	<u>8</u>	
T(df)		1.90(3)	
		P > 0.25	

TABLE 21

DISTRIBUTION OF WHITE CRAPPIE RELATIVE TO SUBSTRATES  
 SAMPLED DURING SPRING 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 2	4,000	15	23.5
2 - 4	2,900	22	17.0
4 - 6	2,750	15	16.2
5 - 8	1,125	15	6.6
> 8	625	0	3.7
Total	11,400	57	
T(df)		19.02(4)	
		P < 0.001	

TABLE 22

DISTRIBUTION OF WHITE CRAPPIE RELATIVE TO DEPTHS SAMPLED  
DURING SPRING 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	1,000	12	5.9
1 - 2	3,400	17	20.0
2 - 3	2,126	30	12.5
3 - 4	1,125	0	6.6
4 - 5	1,875	8	11.0
5 - 6	625	0	3.7
6 - 7	1,250	0	7.3
Total	<u>11,400</u>	<u>67</u>	
T(df)		49.67(6)	
		P < 0.001	

TABLE 23

DISTRIBUTION OF WHITE CRAPPIE RELATIVE TO SUBSTRATES  
 SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 2	3,125	36	37.14
2 - 4	1,250	14	14.86
4 - 6	1,875	37	22.29
5 - 8	2,500	17	29.71
Total	8,750	104	
T(df)		15.23(3)	
		P < 0.005	

TABLE 24

DISTRIBUTION OF WHITE CRAPPIE RELATIVE TO DEPTHS  
 SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	4	5.56
1 - 2	500	2	5.56
2 - 3	2,375	30	26.41
3 - 4	2,500	27	27.80
4 - 5	3,125	49	34.76
6 - 7	1,250	2	13.90
Total	<u>11,400</u>	<u>67</u>	
T(df)		20.12(5)	
		P < 0.005	

TABLE 25

DISTRIBUTION OF WHITE CRAPPIE RELATIVE TO SUBSTRATES  
 SAMPLED DURING FALL 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 2	3,750	29	29.20
2 - 4	2,500	12	19.47
4 - 6	1,250	22	9.73
5 - 8	1,875	10	14.60
Total	9,375	73	
T(df)		19.79(3)	
		P < 0.005	

TABLE 26

DISTRIBUTION OF WHITE CRAPPIE RELATIVE TO DEPTHS  
SAMPLED DURING FALL 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	8	4.47
1 - 2	2,250	11	20.10
2 - 3	2,750	40	24.56
3 - 4	500	1	4.47
4 - 5	3,750	38	33.50
5 - 6	2,500	16	22.33
7 - 8	625	1	5.58
Total	<u>12,875</u>	<u>115</u>	
T(df)		25.46(6)	
		P < 0.001	



TABLE 27

DISTRIBUTION OF WHITE BASS RELATIVE TO DEPTHS SAMPLED  
DURING WINTER 1983-1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	675	0	39.61
2 - 3	625	167	36.68
4 - 5	1,875	56	110.03
5 - 6	625	0	36.68
Total	<u>3,800</u>	<u>223</u>	
T(df)		565.83(3)	
		P < 0.001	

TABLE 28

DISTRIBUTION OF WHITE BASS RELATIVE TO SUBSTRATES  
 SAMPLED DURING SPRING 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 2	4,000	4	24.6
2 - 4	2,900	9	17.8
4 - 6	2,750	27	16.9
5 - 8	1,125	25	6.9
> 8	625	5	3.8
Total	11,400	70	
T(df)		75.50(4)	
		P < 0.001	

TABLE 29

DISTRIBUTION OF WHITE BASS RELATIVE TO DEPTHS SAMPLED  
DURING SPRING 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	1,000	0	6.1
1 - 2	3,400	3	20.9
2 - 3	2,125	34	13.0
3 - 4	1,125	5	6.9
4 - 5	1,875	28	11.5
5 - 6	625	0	3.8
6 - 7	1,250	0	7.7
Total	<u>11,400</u>	<u>70</u>	
T(df)		91.15(6)	
		P < 0.001	

TABLE 30

DISTRIBUTION OF WHITE BASS RELATIVE TO SUBSTRATES  
 SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,125	125	81.43
2 - 4	1,250	10	32.57
4 - 6	1,875	62	48.86
6 - 8	2,500	31	65.14
Total	<u>8,750</u>	<u>228</u>	
T(df)		60.38(3)	
		P < 0.001	

TABLE 31

DISTRIBUTION OF WHITE BASS RELATIVE TO DEPTHS  
 SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	2	11.22
1 - 2	500	0	11.22
2 - 3	2,375	29	53.29
3 - 4	2,500	81	56.10
4 - 5	3,125	109	70.12
6 - 7	1,250	9	28.05
Total	<u>10,250</u>	<u>230</u>	
T(df)		75.42(5)	
		P < 0.001	

TABLE 32

DISTRIBUTION OF WHITE BASS RELATIVE TO SUBSTRATES  
 SAMPLED DURING FALL 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,750	22	23.20
2 - 4	2,500	5	15.47
4 - 6	1,250	3	7.73
6 - 8	1,875	28	11.60
Total	<u>9,375</u>	<u>58</u>	
T(df)		33.23(3)	
		P < 0.001	

TABLE 33

DISTRIBUTION OF WHITE BASS RELATIVE TO DEPTHS  
 SAMPLED DURING FALL 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	0	2.83
1 - 2	2,250	30	12.76
2 - 3	2,750	11	15.59
3 - 4	500	0	2.83
4 - 5	3,750	19	21.26
5 - 6	2,500	13	14.17
7 - 8	625	0	3.54
Total	<u>12,875</u>	<u>73</u>	
T(df)		34.20(6)	
		P < 0.001	

TABLE 34

DISTRIBUTION OF SPOTTED GAR RELATIVE TO DEPTHS  
 SAMPLED DURING WINTER 1983-1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	675	0	51.33
2 - 3	625	0	47.53
4 - 5	1,875	244	142.60
5 - 6	625	45	47.53
Total	<u>13,800</u>	<u>289</u>	
T(df)		171.12(3)	
		P < 0.001	



TABLE 35

DISTRIBUTION OF SPOTTED GAR RELATIVE TO SUBSTRATES  
 SAMPLED DURING SPRING 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	4,000	2	8.4
2 - 4	2,900	17	6.1
4 - 6	2,750	3	5.8
6 - 8	1,125	2	2.4
> 8	625	0	1.3
Total	11,400	24	
T(df)		27.07(4)	
		P < 0.001	

TABLE 36

DISTRIBUTION OF SPOTTED GAR RELATIVE TO DEPTHS  
 SAMPLED DURING SPRING 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	1,000	17	2.1
1 - 2	3,400	1	7.2
2 - 3	2,125	3	4.5
3 - 4	1,125	0	2.4
4 - 5	1,875	2	3.9
5 - 6	625	0	1.3
6 - 7	1,250	1	2.6
Total	<u>11,400</u>	<u>24</u>	
T(df)		117.17(6)	
		P < 0.001	

TABLE 37

DISTRIBUTION OF SPOTTED GAR RELATIVE TO SUBSTRATES  
 SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,125	22	41.43
2 - 4	1,250	5	16.57
4 - 6	1,875	50	24.86
6 - 8	2,500	39	33.14
Total	8,750	116	
T(df)		43.65(3)	
		P < 0.001	

TABLE 38

DISTRIBUTION OF SPOTTED GAR RELATIVE TO DEPTHS  
 SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	2	5.76
1 - 2	500	0	5.76
2 - 3	2,375	37	27.34
3 - 4	2,500	31	28.78
4 - 5	3,125	29	35.98
6 - 7	1,250	19	14.39
Total	<u>10,250</u>	<u>118</u>	
T(df)		12.17(5)	
		P < 0.05	

TABLE 39

DISTRIBUTION OF SPOTTED GAR RELATIVE TO SUBSTRATES  
 SAMPLED DURING FALL 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,750	2	4.8
2 - 4	2,500	0	3.2
4 - 6	1,250	3	1.6
6 - 8	1,875	7	2.4
Total	<u>9,375</u>	<u>12</u>	
T(df)		14.88(3)	
		P < 0.005	

TABLE 40  
 DISTRIBUTION OF SPOTTED GAR RELATIVE TO DEPTHS  
 SAMPLED DURING FALL 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	0	0.39
1 - 2	2,250	3	1.75
2 - 3	2,750	2	2.14
3 - 4	500	0	0.39
4 - 5	3,750	3	2.91
5 - 6	2,500	2	1.94
7 - 8	625	0	0.49
Total	<u>12,875</u>	<u>10</u>	
T(df)		2.17(6)	
		P < 0.25	

TABLE 41

DISTRIBUTION OF GIZZARD SHAD RELATIVE TO DEPTHS  
 SAMPLED DURING WINTER 1983-1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	675	1	5.51
2 - 3	625	23	5.10
4 - 5	1,875	7	15.30
5 - 6	625	0	5.10
Total	<u>3,800</u>	<u>31</u>	
T(df)		76.11(3)	
		P < 0.001	

TABLE 42

DISTRIBUTION OF GIZZARD SHAD RELATIVE TO SUBSTRATES  
 SAMPLED DURING SPRING 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	4,000	5	15.1
2 - 4	2,900	25	10.9
4 - 6	2,750	8	10.4
6 - 8	1,125	5	4.2
> 8	625	0	2.4
Total	11,400	43	
T(df)		28.10(4)	
		P < 0.001	



TABLE 43

DISTRIBUTION OF GIZZARD SHAD RELATIVE TO DEPTHS  
 SAMPLED DURING SPRING 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	1,000	9	3.8
1 - 2	3,400	28	12.8
2 - 3	2,125	5	8.0
3 - 4	1,125	0	4.2
4 - 5	1,875	1	7.1
5 - 6	625	0	2.4
6 - 7	1,250	0	4.7
Total	<u>11,400</u>	<u>43</u>	
T(df)		42.83(6)	
		P < 0.001	

TABLE 44

DISTRIBUTION OF GIZZARD SHAD RELATIVE TO SUBSTRATES  
 SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,125	46	47.86
2 - 4	1,250	34	19.14
4 - 6	1,875	39	28.71
6 - 8	2,500	15	38.29
Total	8,750	134	
T(df)		29.46(3)	
		P < 0.001	

TABLE 45

DISTRIBUTION OF GIZZARD SHAD RELATIVE TO DEPTHS  
SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	46	8.78
1 - 2	500	0	8.78
2 - 3	2,375	39	41.71
3 - 4	2,500	14	43.90
4 - 5	3,125	80	54.88
6 - 7	1,250	1	21.95
Total	<u>10,250</u>	<u>180</u>	
T(df)		218.60(5)	
		P < 0.001	

TABLE 46

DISTRIBUTION OF GIZZARD SHAD RELATIVE TO SUBSTRATES  
 SAMPLED DURING FALL 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,750	204	126.80
2 - 4	2,500	67	84.53
4 - 6	1,250	19	42.27
6 - 8	1,875	27	63.40
Total	<u>9,375</u>	<u>317</u>	
T(df)		84.35(3)	
		P < 0.001	

TABLE 47

DISTRIBUTION OF GIZZARD SHAD RELATIVE TO DEPTHS  
 SAMPLED DURING FALL 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	1	12.78
1 - 2	2,250	18	57.50
2 - 3	2,750	39	70.27
3 - 4	500	0	10.78
4 - 5	3,750	201	95.83
6 - 7	2,500	67	63.88
7 - 8	625	3	15.97
Total	<u>12,875</u>	<u>329</u>	
T(df)		190.78(6)	
		P < 0.001	

TABLE 48

DISTRIBUTION OF CARP RELATIVE TO DEPTHS SAMPLED  
DURING WINTER 1983-1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	675	0	1.24
2 - 3	625	2	1.15
4 - 5	1,875	5	3.45
5 - 6	625	0	1.16
Total	<u>3,800</u>	<u>7</u>	
T(df)		3.73(3)	
		P < 0.25	

TABLE 49

DISTRIBUTION OF CARP RELATIVE TO SUBSTRATES SAMPLED  
DURING SPRING 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	4,000	62	72.6
2 - 4	2,900	34	52.7
4 - 6	2,750	44	49.9
6 - 8	1,125	32	20.4
> 8	625	35	11.3
Total	<u>11,400</u>	<u>207</u>	
T(df)		65.28(4)	
		P < 0.001	

TABLE 50

DISTRIBUTION OF CARP RELATIVE TO DEPTHS SAMPLED  
DURING SPRING 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	1,000	15	18.2
1 - 2	2,400	6	61.7
2 - 3	2,125	86	38.6
4 - 5	1,875	65	34.0
5 - 6	625	0	11.3
6 - 7	1,250	0	22.7
Total	<u>11,400</u>	<u>207</u>	
T(df)		181.87(6)	
		P < 0.001	



TABLE 51

DISTRIBUTION OF CARP RELATIVE TO SUBSTRATES SAMPLED  
DURING SUMMER 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,125	58	87.50
2 - 4	1,250	25	35.00
4 - 6	1,875	115	52.50
6 - 8	2,500	47	70.00
Total	<u>8,750</u>	<u>245</u>	
T(df)		94.76(3)	
		P < 0.001	

TABLE 52

DISTRIBUTION OF CARP RELATIVE TO DEPTHS SAMPLED  
DURING SUMMER 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	0	12.10
1 - 2	500	2	12.10
2 - 3	2,375	50	57.46
3 - 4	2,500	89	60.49
4 - 5	3,125	99	75.61
6 - 7	1,250	8	30.24
Total	<u>10,250</u>	<u>248</u>	
T(df)		58.53(5)	
		P < 0.001	

TABLE 53

DISTRIBUTION OF CARP RELATIVE TO SUBSTRATES SAMPLED  
DURING FALL 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,750	17	22.00
2 - 4	2,500	19	14.67
4 - 6	1,250	4	7.33
6 - 8	1,875	15	11.00
Total	<u>9,375</u>	<u>55</u>	
T(df)		5.38(3)	
		P < 0.10	

TABLE 54

DISTRIBUTION OF CARP RELATIVE TO DEPTHS SAMPLED  
DURING FALL 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	6	2.45
1 - 2	2,250	13	11.01
2 - 3	2,750	10	13.46
3 - 4	500	0	2.45
4 - 5	3,750	25	18.35
5 - 6	2,500	9	12.23
7 - 8	625	0	3.06
Total	<u>12,875</u>	<u>63</u>	
T(df)		15.15(6)	
		P < 0.01	

TABLE 55

DISTRIBUTION OF BLACK BULLHEAD RELATIVE TO DEPTHS SAMPLED  
DURING WINTER 1983-1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	675	1	14.03
2 - 3	625	54	12.99
4 - 5	1,875	24	38.89
5 - 6	625	0	12.99
Total	<u>3,800</u>	<u>79</u>	
T(df)		160.33(3)	
		P < 0.001	

TABLE 56

DISTRIBUTION OF BLACK BULLHEAD RELATIVE TO SUBSTRATES  
 SAMPLED DURING SPRING 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	4,000	61	57.5
2 - 4	2,900	43	41.7
4 - 6	2,750	11	39.6
6 - 8	1,125	35	16.2
> 8	625	14	9.0
Total	<u>11,400</u>	<u>164</u>	
T(df)		45.50(4)	
		P < 0.001	

TABLE 57

DISTRIBUTION OF BLACK BULLHEAD RELATIVE TO DEPTHS  
 SAMPLED DURING SPRING 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	1,000	11	14.4
1 - 2	3,400	46	48.9
2 - 3	2,125	79	30.6
4 - 5	1,875	14	16.2
5 - 6	625	4	9.0
6 - 7	1,250	0	18.0
Total	<u>11,400</u>	<u>164</u>	
T(df)		109.22(6)	
		P < 0.001	

TABLE 58

DISTRIBUTION OF BLACK BULLHEAD RELATIVE TO SUBSTRATES  
 SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,125	140	103.57
2 - 4	1,250	60	41.43
4 - 6	1,875	37	62.14
6 - 8	2,500	53	82.86
Total	8,750	290	
T(df)		42.07(3)	
		P < 0.001	



TABLE 59

DISTRIBUTION OF BLACK BULLHEAD RELATIVE TO DEPTHS  
 SAMPLED DURING SUMMER 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	0	13.85
1 - 2	500	0	13.85
2 - 3	2,375	60	65.80
3 - 4	2,500	118	65.80
4 - 5	3,125	90	69.27
6 - 7	1,250	16	34.63
Total	<u>10,250</u>	<u>284</u>	
T(df)		72.66(5)	
		P < 0.001	

TABLE 60

DISTRIBUTION OF BLACK BULLHEAD RELATIVE TO SUBSTRATES  
 SAMPLED DURING FALL 1984, COPAN RESERVOIR

Substrate interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
1 - 2	3,750	106	79.20
2 - 4	2,500	35	52.80
4 - 6	1,250	2	26.40
6 - 8	1,875	55	39.60
Total	9,375	198	
T(df)		43.61(3)	
		P < 0.001	

TABLE 61

DISTRIBUTION OF BLACK BULLHEAD RELATIVE TO DEPTHS  
 SAMPLED DURING FALL 1984, COPAN RESERVOIR

Depth interval (m)	Area sampled (m <sup>2</sup> )	Observed frequency	Expected frequency
0 - 1	500	15	9.20
1 - 2	2,250	56	41.42
2 - 3	2,750	65	50.62
3 - 4	500	0	9.20
4 - 5	3,750	46	69.03
5 - 6	2,500	54	46.02
7 - 7.99	625	1	11.50
Total	<u>12,875</u>	<u>237</u>	
T(df)		40.74(6)	
		P < 0.001	

TABLE 62

SORTED ROTATED FACTOR LOADINGS OF FALL 1984 HABITAT DATA,  
COPAN RESERVOIR  
(LOADINGS LESS THAN 0.25 NOT SHOWN)

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
SD	0.965	-	-	-	-	-	-
SH	0.890	-	-	-	-	-	-
HD	0.860	-	-	0.412	-	-	-
DO	-0.619	-	-0.615	-	0.349	-	-
PB	-	0.908	-	-	0.322	-	-
CON	-	0.850	-	-	-	0.374	-
AM	0.264	0.786	-	-	-	0.315	-
WT	-	0.722	0.419	-	-	0.343	-
NTU	-	-0.598	-0.417	-0.396	0.358	-	-
PH	-	-	0.880	-	-	-	-
SS	0.403	-	-	0.856	-	-	-
MS	0.367	-	-	0.645	-0.330	-	-0.307
SC	-	0.262	-	-	0.864	-	0.261
SP	-	0.364	-	-	-	0.868	-
AL	-	-	-	-	-	-	0.944
MD	0.618	-	-	-	-	-	-
NO	-	0.472	0.287	-0.260	-	-	-
Eigenvalues	3.711	3.668	1.872	1.750	1.392	1.327	1.230

TABLE 63

STEPWISE MULTIPLE REGRESSIONS OF SPECIES RICHNESS  
AND TOTAL NUMBERS OF FISHES, STANDARDIZED FOR  
EFFORT, COPAN RESERVOIR, FALL 1984

Dependent	Regression	F	P	R <sup>2</sup>
SP	0.107 - 0.219(PB) - 1.200(MD) + 1.731(NTU) + 3.060(WT) - 1.902(NO)	346.04	0.041	1.00
NO	- 0.085 - 0.225(SD) + 0.470(NTU) + 1.172(WT)	20.92	0.016	0.95

TABLE 64

SORTED ROTATED FACTOR LOADINGS OF FALL 1984  
HABITAT DATA WITH NUMERICALLY IMPORTANT SPECIES  
(LOADINGS LESS THAN 0.25 NOT SHOWN)

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
LO	0.876	-	-	-	-	-	-	0.278	-
PB	0.771	-	-	-	-	0.414	-	-	-
CON	0.768	-	0.262	-	-	-	-	-	0.331
AM	0.766	0.284	-	0.388	-	-	-	-	-
WT	0.677	-	0.411	0.367	-	-	-	0.252	-0.252
WB	0.665	-	-	-	-0.347	-	-0.377	-	-0.450
SD	-	0.947	-	-	-	-	-	-	-
HD	-	0.935	-	-	-	-	-	-	-
SH	-	0.879	-	-	-	-	-	-	-
DO	-	-0.686	-0.489	-0.251	-	0.368	-	-	-
SS	-	0.581	0.425	-0.353	-	-	-0.387	0.259	-
MS	-	0.525	0.294	-	-0.268	-0.411	-	0.345	-0.412
NTU	-0.379	-	-0.811	-	-	-	-	-	-
PH	-	-	0.789	-	-	-	-	0.378	-
CC	0.490	-0.287	0.656	-	-	-	0.324	-	-
DC	-	-	-	0.949	-	-	-	-	-

TABLE 64 (continued)

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
NO	0.321	-	-	0.812	-	-	0.308	-	-
AL	-	-	-	-	0.871	0.319	-0.292	-	-
WC	0.446	-	-	0.259	0.722	-	0.275	-	-
SC	-	-	-	-	-	0.925	-	-	-
BB	-	-	-	-	-	-	0.915	-	-
SP	0.440	-	-	-	-	-	-	0.817	-
MD	-	0.542	-	-	-	-	-	-	0.710
Eigenvalues	4.503	4.259	2.838	2.501	1.827	1.739	1.714	1.393	1.276

TABLE 65

STEPWISE MULTIPLE REGRESSION OF FREQUENCIES OF OCCURRENCE  
OF NUMERICALLY ABUNDANT SPECIES, STANDARDIZED FOR  
EFFORT, COPAN RESERVOIR, FALL 1984

Dependent	Regression	F	P	R <sup>2</sup>
LO	- 0.360 + 0.849(MS) - 1.300(CON) - 0.416(WT) + 0.300 (SC) - 0.087(PH) + 0.825(WC)	433.26	0.002	1.00
DC	- 1.162 + 0.458(MD) + 0.062(SS) - 0.020(DO) + 0.344(AL) + 0.046(SC) - 0.178(LO) + 1.311(NO)	89,645,700.00	< 0.001	1.00
CC	0.174 - 0.653(MD)	6.097	0.043	0.47
BB	0.288 - 0.519(MD) - 0.681(AL)	6.028	0.037	0.67
WB	- 0.437 - 0.411(DO) + 0.930(PB) + 0.838(SP)	21.240	0.003	0.93
WC	- 0.076 + 0.365(AL) + 1.096(WT) - 0.529(WB)	9.593	0.016	0.85



**APPENDIX C**

**RELATIVE DENSITY ESTIMATES IN  
RELATION TO DEPTHS AND SUBSTRATES  
FOR EACH SPECIES**

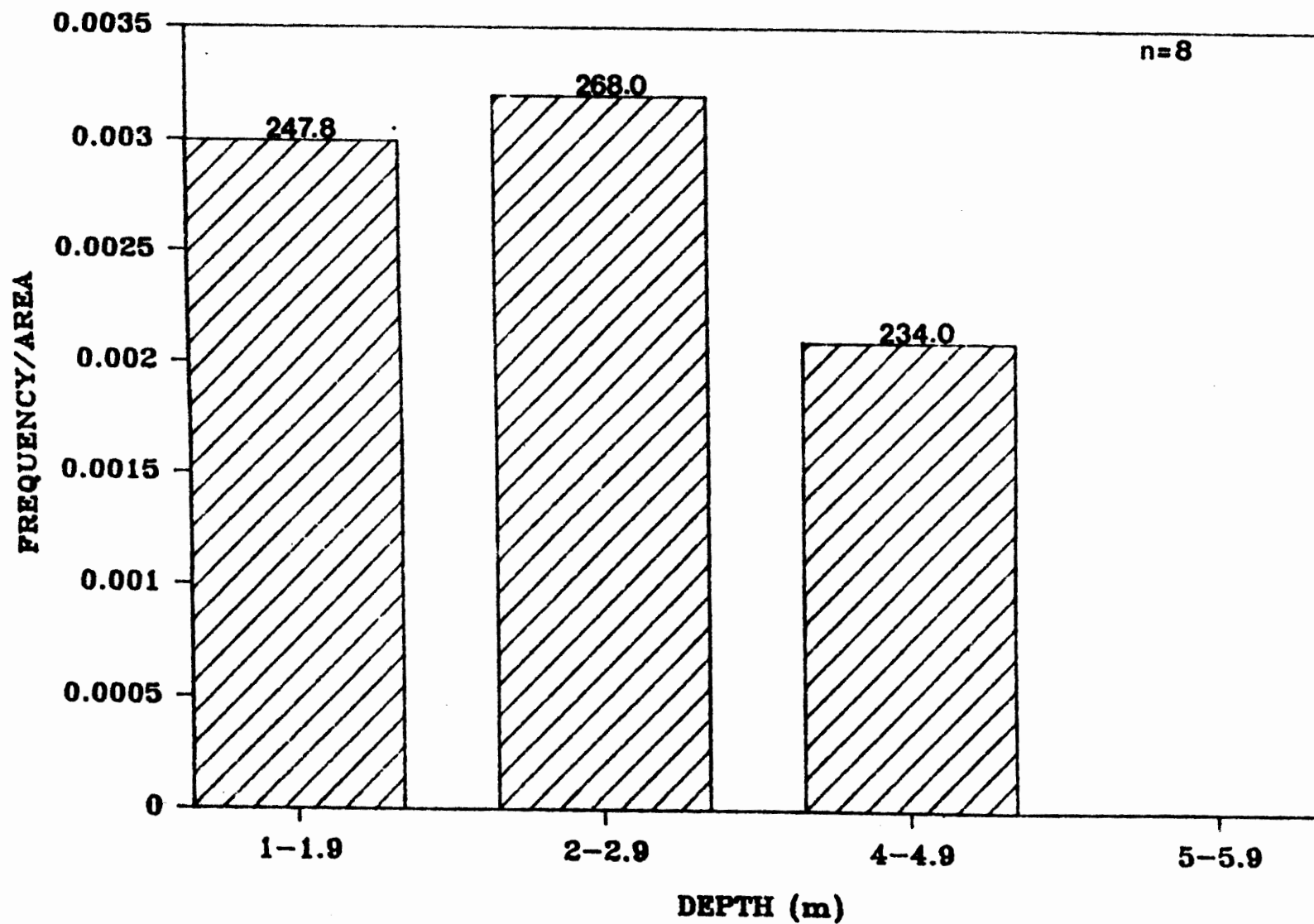


Figure 5. Winter 1984 relative density estimates in relation to depth for white crappie. Mean total length is indicated above each depth category.

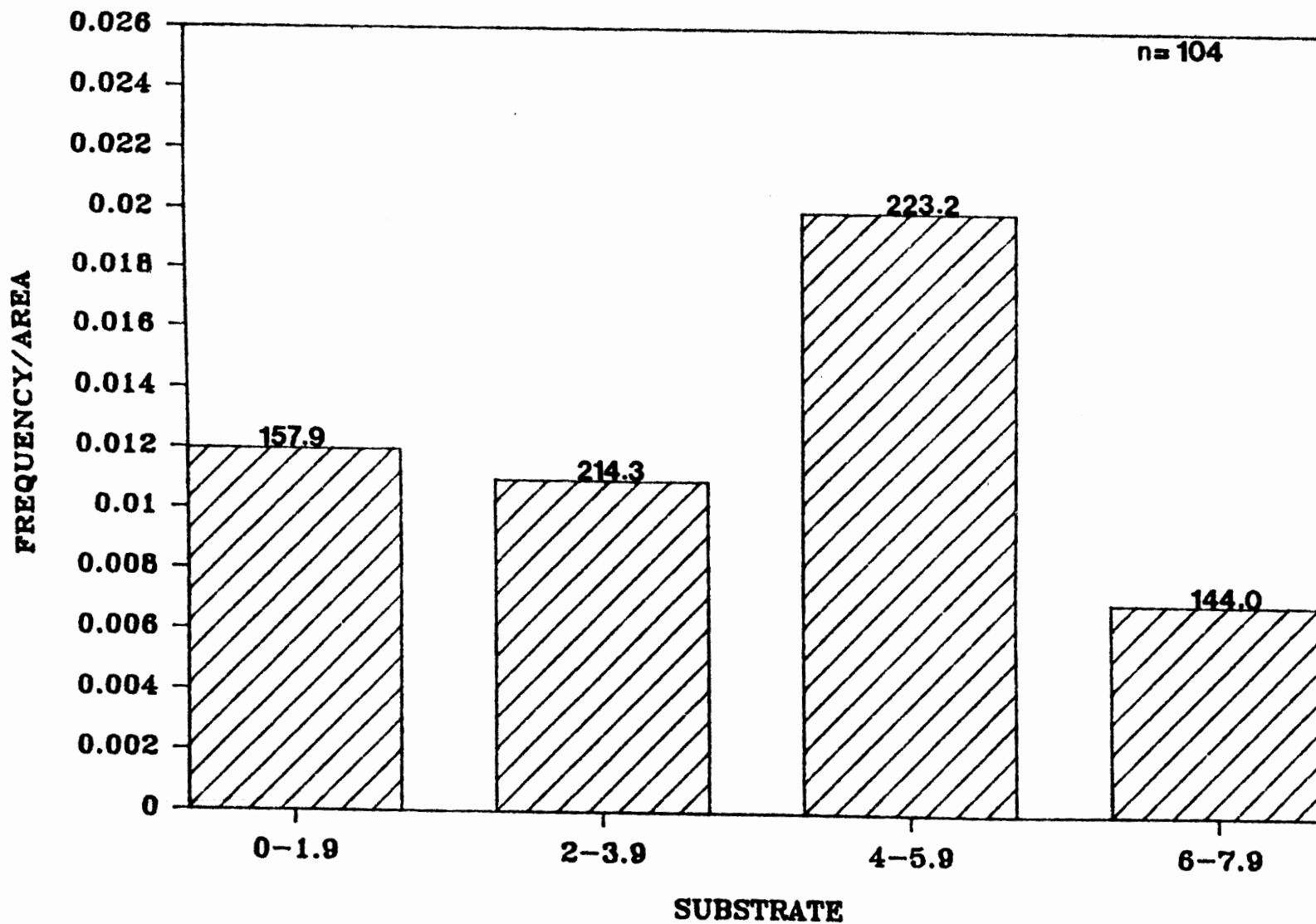


Figure 6. Spring 1984 relative density estimates in relation to substrate for white crappie. Mean total length is indicated above each substrate.

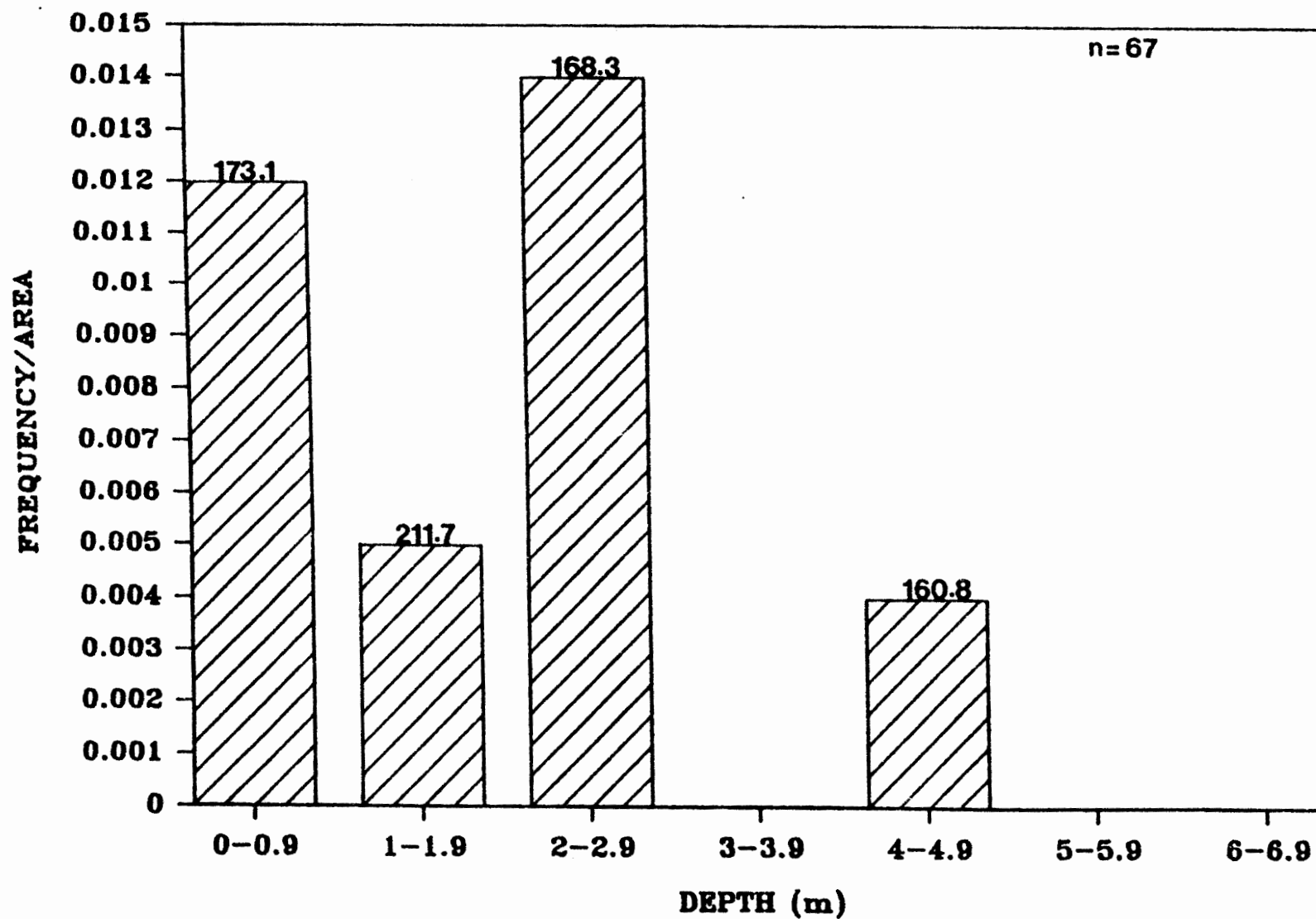


Figure 7. Spring 1984 relative density estimates in relation to depth for white crappie. Mean total length is indicated above each depth category.

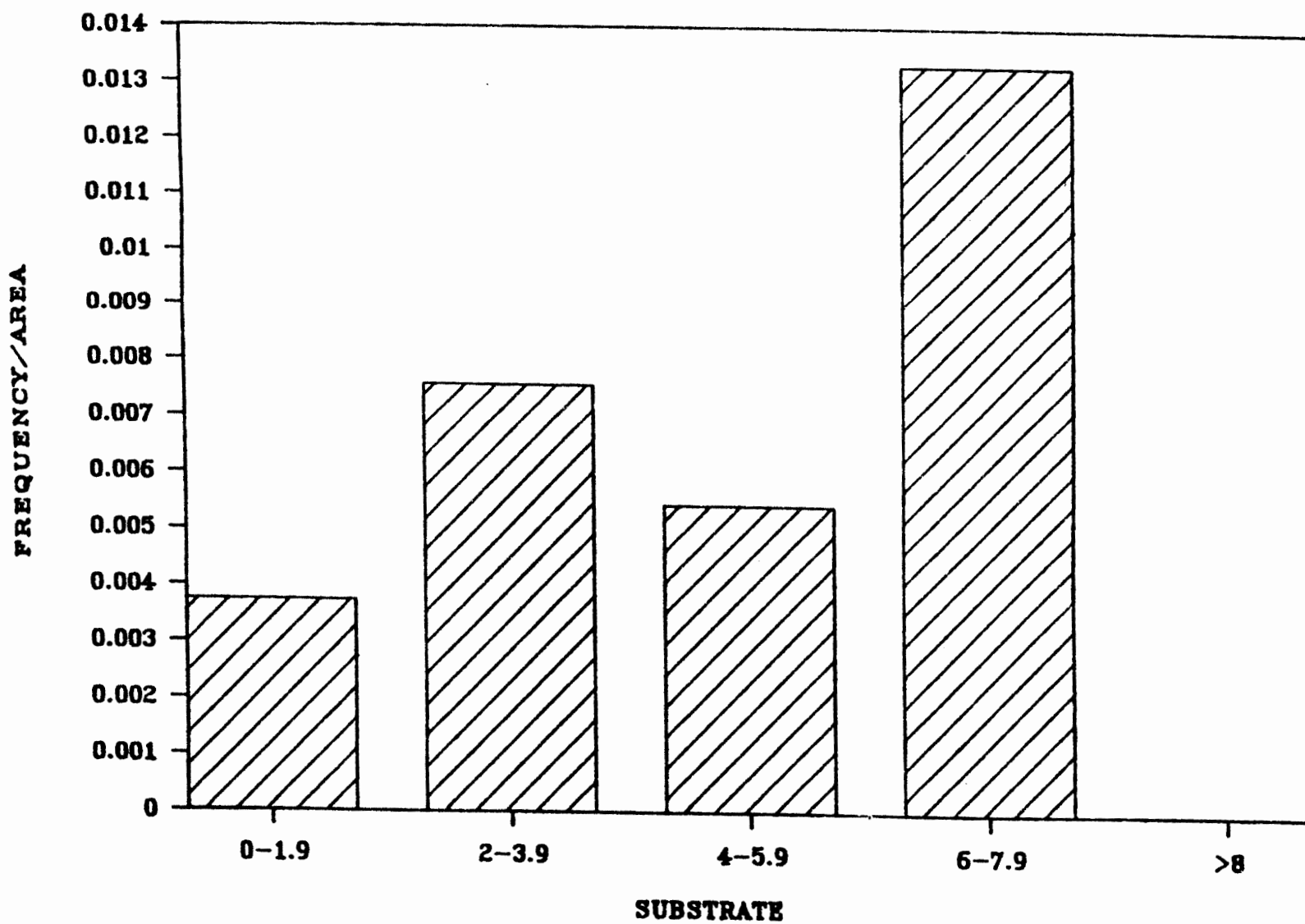


Figure 8. Summer 1984 relative density estimates in relation to substrate for white crappie. Mean total length is indicated above each substrate category.

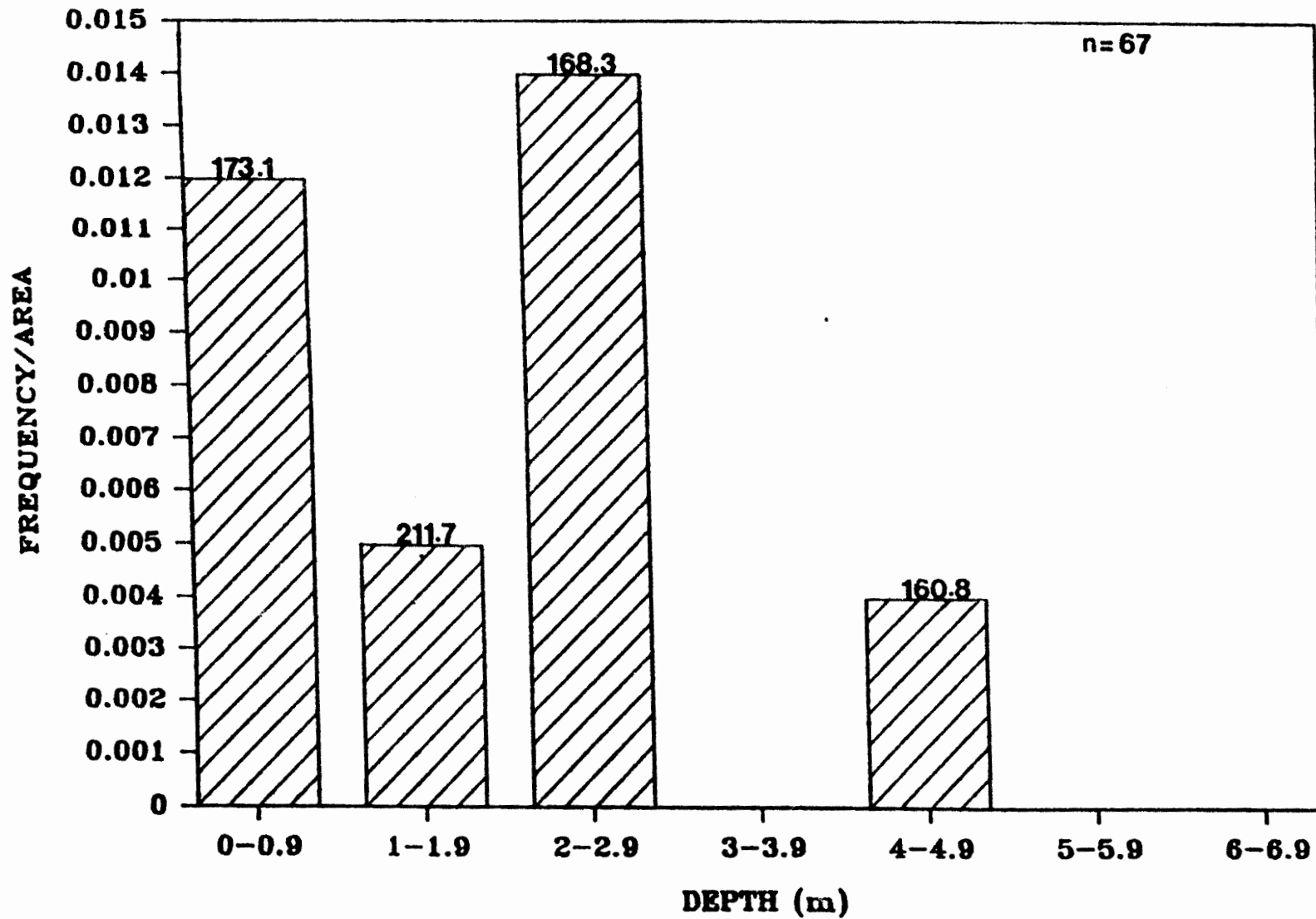


Figure 9. Summer 1984 relative density estimates in relation to depth for white crappie. Mean total length is indicated above each depth category.

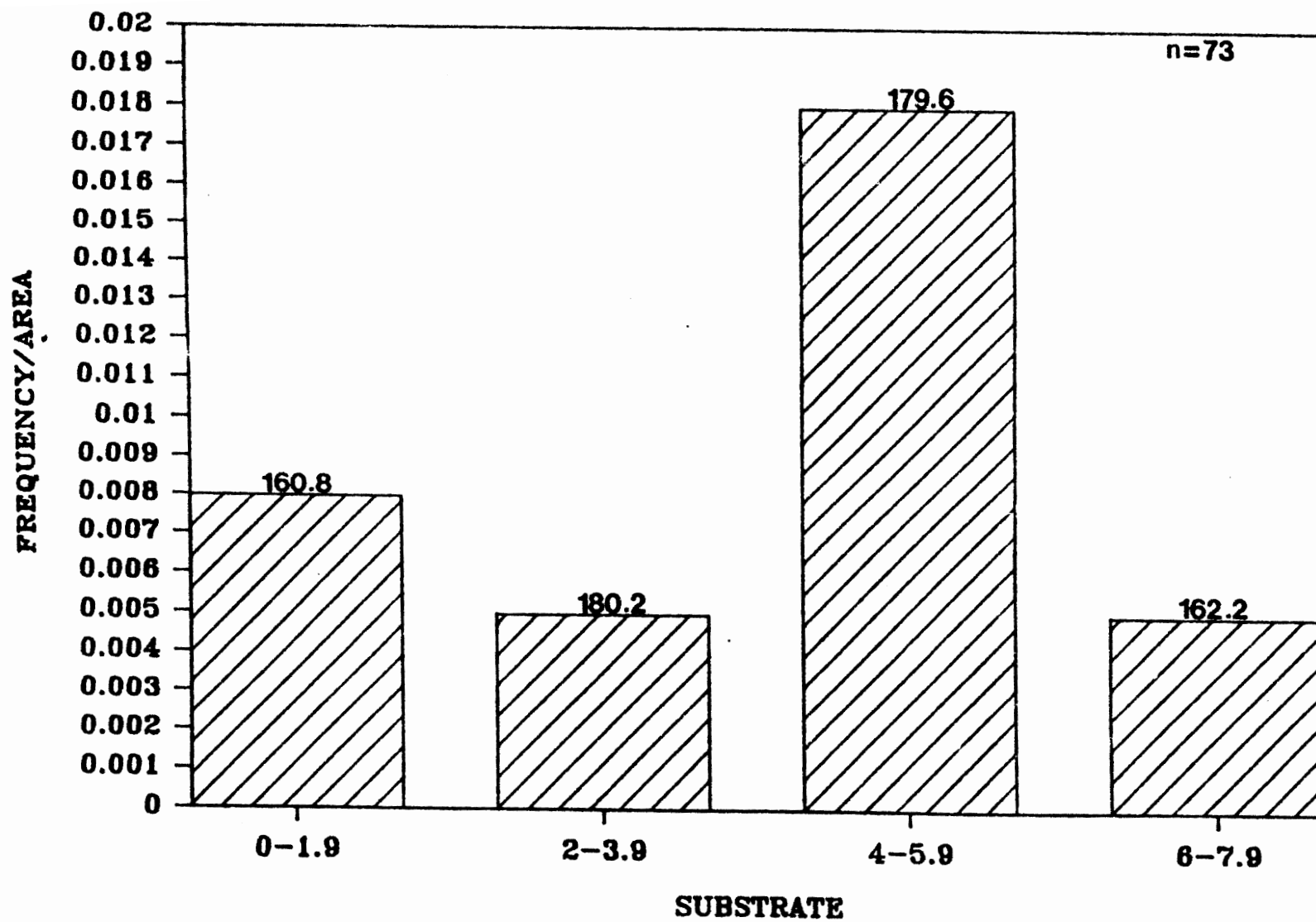


Figure 10. Fall 1984 relative density estimates in relation to substrate for white crappie. Mean total length is indicated above each substrate category.

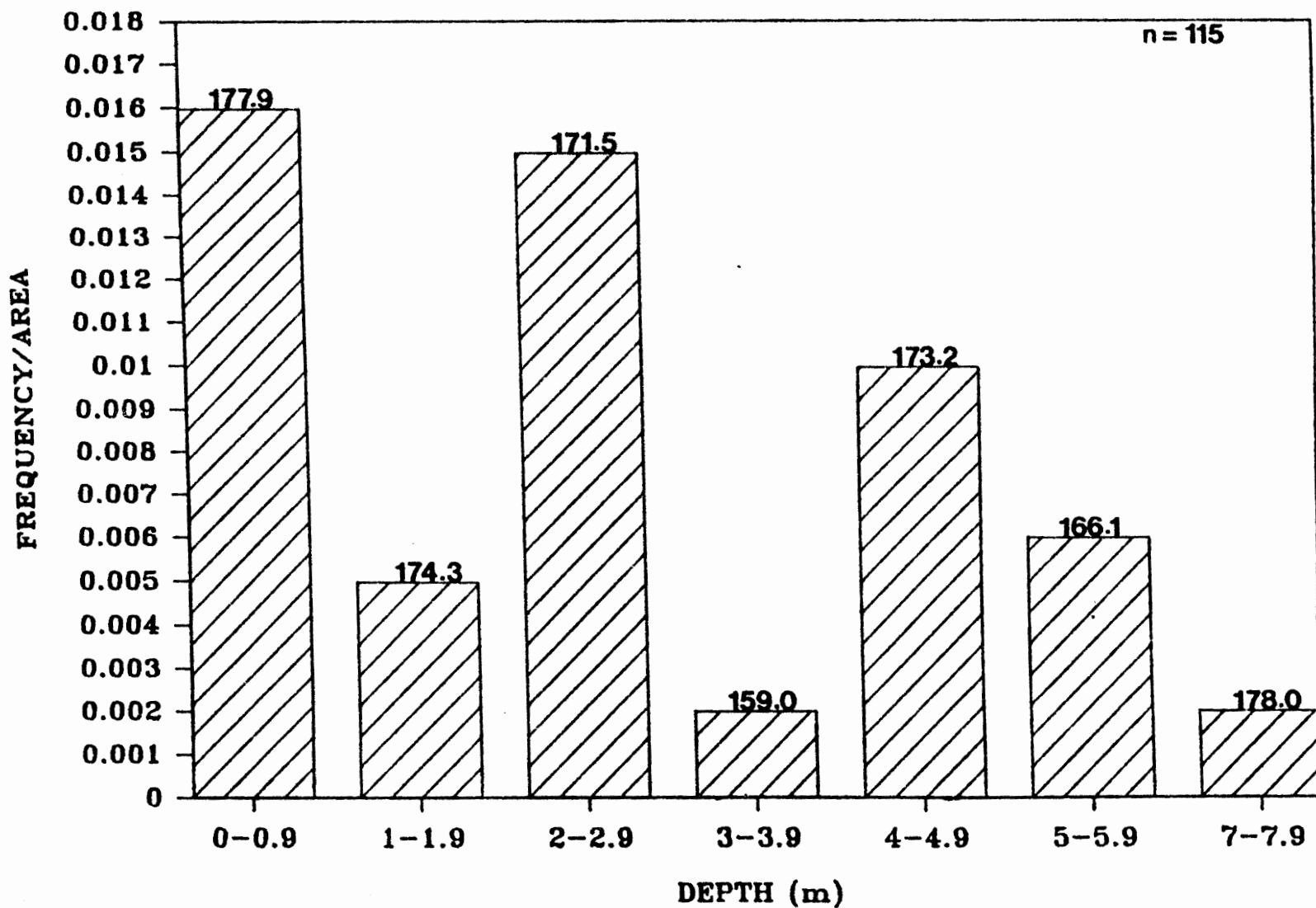


Figure 11. Fall 1984 relative density estimates in relation to depth for white crappie. Mean total length is indicated above each depth category.



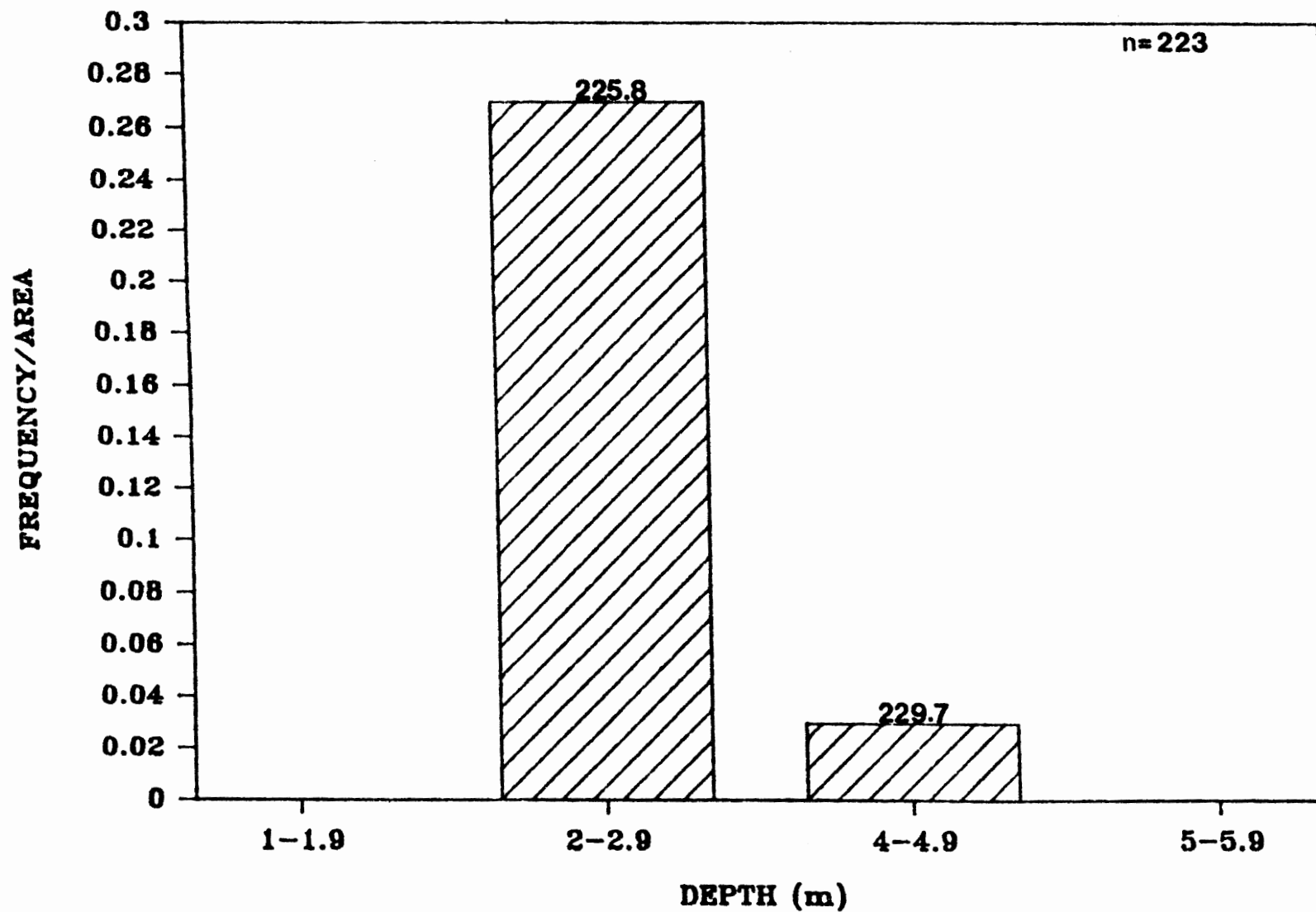


Figure 12. Winter 1984 relative density estimates in relation to depth for white bass. Mean total length is indicated above each depth category.

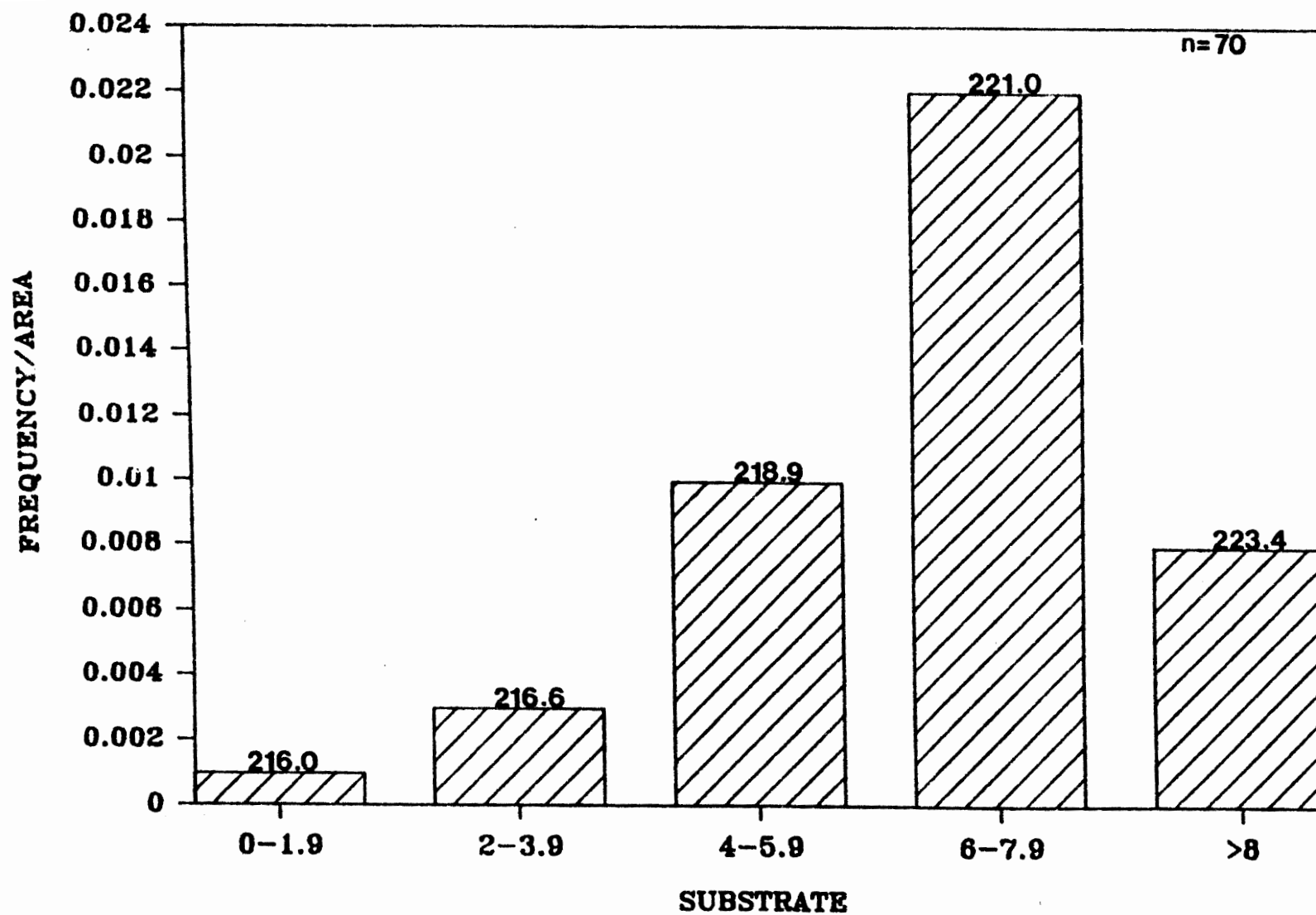


Figure 13. Spring 1984 relative density estimates in relation to substrate for white bass. Mean total length is indicated above each substrate category.

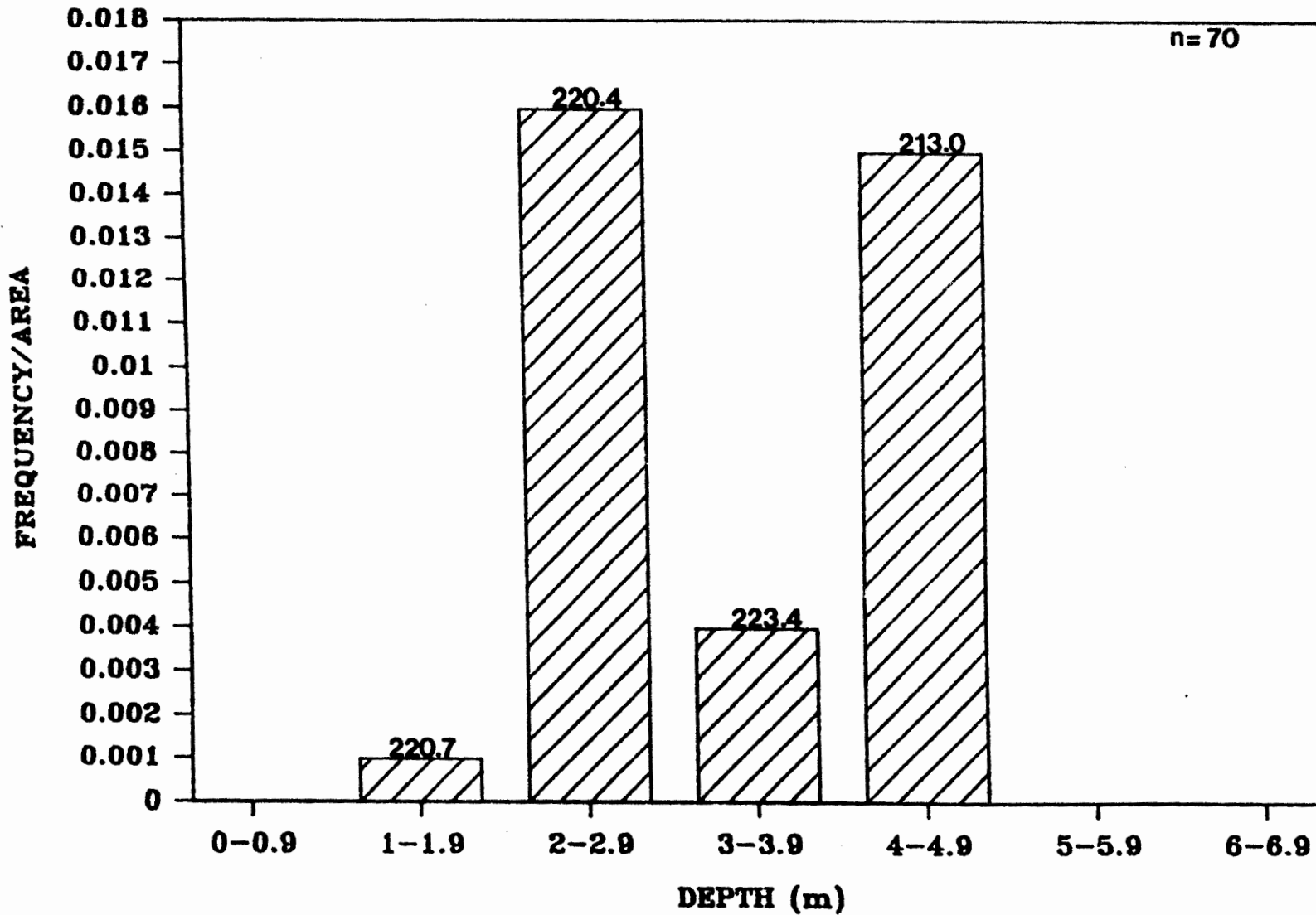


Figure 14. Spring 1984 relative density estimates in relation to depth for white bass. Mean total length is indicated above each depth category.

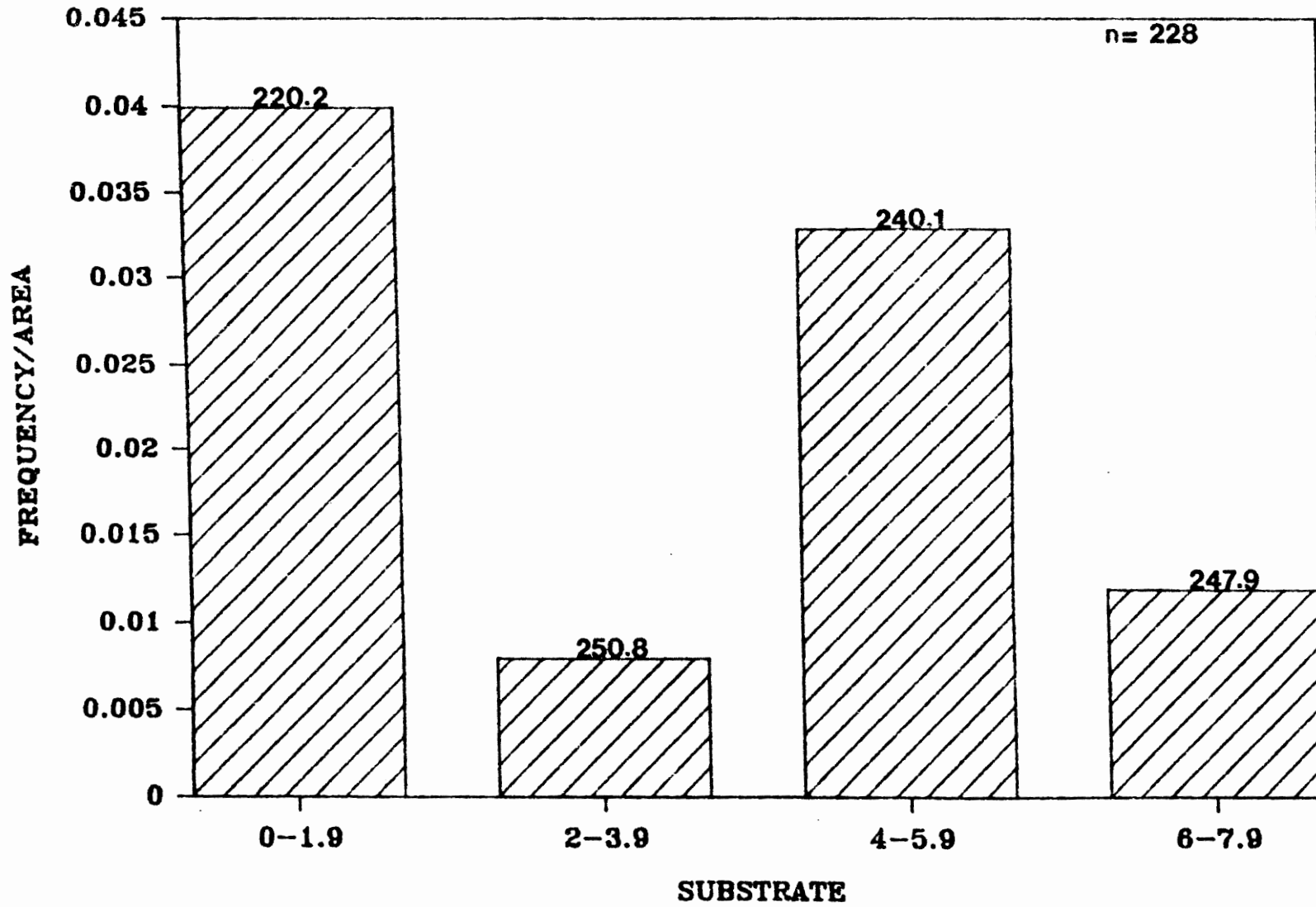


Figure 15. Summer 1984 relative density estimates in relation to substrate for white bass. Mean total length is indicated above each substrate category.

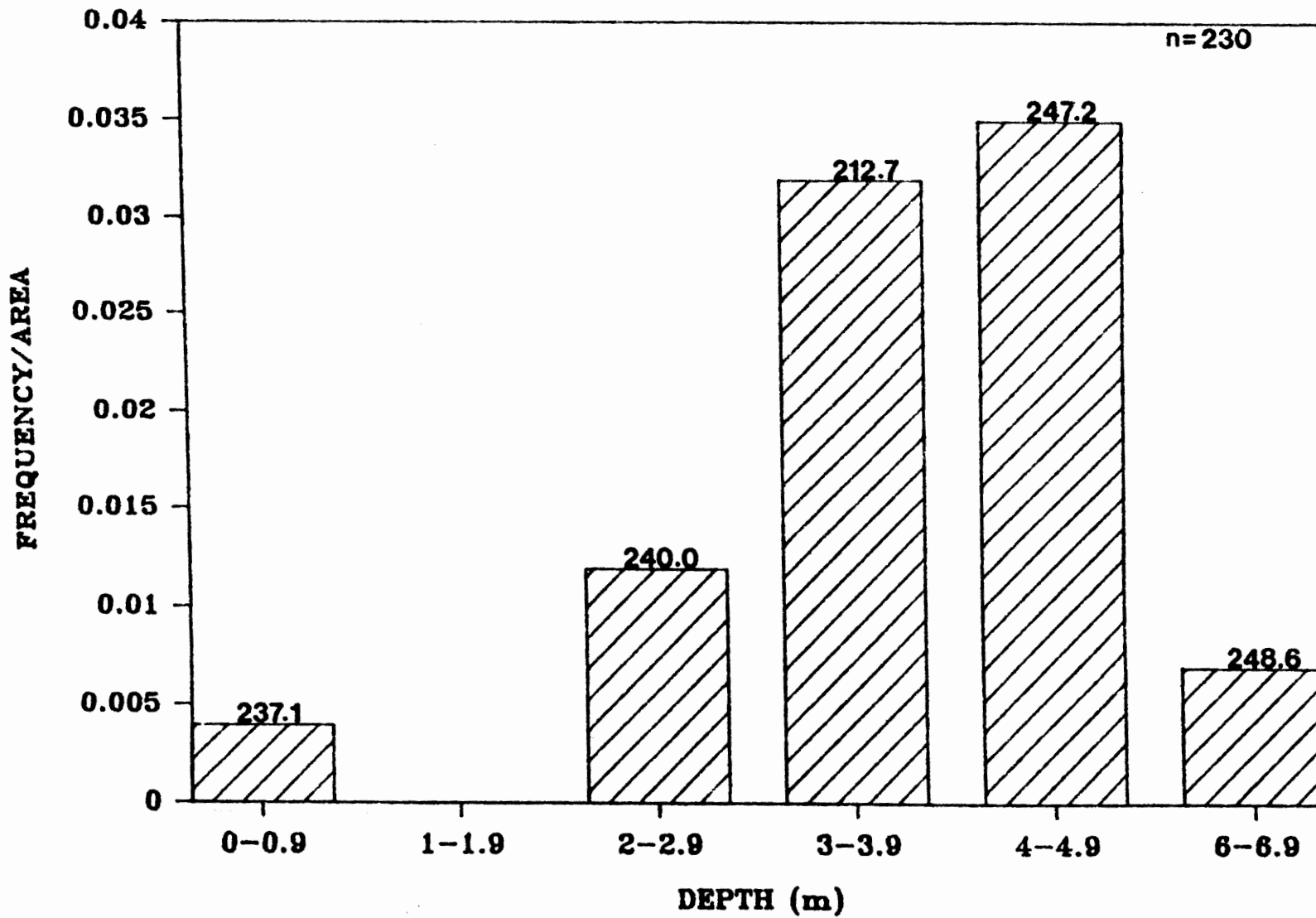


Figure 16. Summer 1984 relative density estimates in relation to depth for white bass. Mean total length is indicated above each depth category.

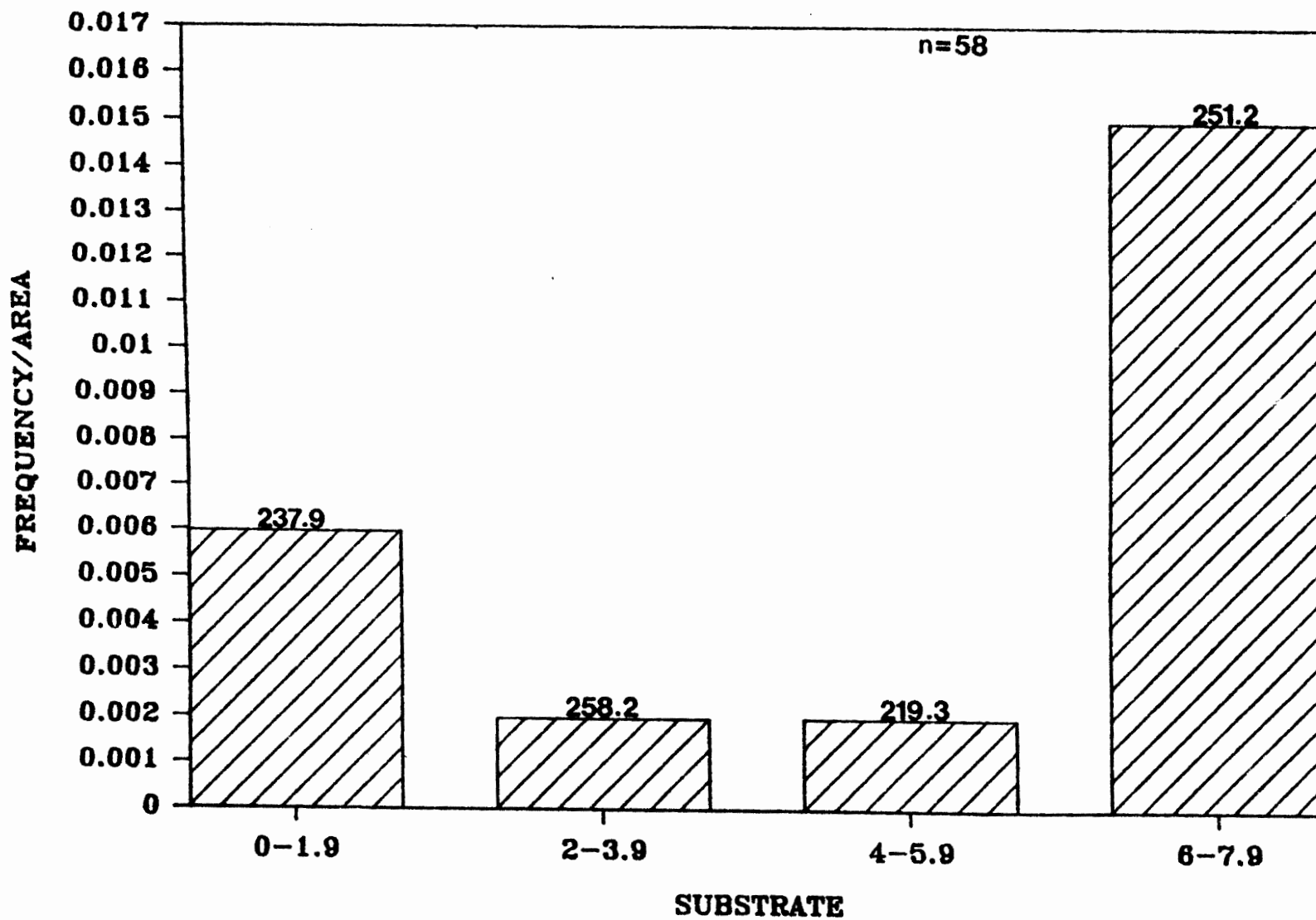


Figure 17. Fall 1984 relative density estimates in relation to substrate for white bass. Mean total length is indicated above each substrate category.

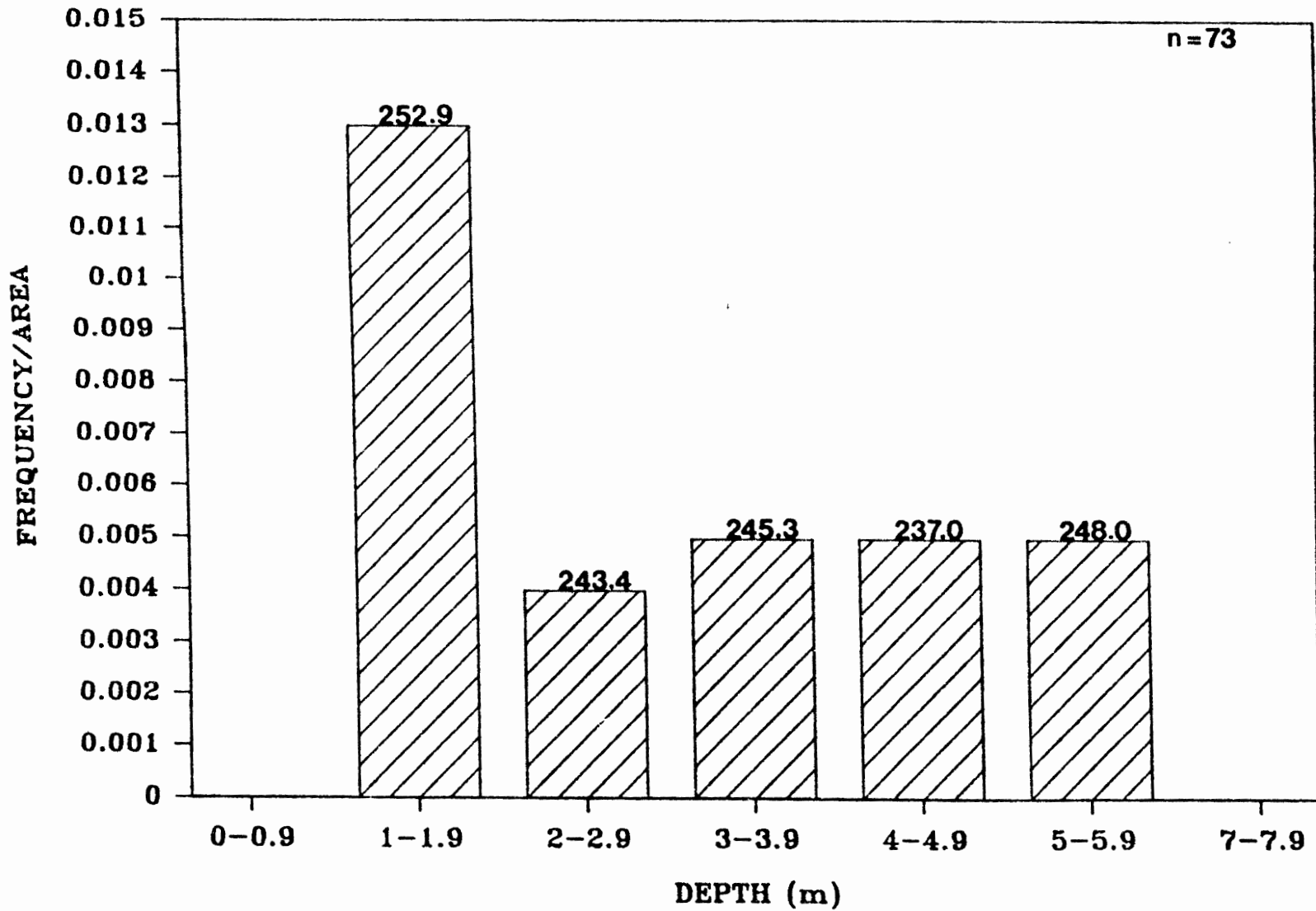


Figure 18. Fall 1984 relative density estimates in relation to depth for white bass. Mean total length is indicated above each depth category.

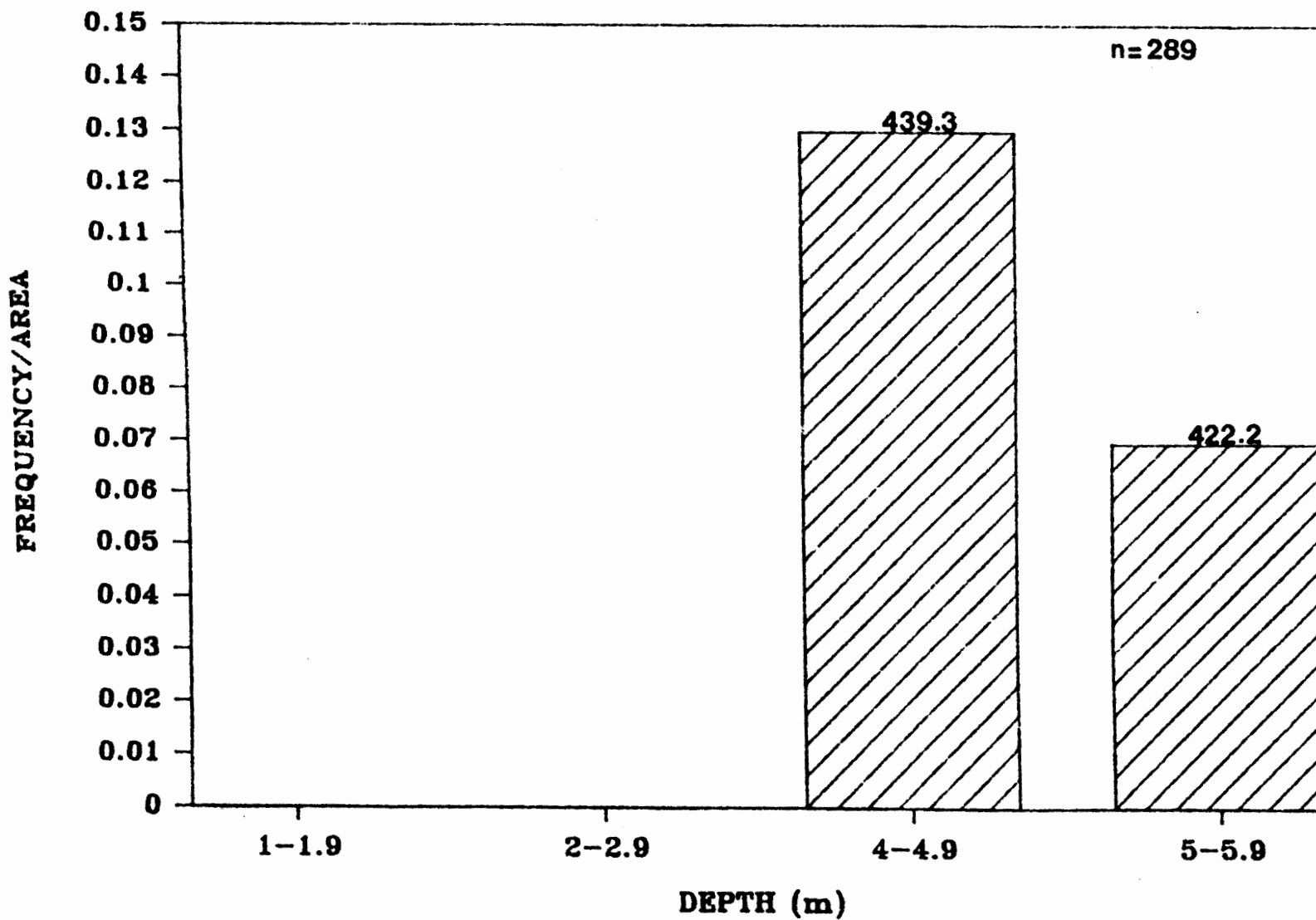


Figure 19. Winter 1984 relative density estimates in relation to depth for spotted gar. Mean total length is indicated above each depth category.



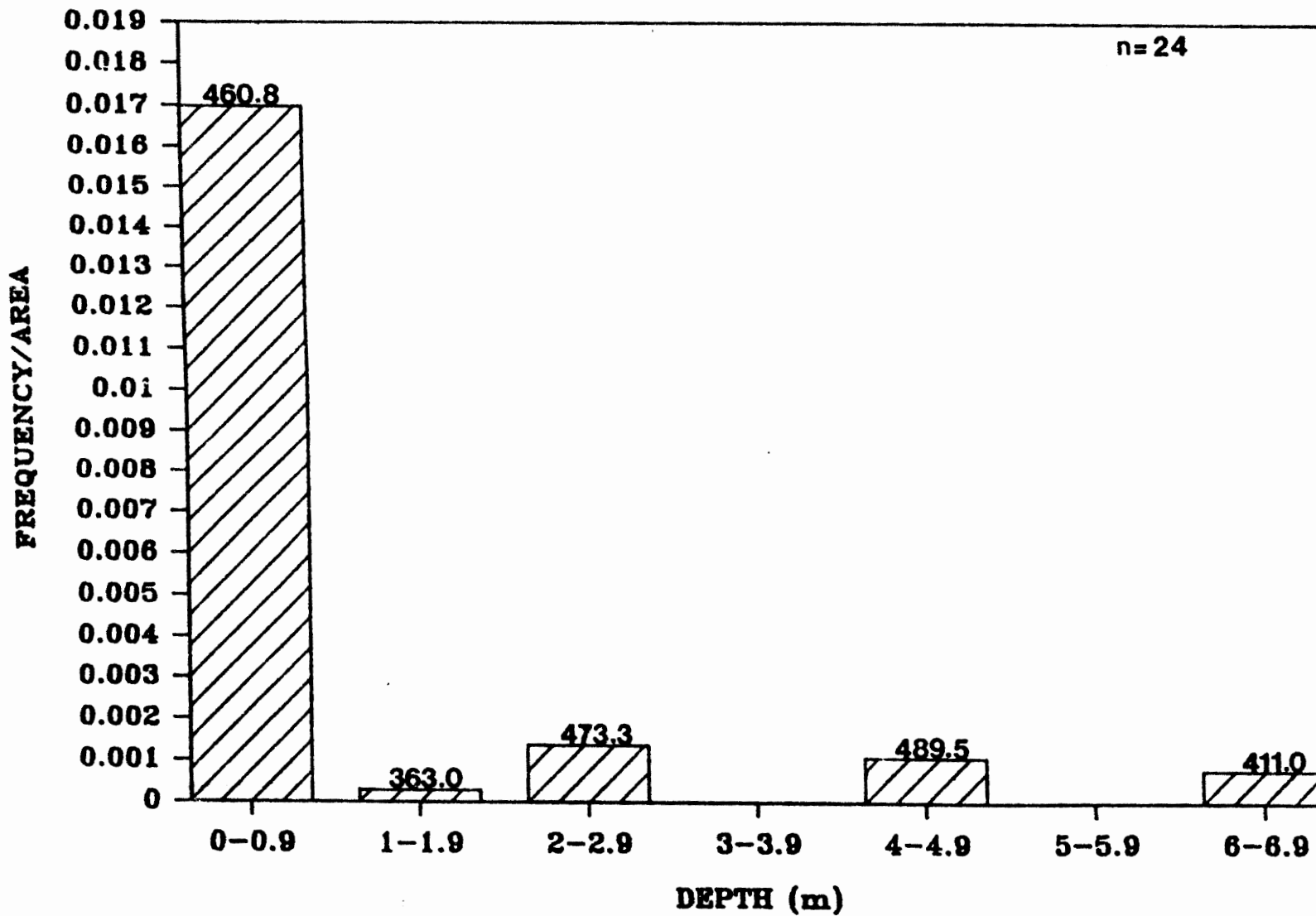


Figure 20. Spring 1984 relative density estimates in relation to substrate for spotted gar. Mean total length is indicated above each substrate category.

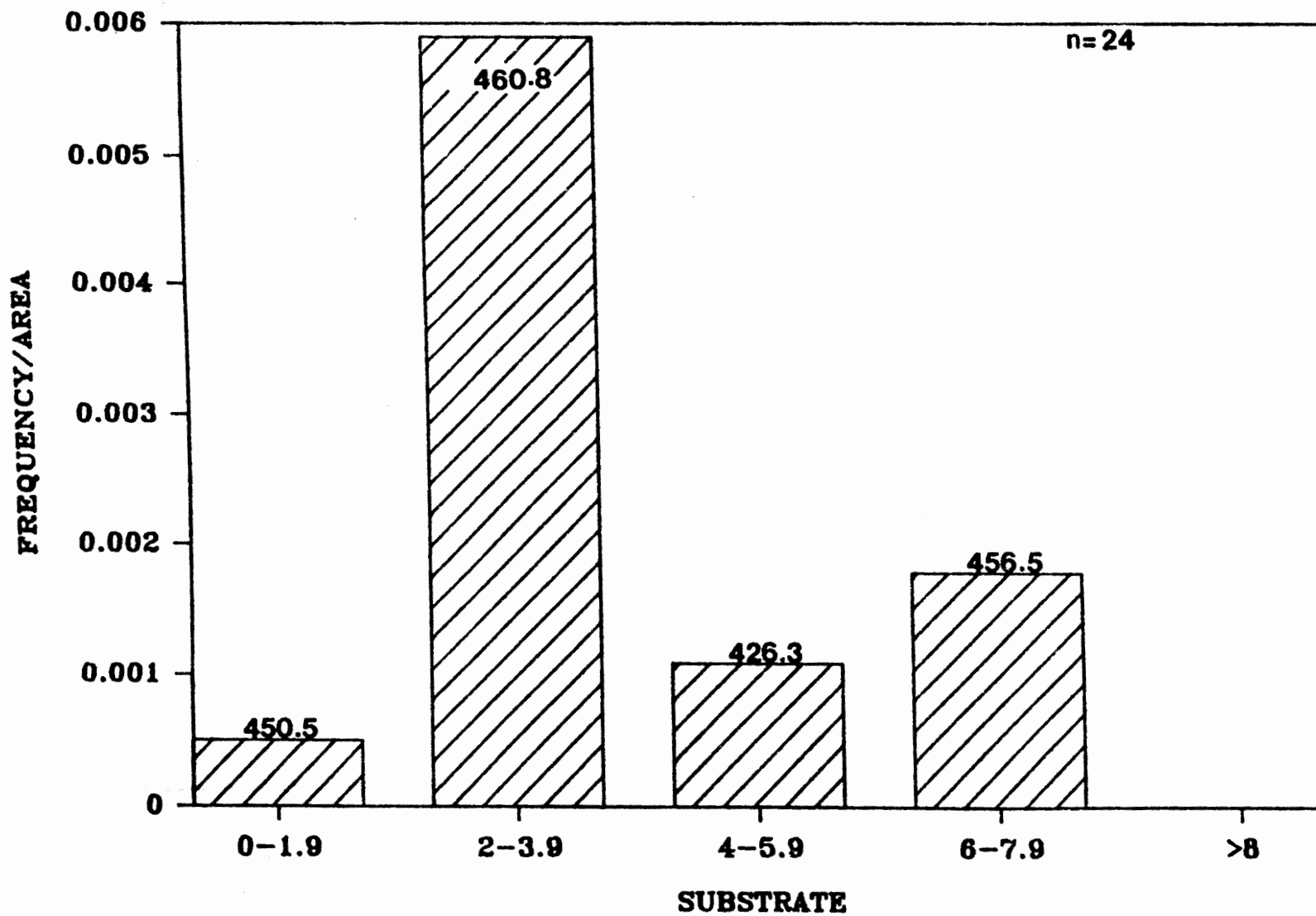


Figure 21. Spring 1984 relative density estimates in relation to depth for spotted gar. Mean total length is indicated above each depth category.

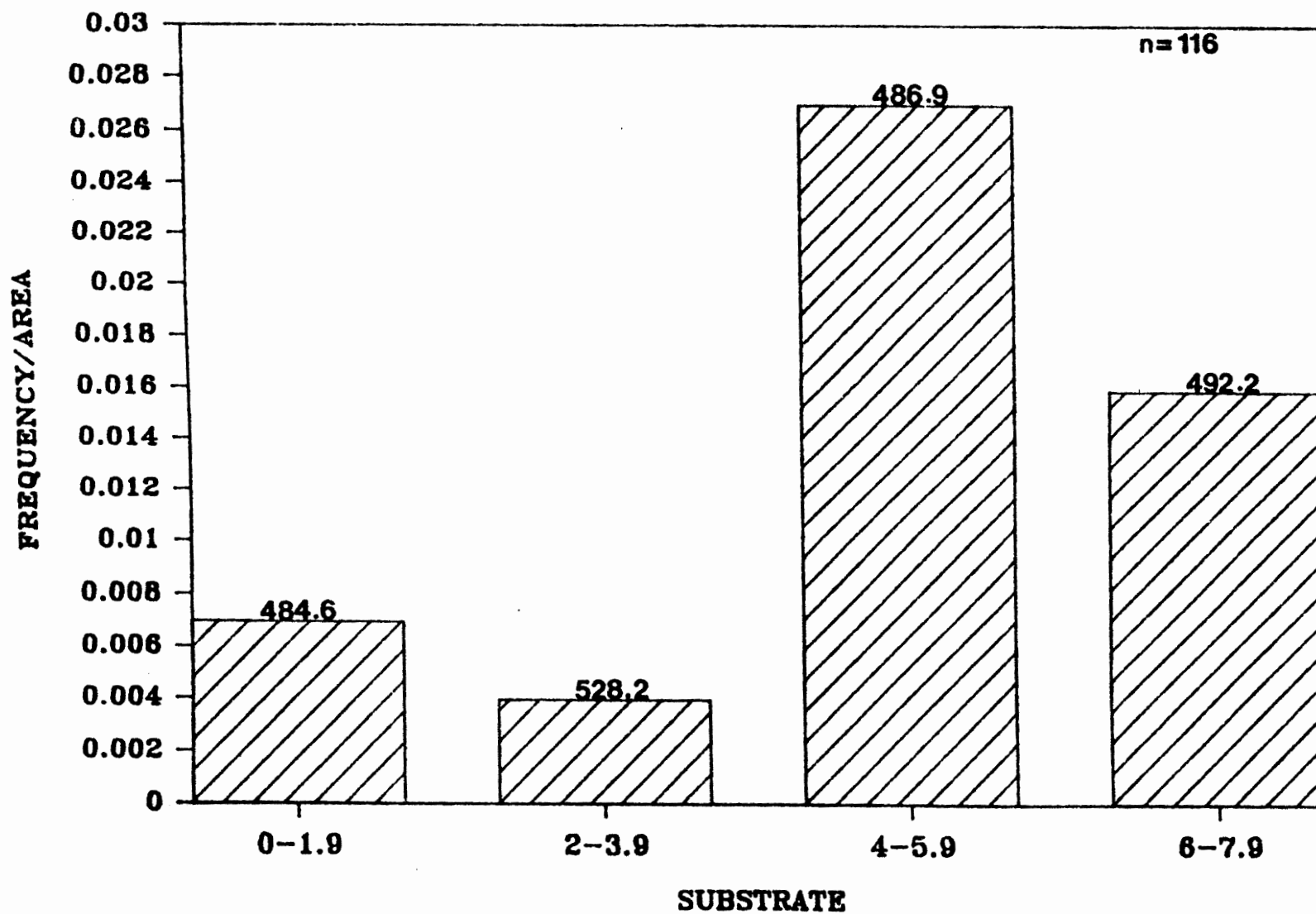


Figure 22. Summer 1984 relative density estimates in relation to substrate for spotted gar. Mean total length is indicated above each substrate category.

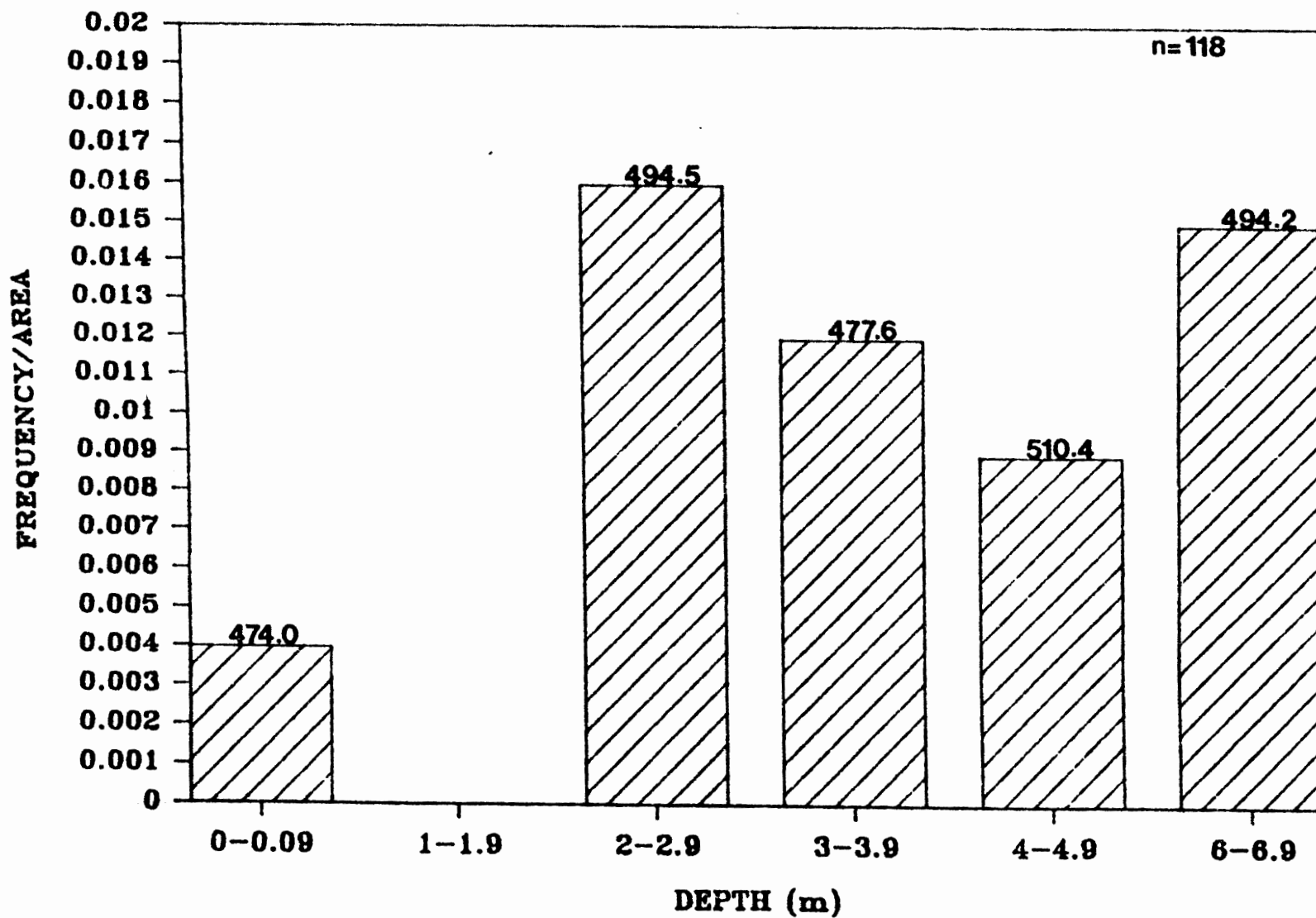


Figure 23. Summer 1984 relative density estimates in relation to depth for spotted gar. Mean total length is indicated above each depth category.

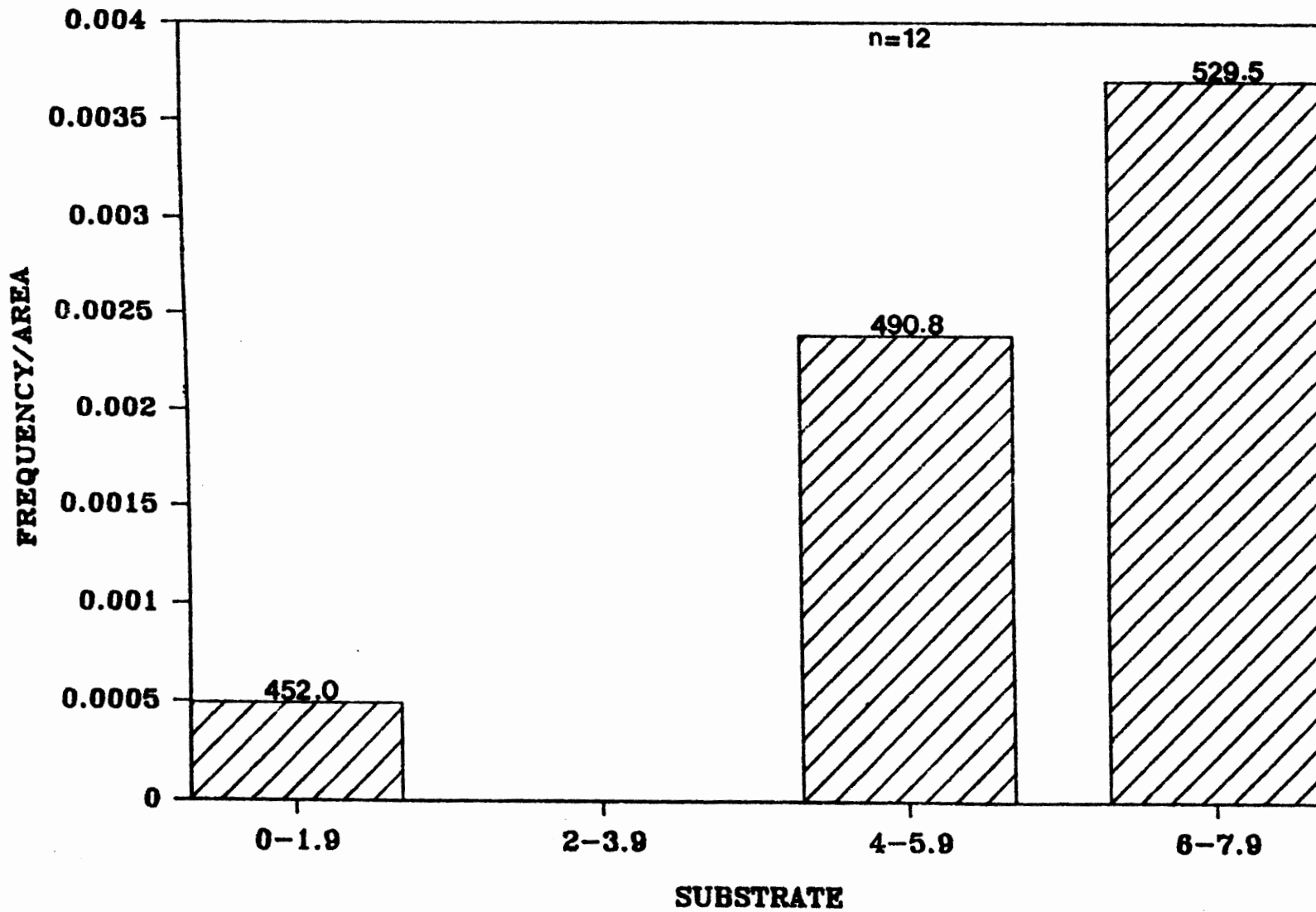


Figure 24. Fall 1984 relative density estimates in relation to substrate for spotted gar. Mean total length is indicated above each substrate category.

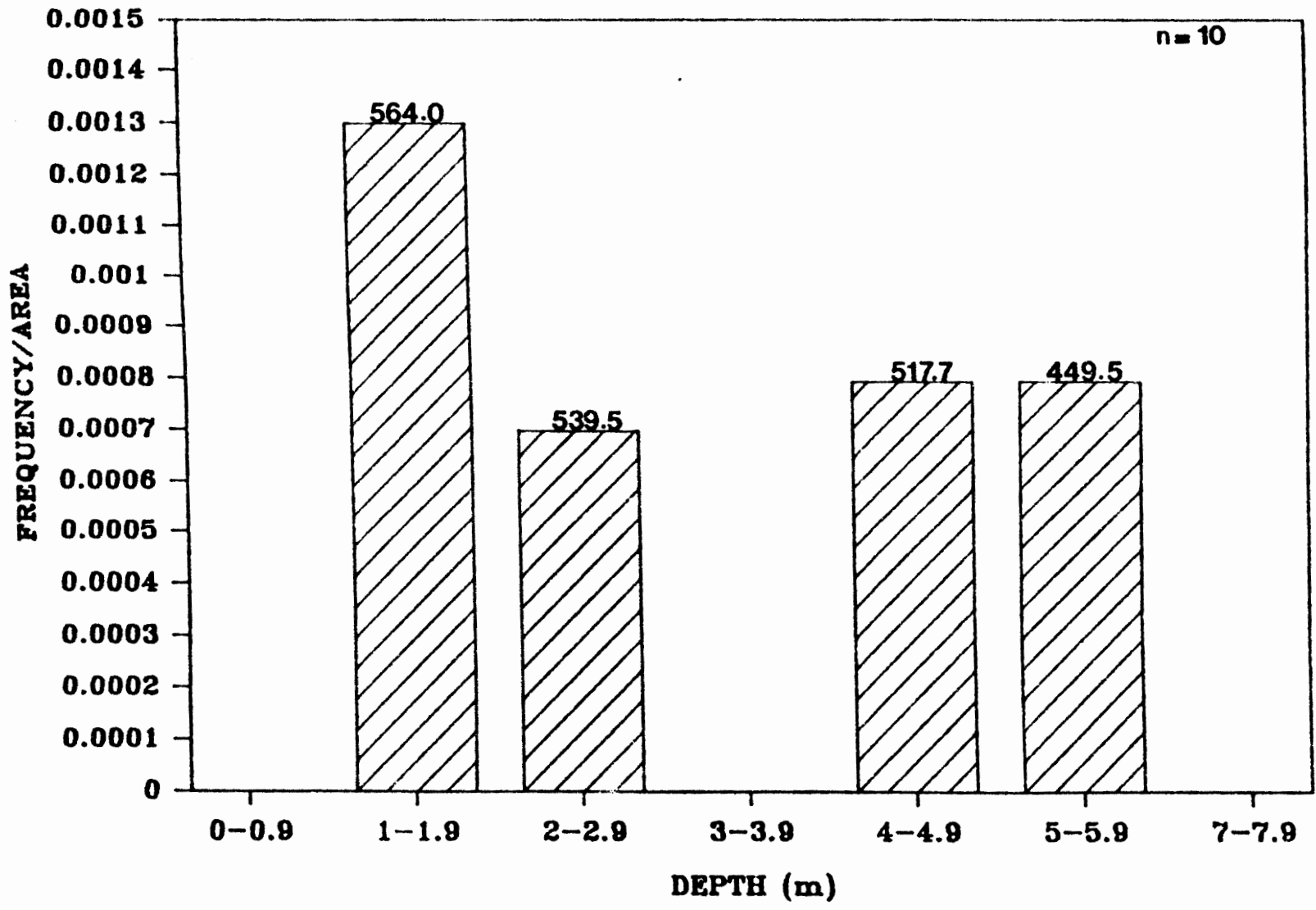


Figure 25. Fall 1984 relative density estimates in relation to depth for spotted gar. Mean total length is indicated above each depth category.

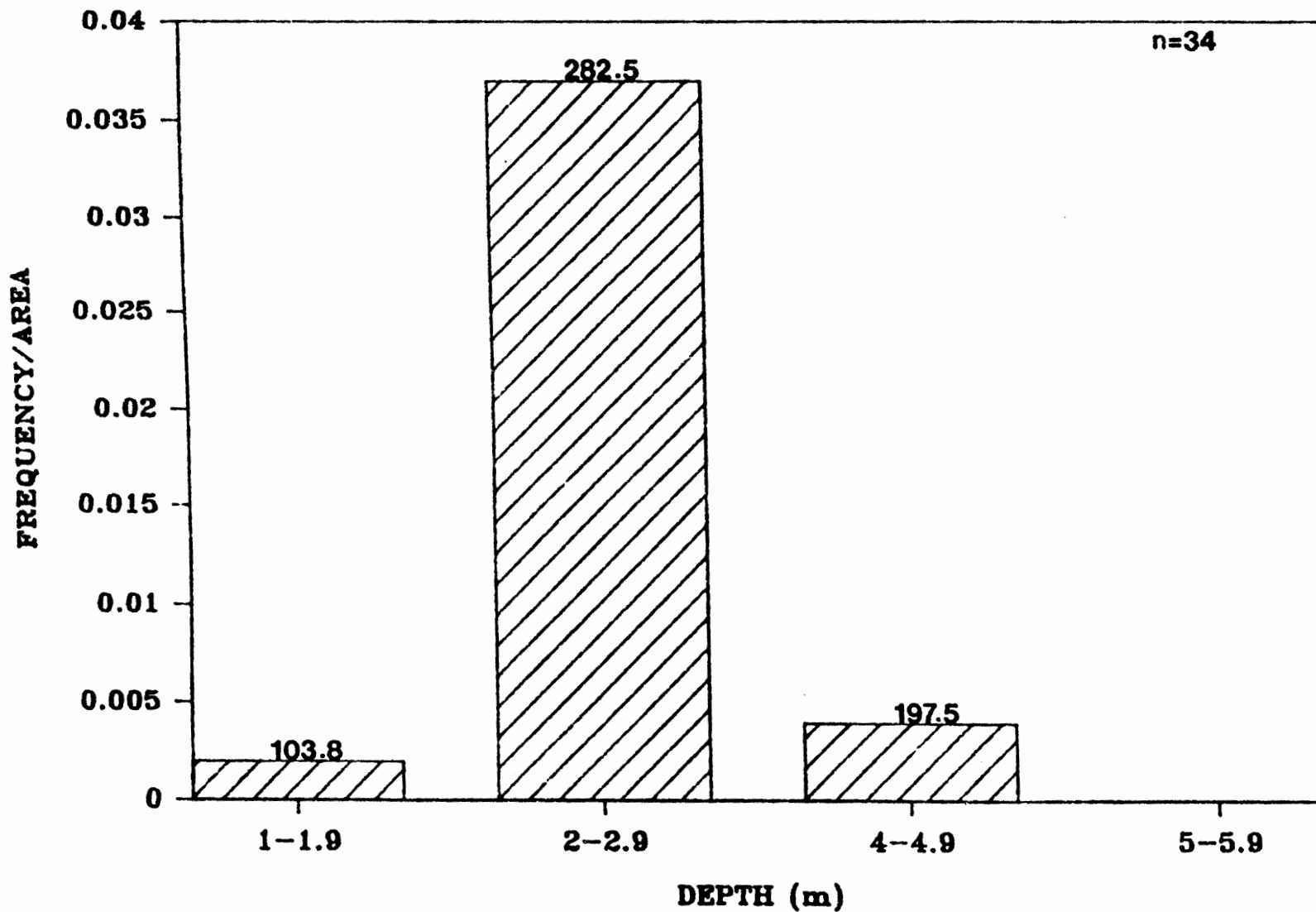


Figure 26. Winter 1984 relative density estimates in relation to depth for gizzard shad. Mean total length is indicated above each depth category.

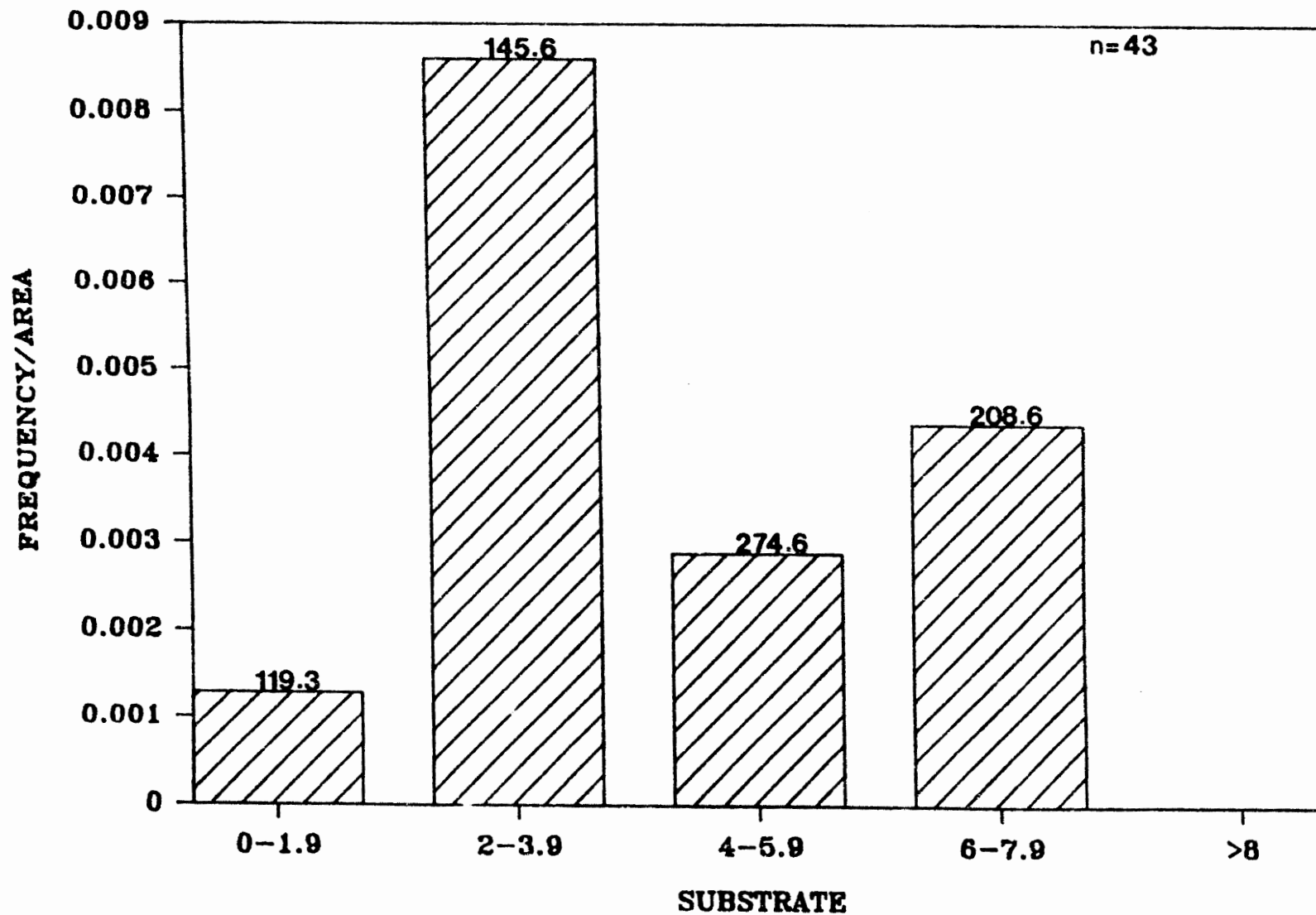


Figure 27. Spring 1984 relative density estimates in relation to substrate for gizzard shad. Mean total length is indicated above each substrate category.



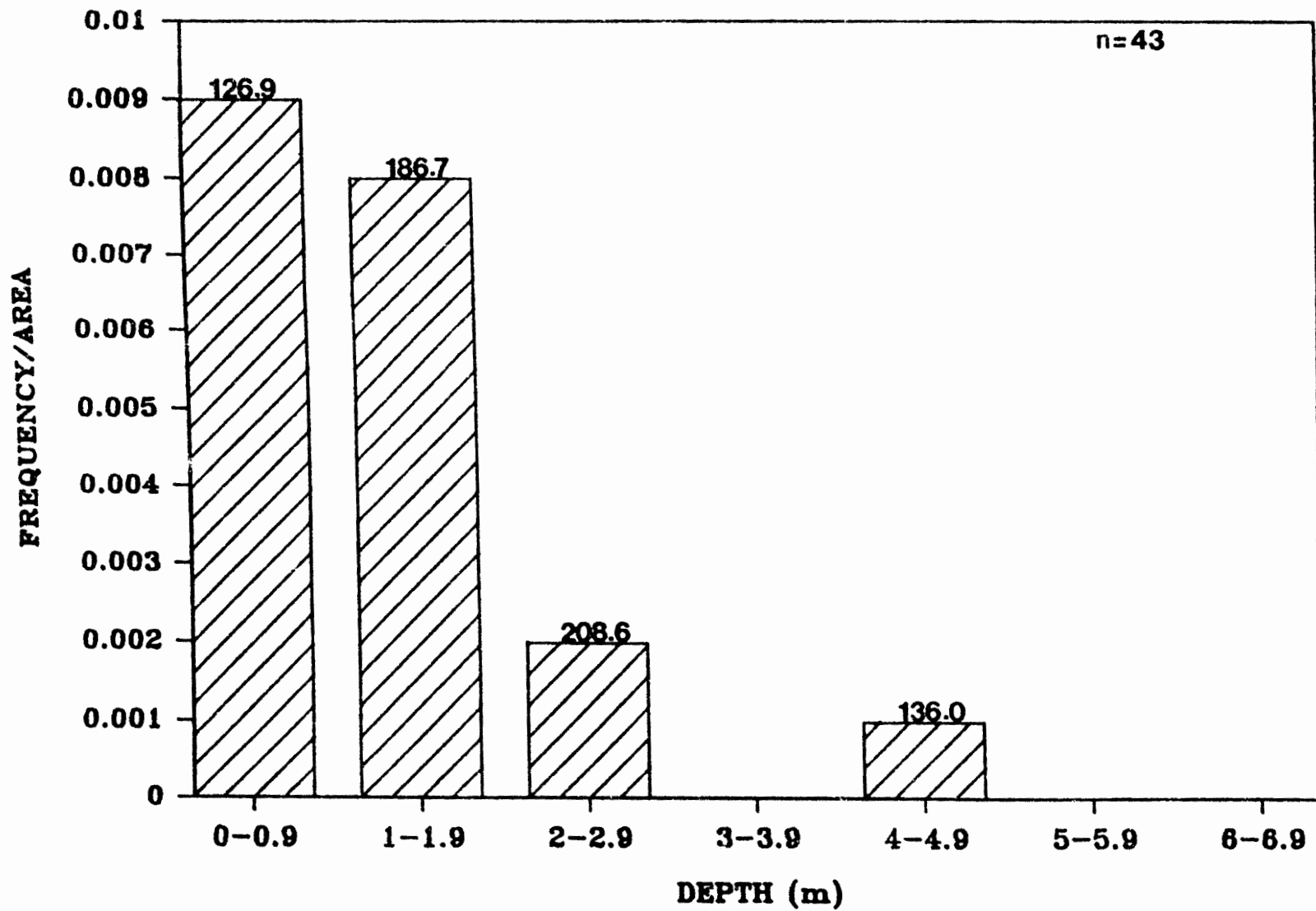


Figure 28. Spring 1984 relative density estimates in relation to depth for gizzard shad. Mean total length is indicated above each depth category.

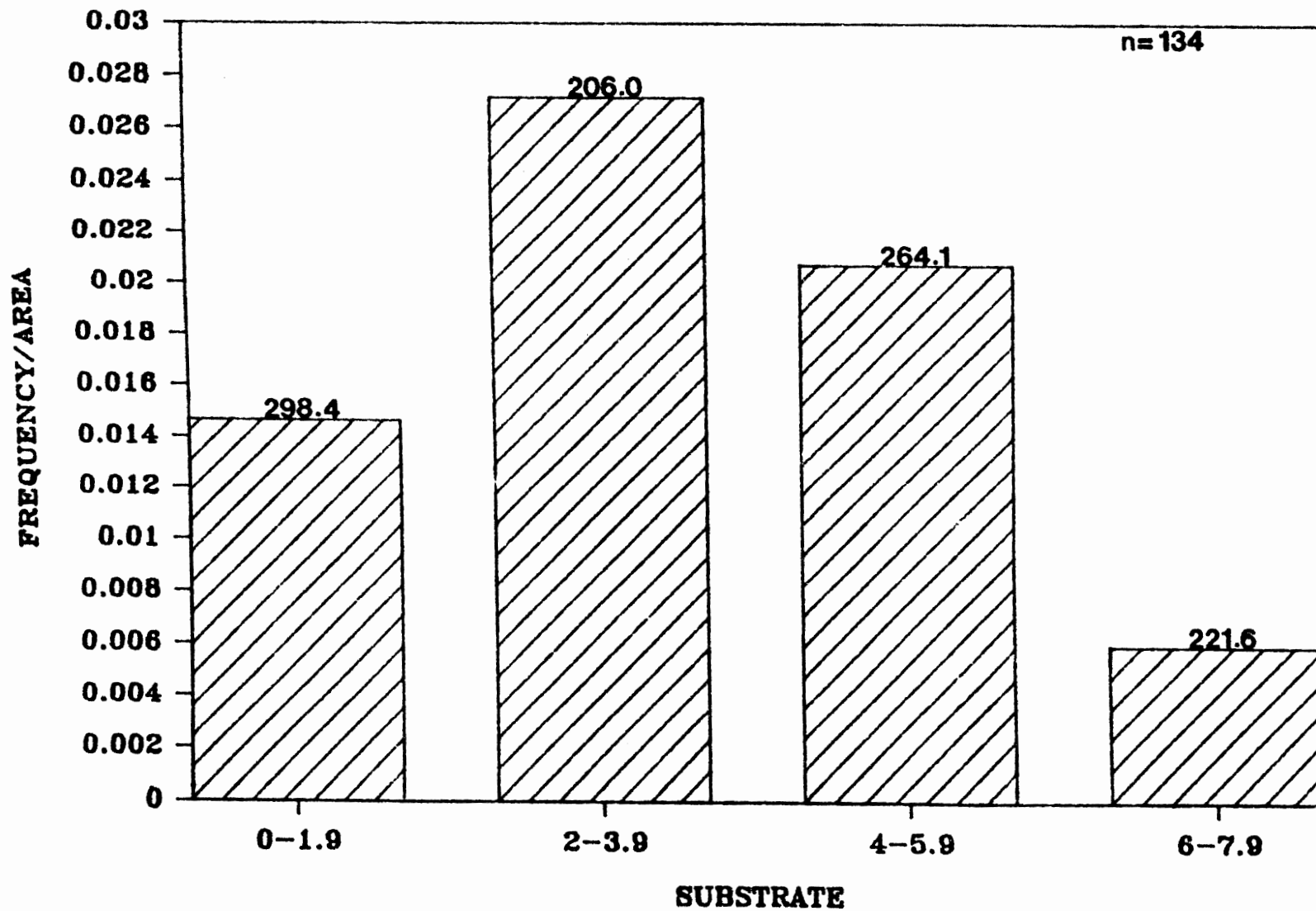


Figure 29. Summer 1984 relative density estimates in relation to substrate for gizzard shad. Mean total length is indicated above each substrate category.

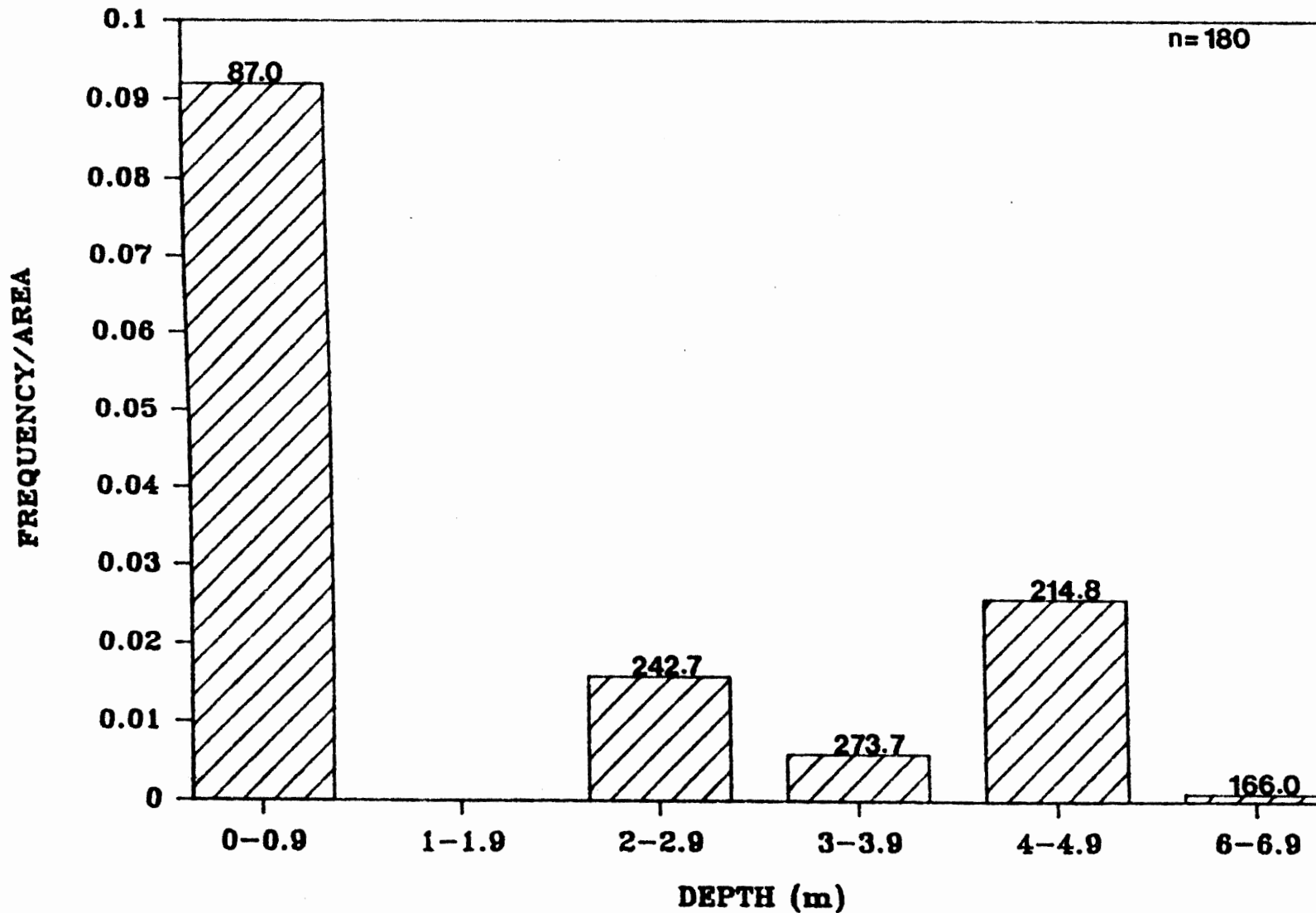


Figure 30. Summer 1984 relative density estimates in relation to depth for gizzard shad. Mean total length is indicated above each depth category.

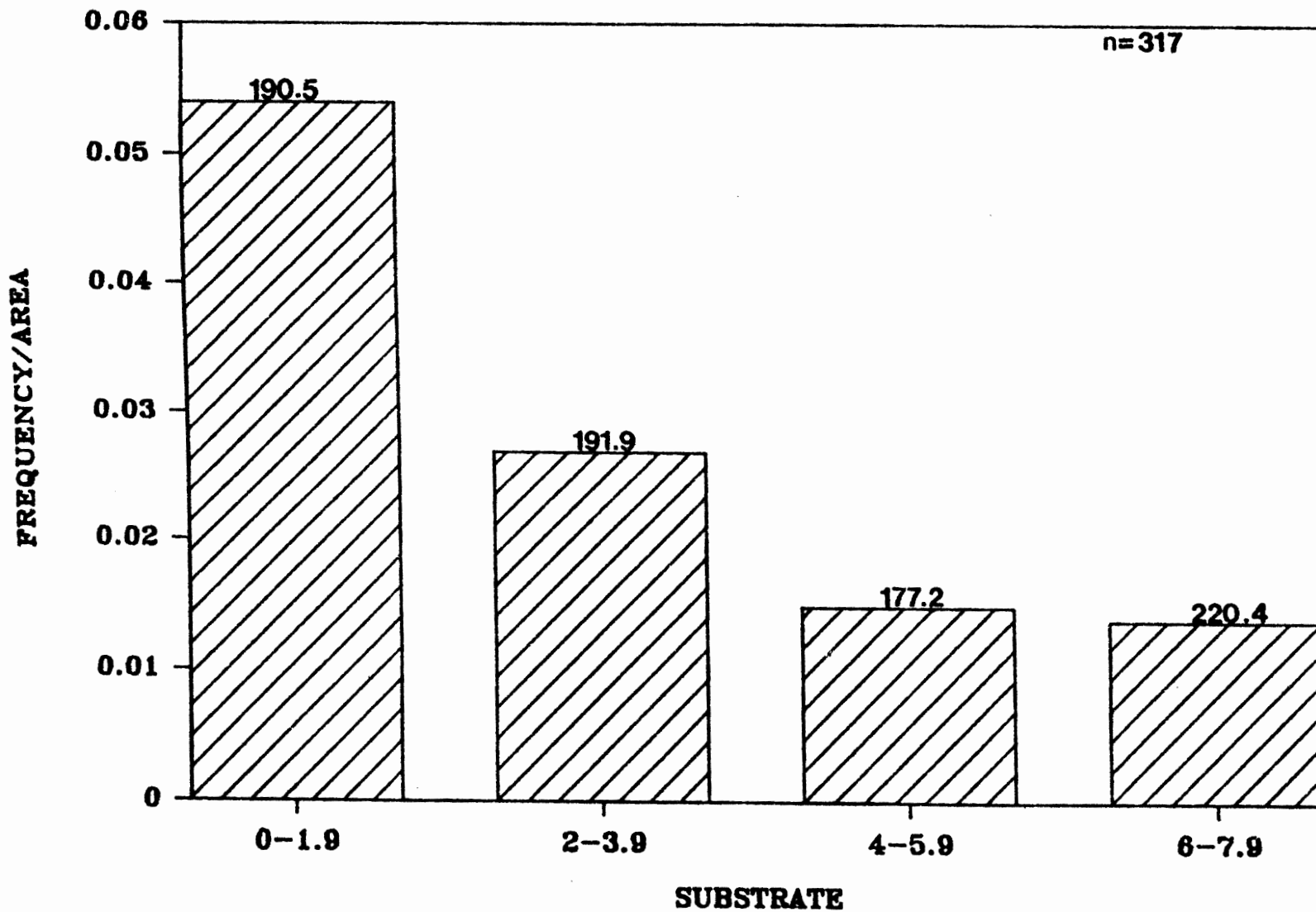


Figure 31. Fall 1984 relative density estimates in relation to substrate for gizzard shad. Mean total length is indicated above each substrate category.

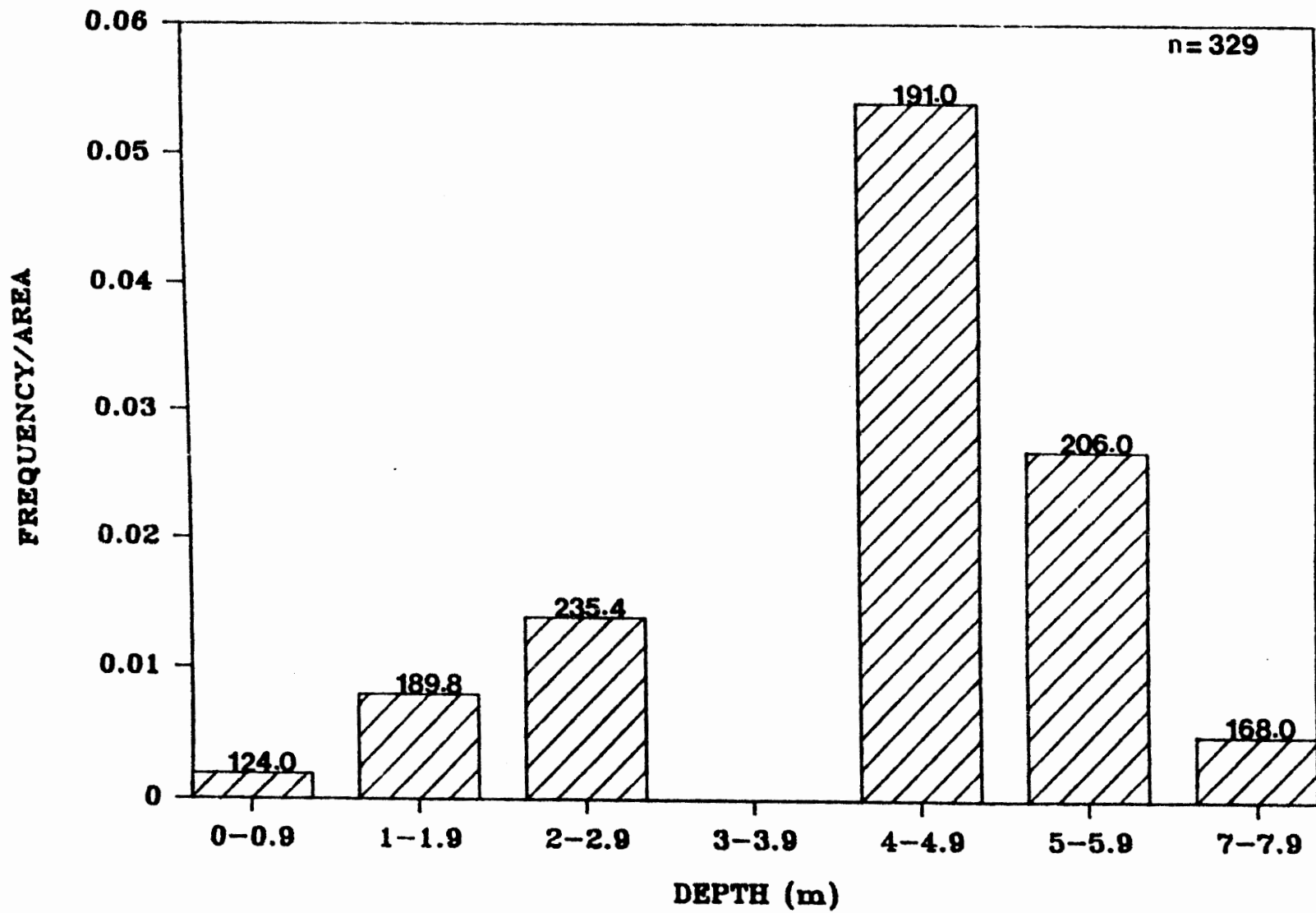


Figure 32. Fall 1984 relative density estimates in relation to depth for gizzard shad. Mean total length is indicated above each depth category.

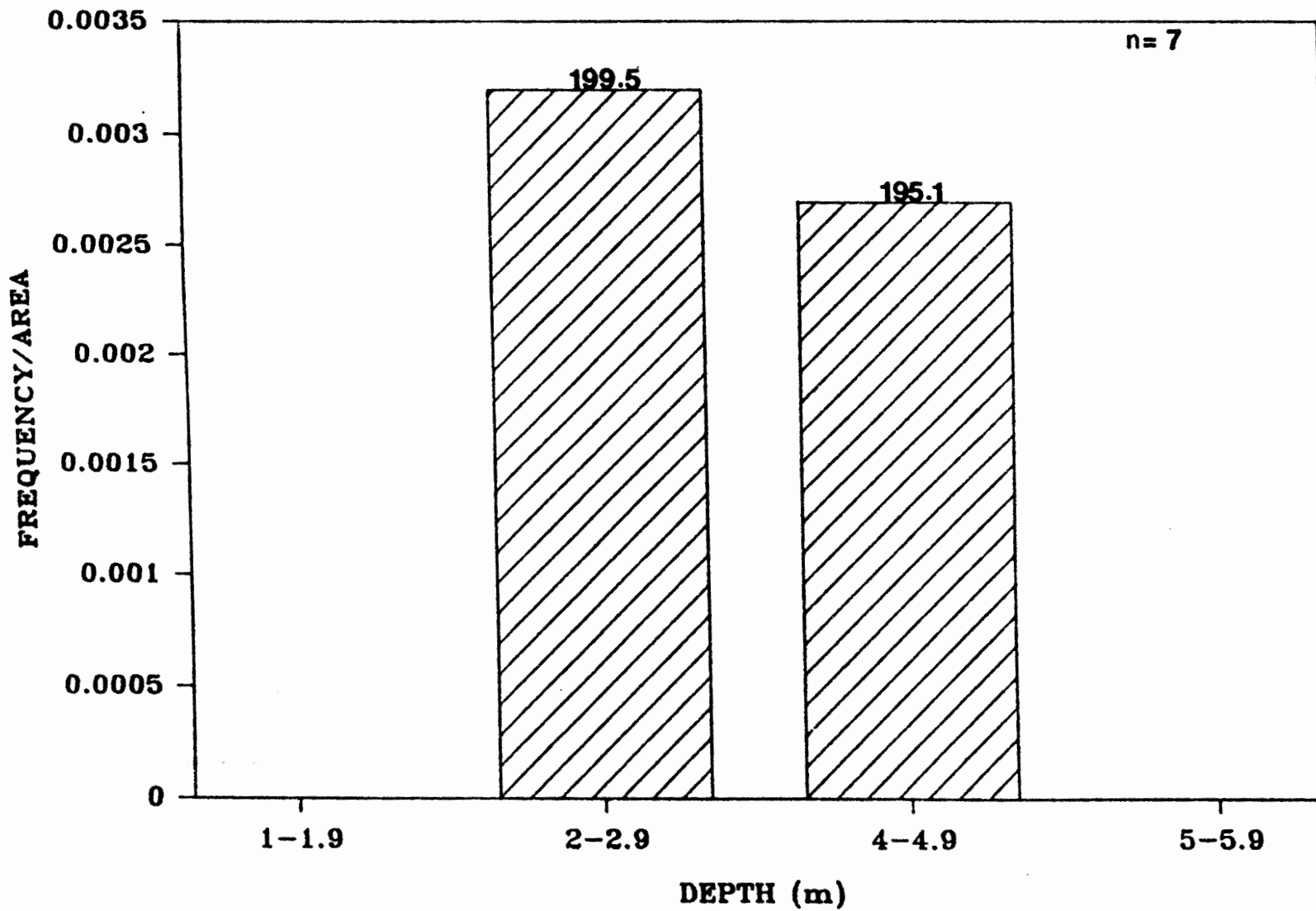


Figure 33. Winter 1984 relative density estimates in relation to depth for carp. Mean total length is indicated above each depth category.

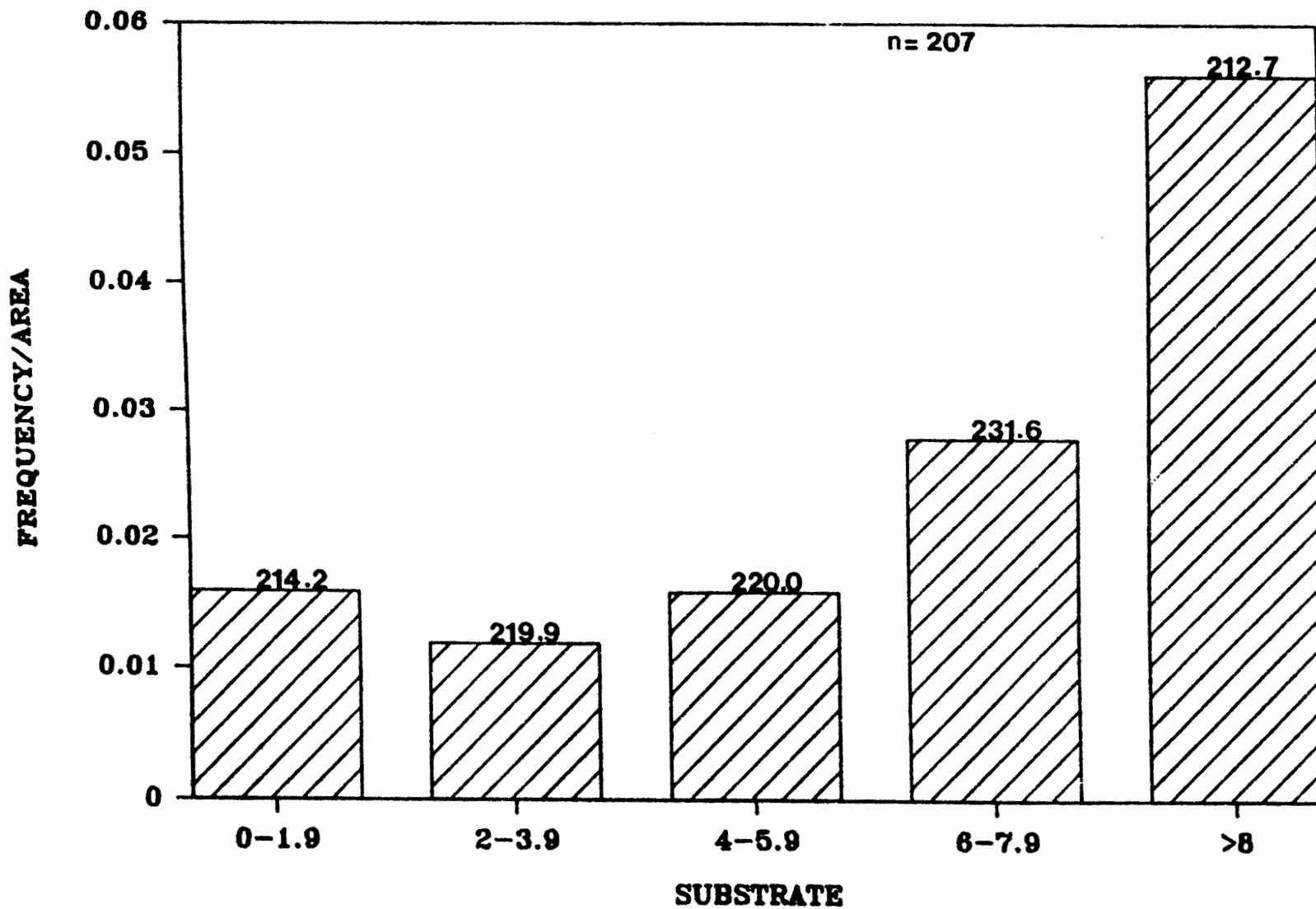


Figure 34. Spring 1984 relative density estimates in relation to substrate for carp. Mean total length is indicated above each substrate category.

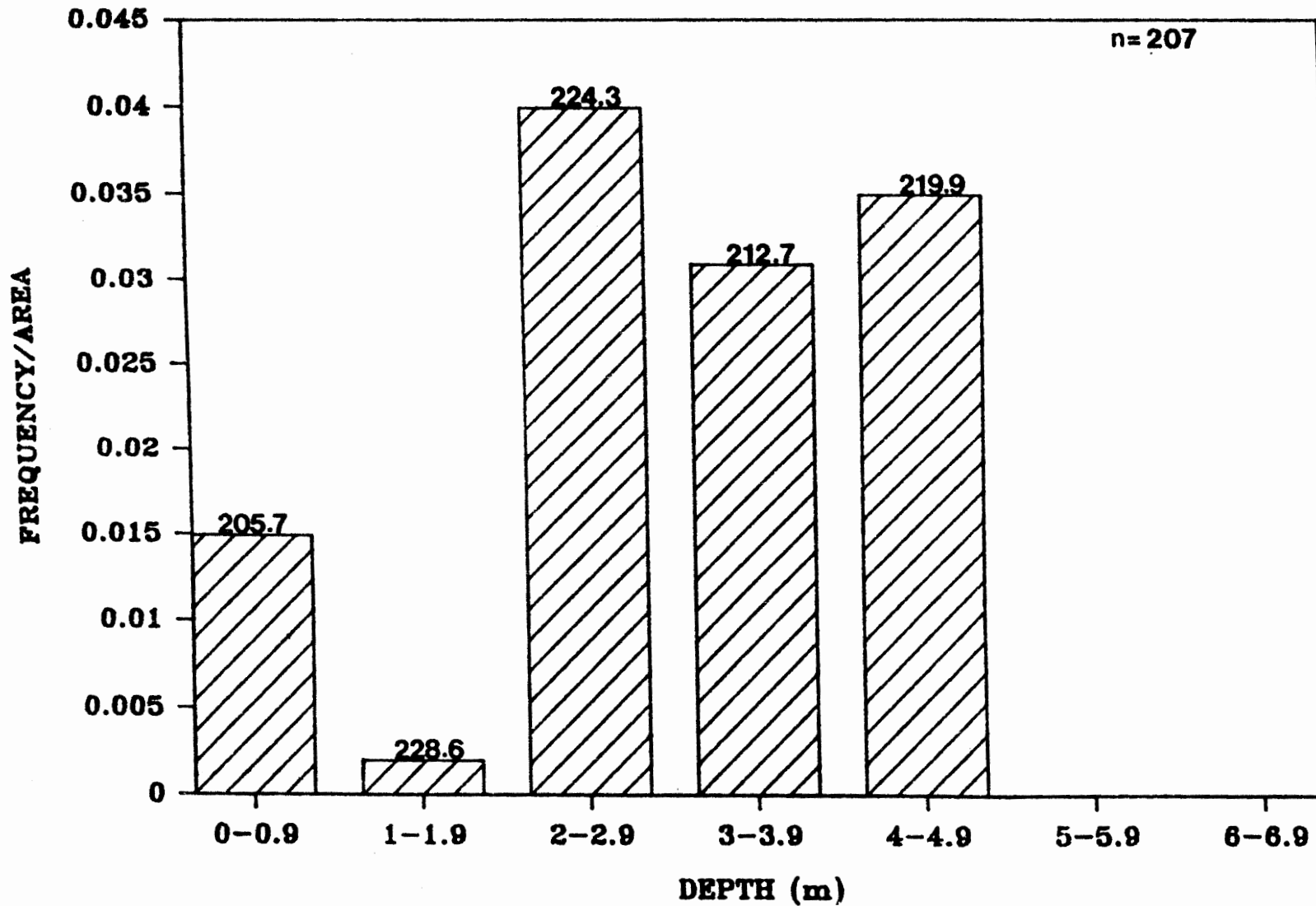


Figure 35. Spring 1984 relative density estimates in relation to depth for carp. Mean total length is indicated above each depth category.



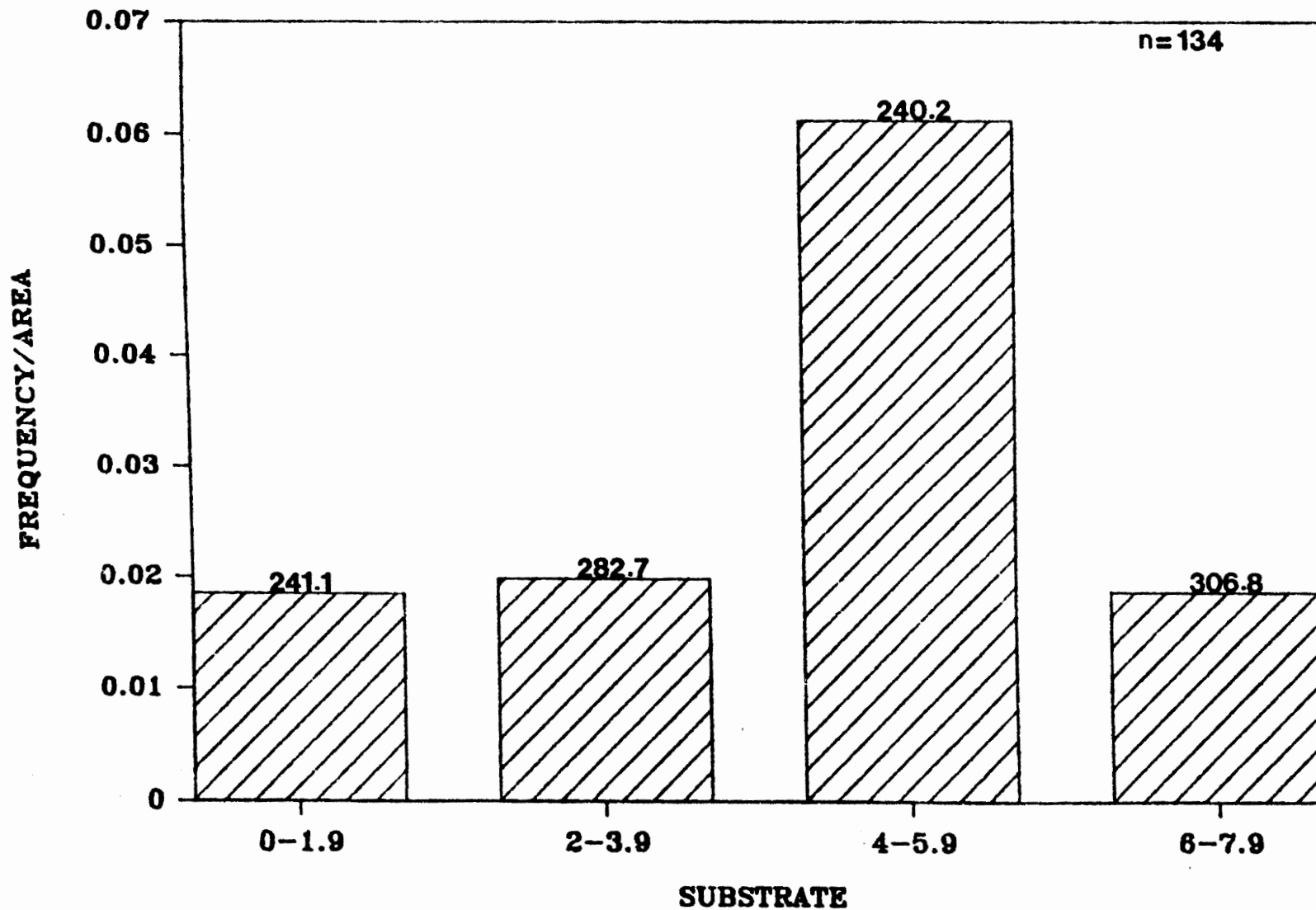


Figure 36. Summer 1984 relative density estimates in relation to substrate for carp. Mean total length is indicated above each substrate category.

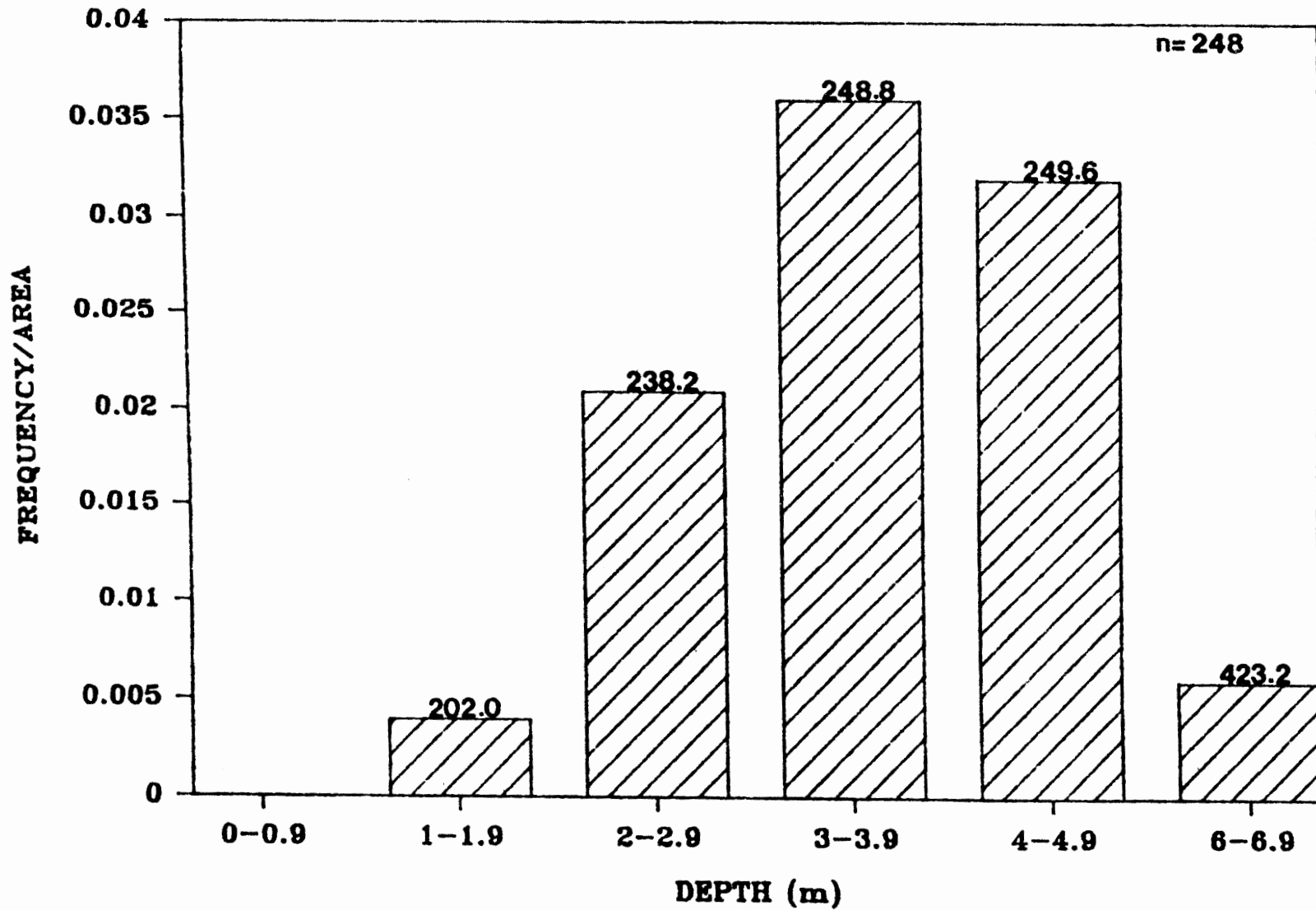


Figure 37. Summer 1984 relative density estimates in relation to depth for carp. Mean total length is indicated above each depth category.

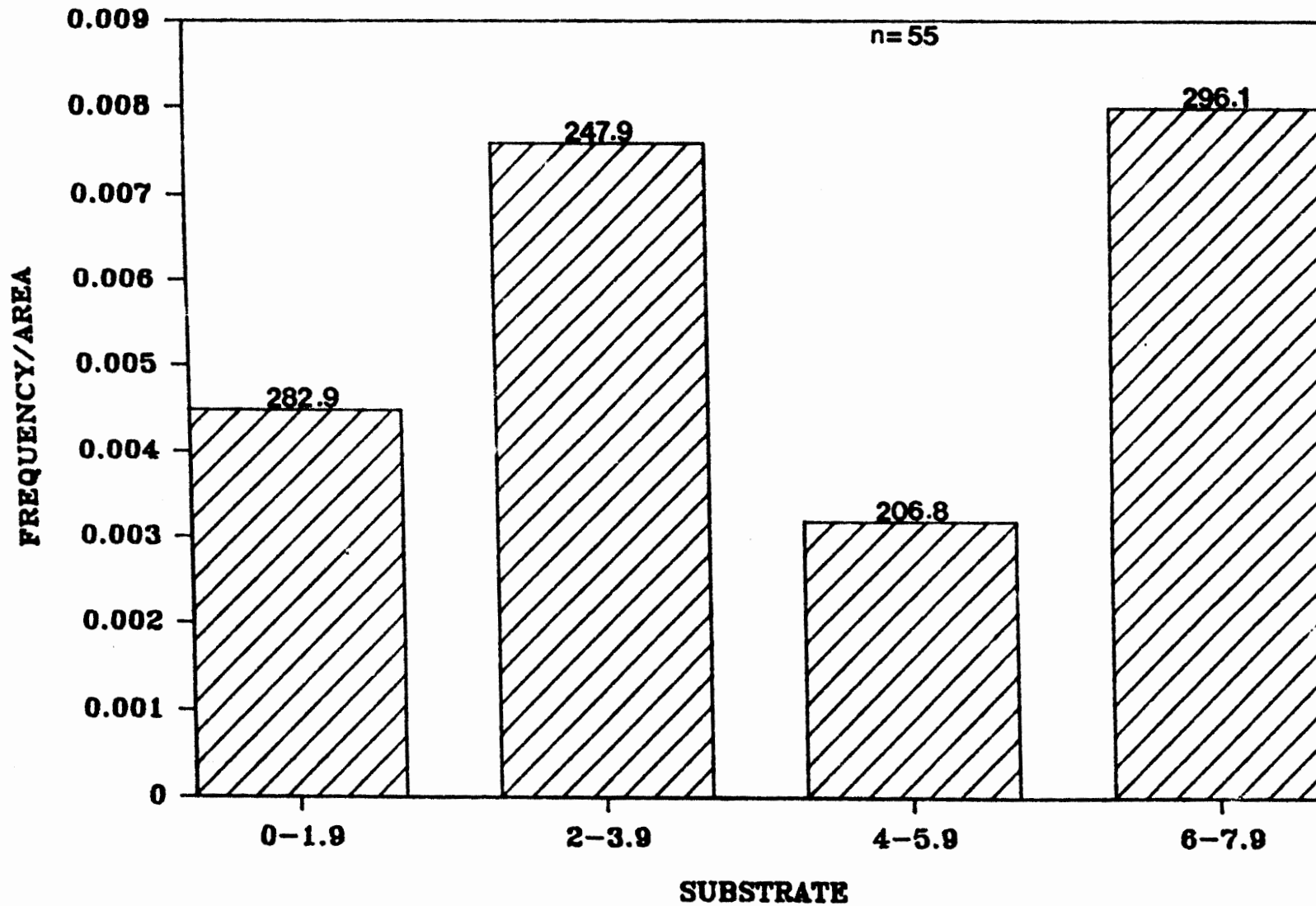


Figure 38. Fall 1984 relative density estimates in relation to substrate for carp. Mean total length is indicated above each substrate category.

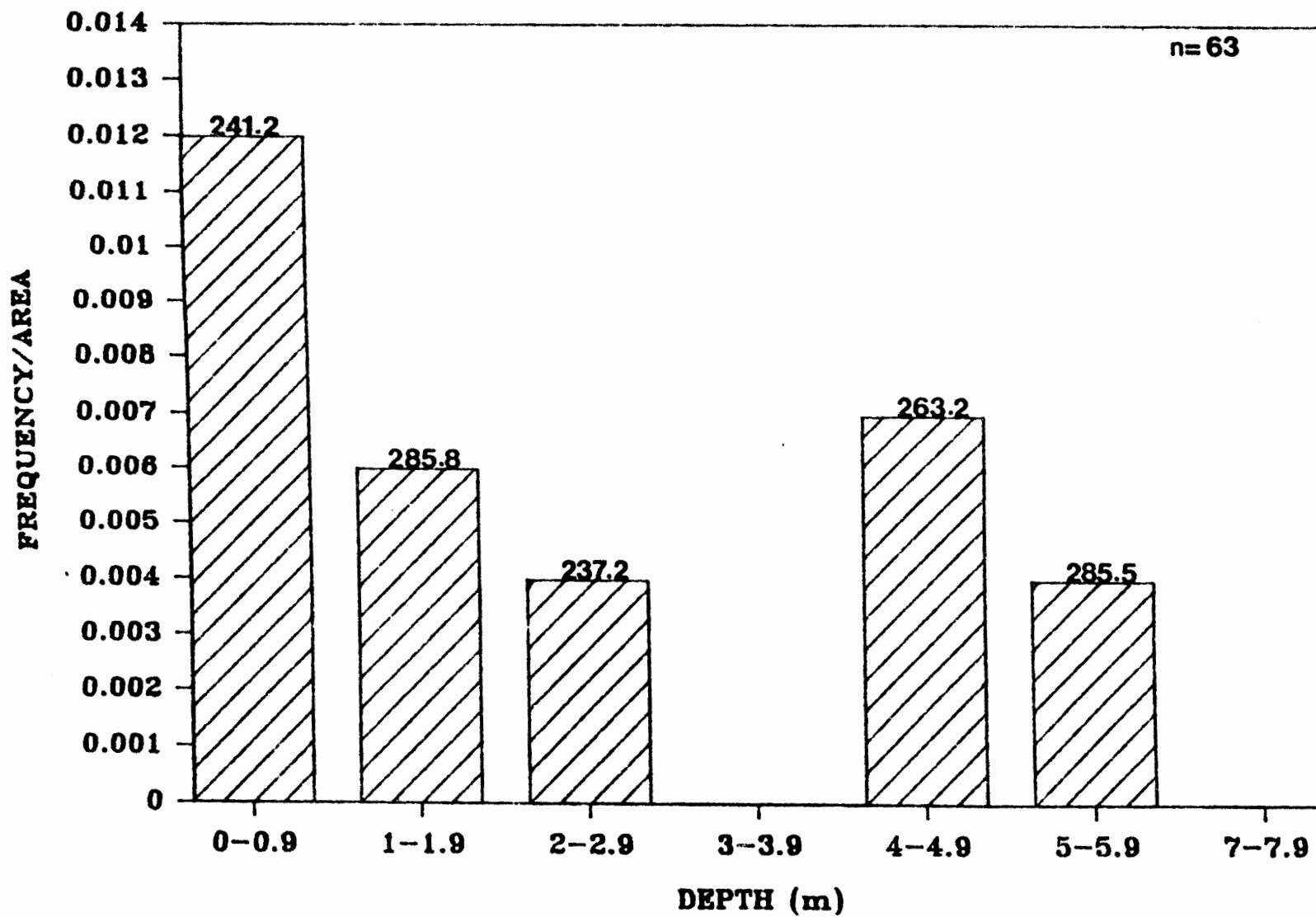


Figure 39. Fall 1984 relative density estimates in relation to depth for carp. Mean total length is indicated above each depth category.

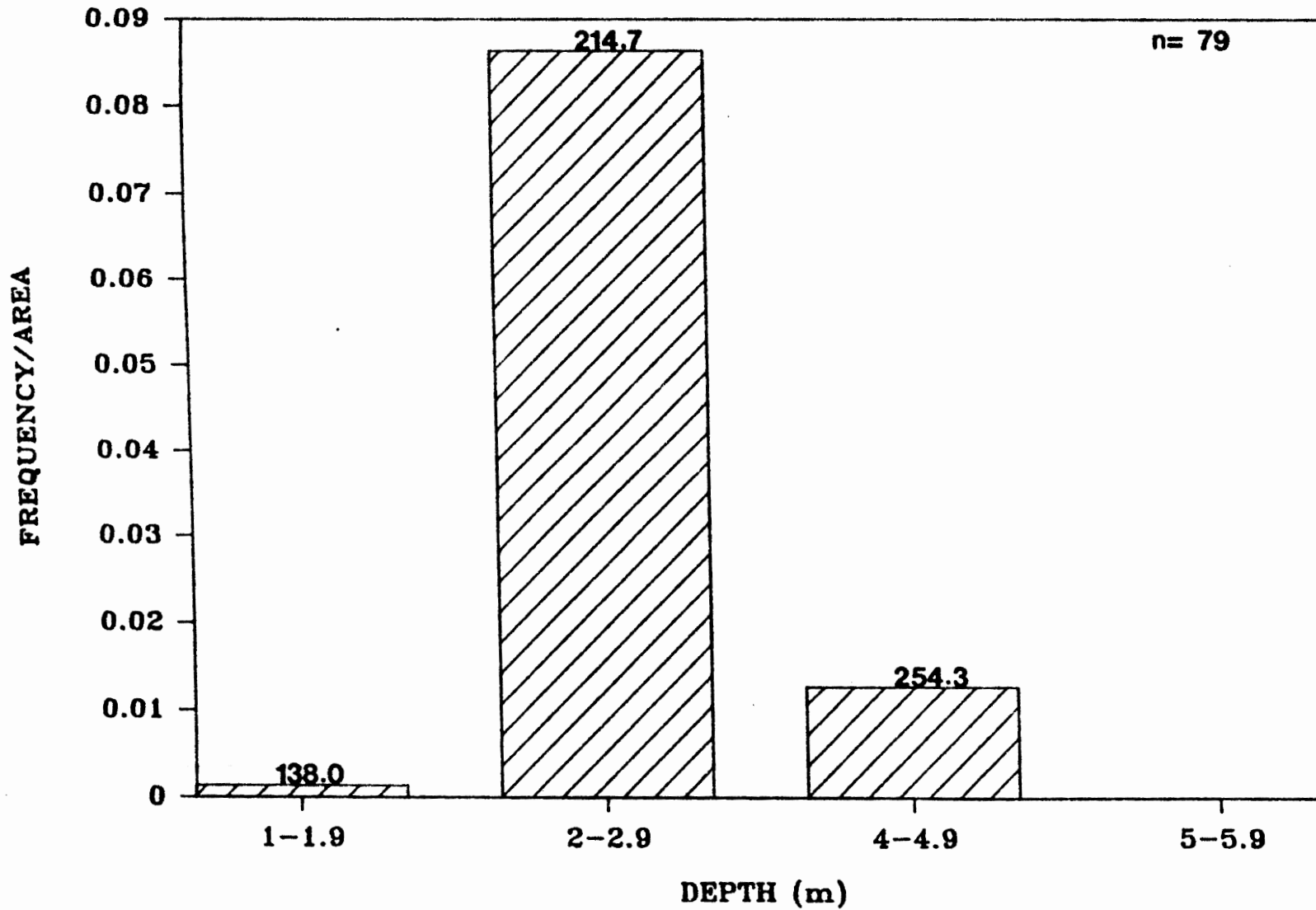


Figure 40. Winter 1984 relative density estimates in relation to depth for black bullhead. Mean total length is indicated above each depth category.

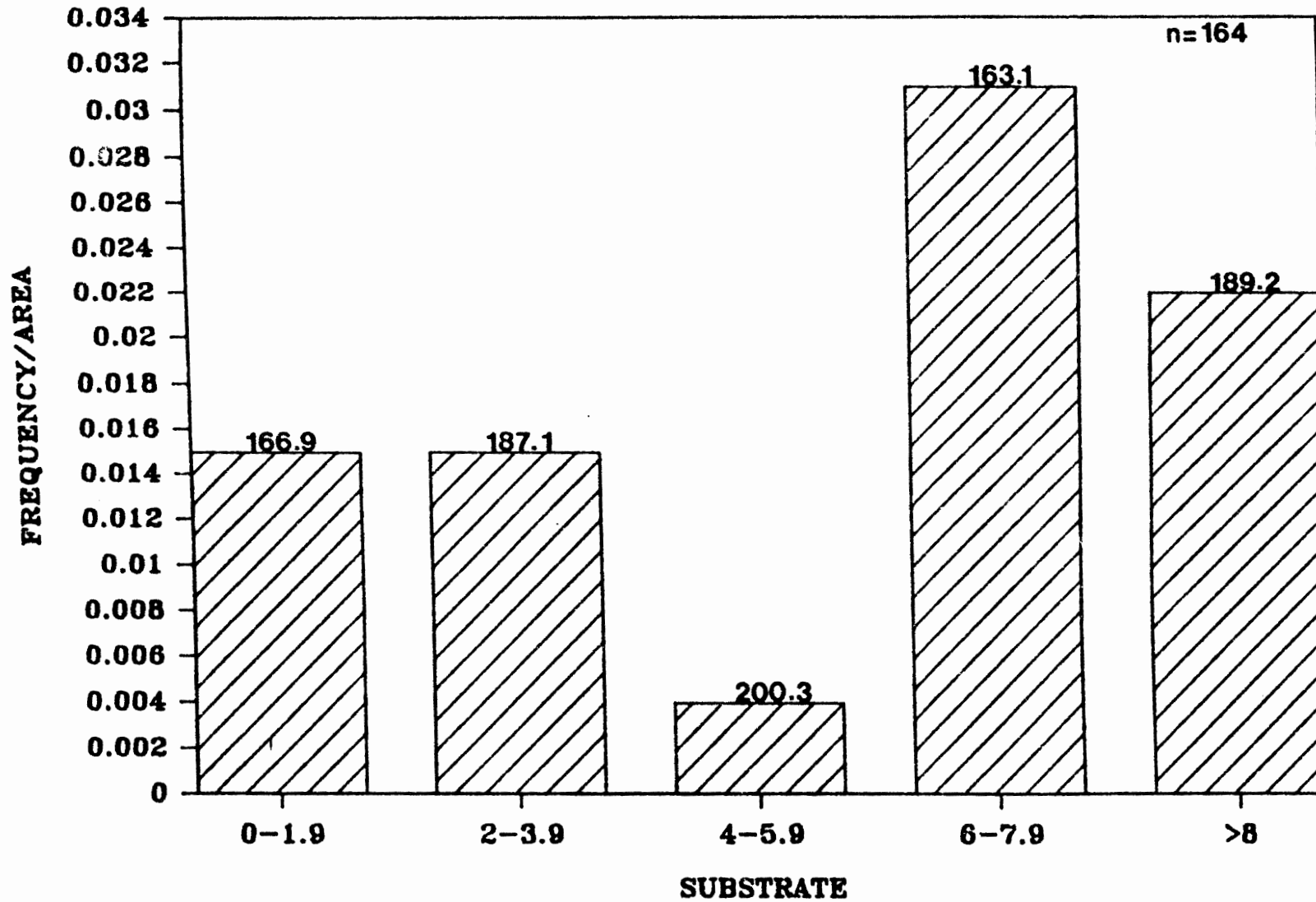


Figure 41. Spring 1984 relative density estimates in relation to substrate for black bullhead. Mean total length is indicated above each substrate category.

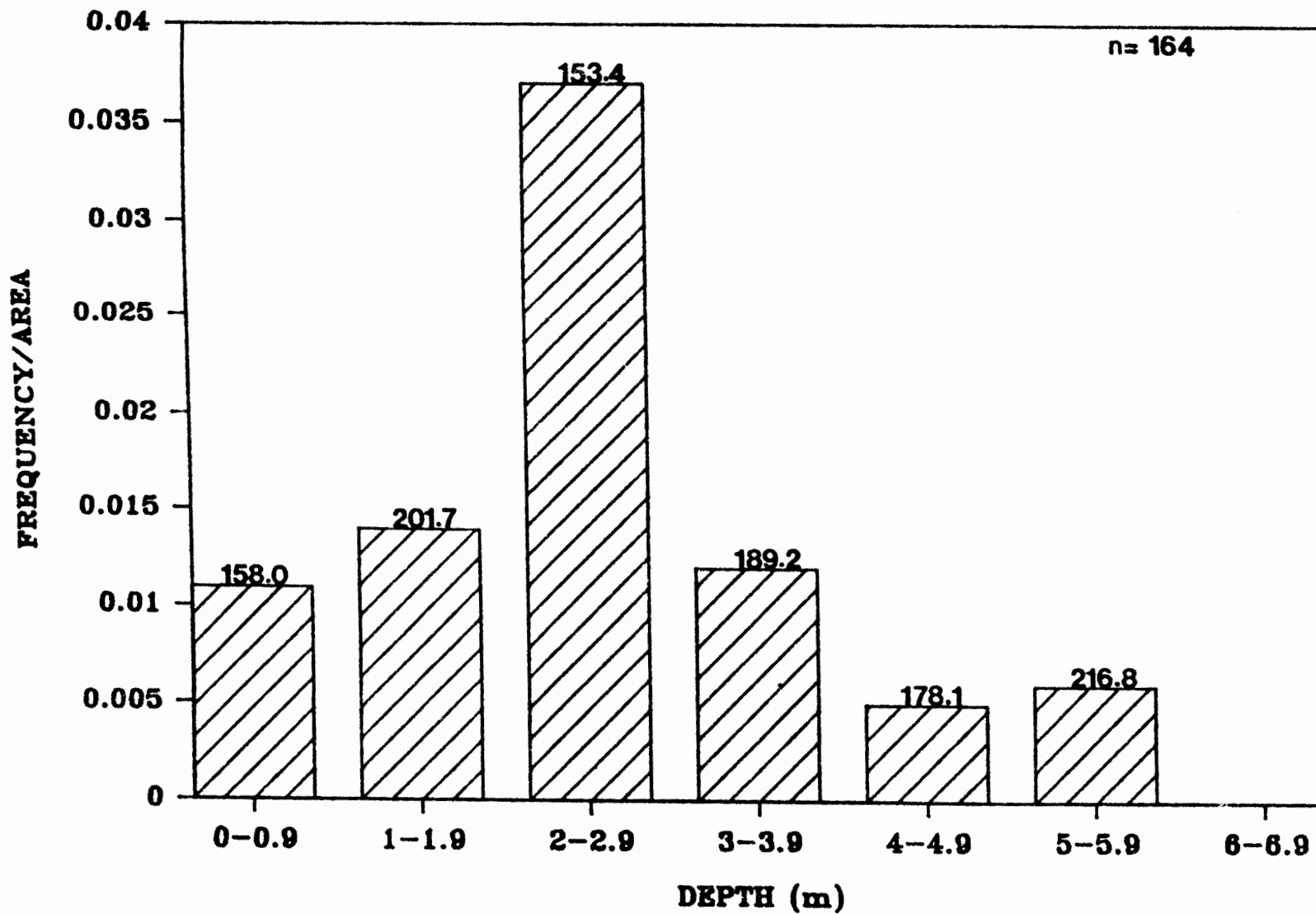


Figure 43. Spring 1984 relative density estimates in relation to depth for black bullhead. Mean total length is indicated above each depth category.

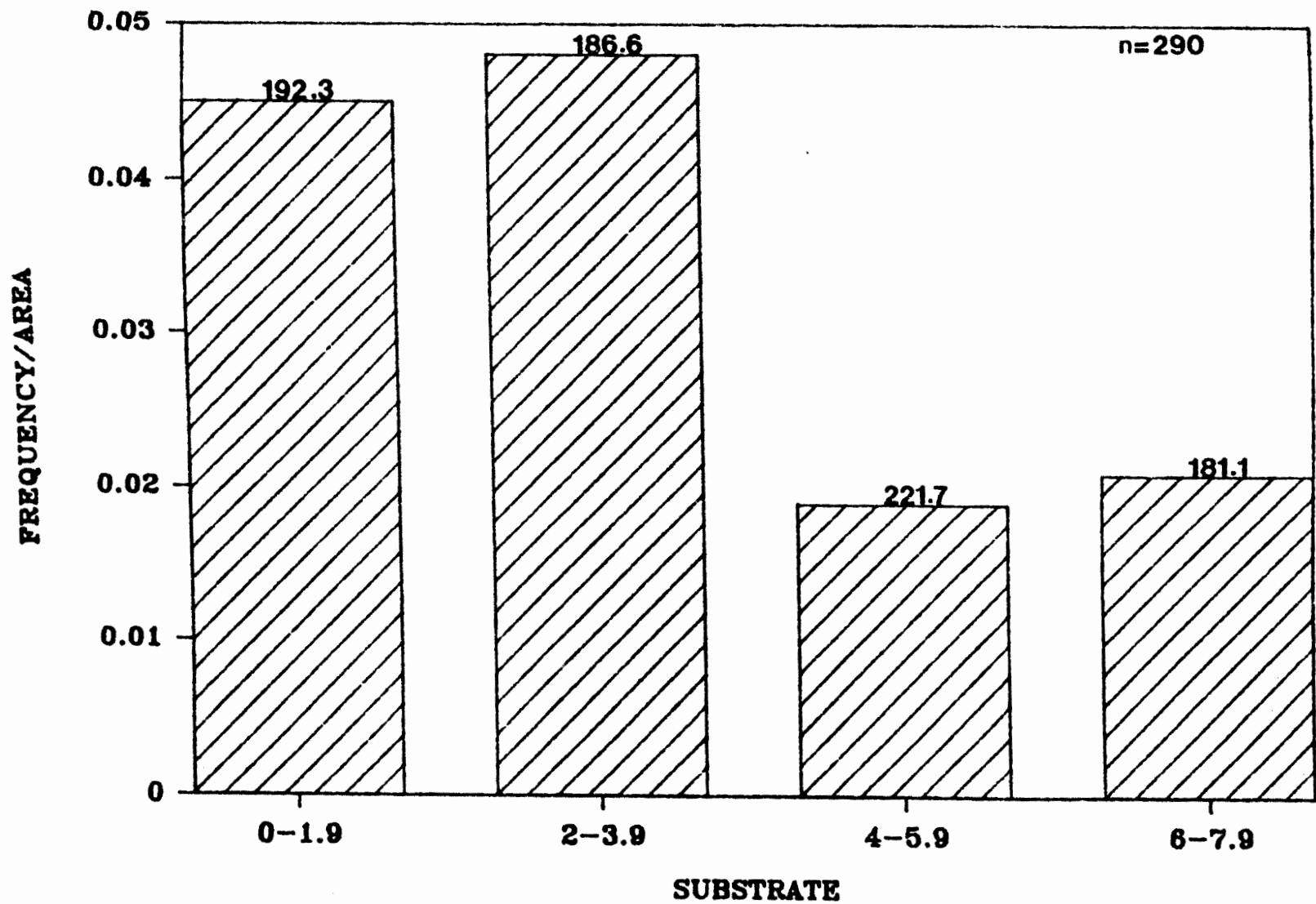


Figure 43. Summer 1984 relative density estimates in relation to substrate for black bullhead. Mean total length is above each substrate category.



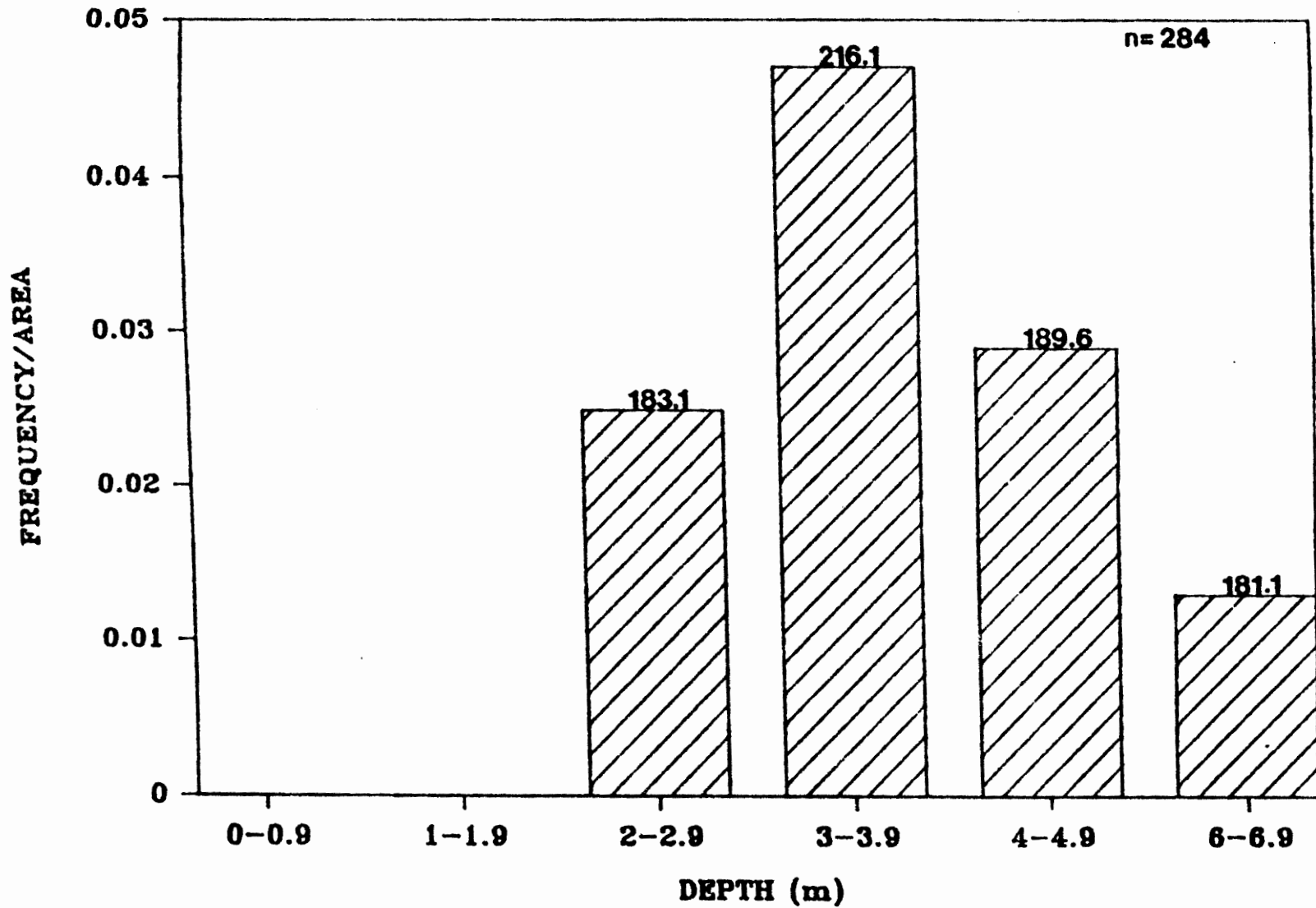


Figure 44. Summer 1984 relative density estimates in relation to depth for black bullhead. Mean total length is indicated above each depth category.

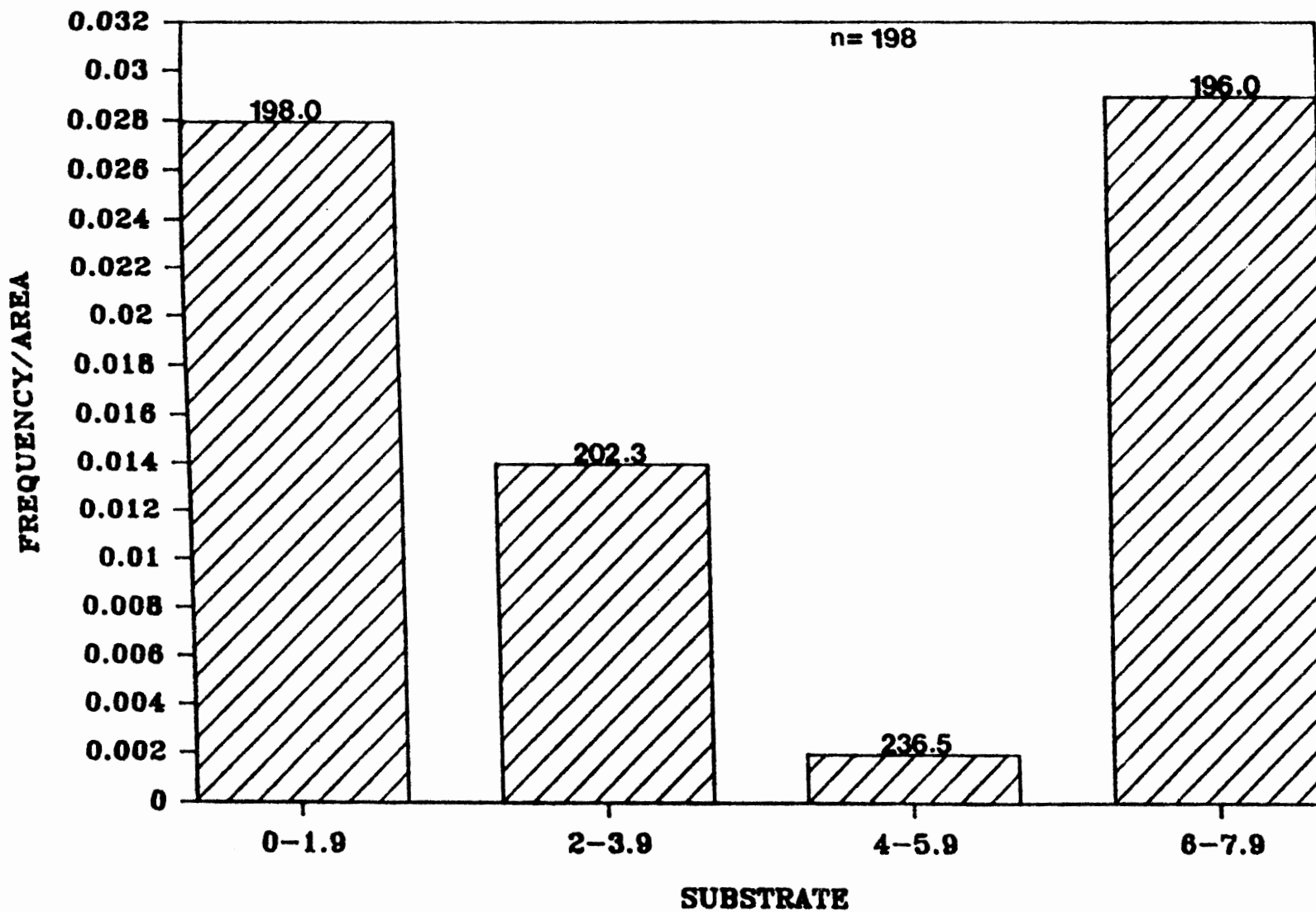


Figure 45. Fall 1984 relative density estimates in relation to substrate for black bullhead. Mean total length is indicated above each substrate category.

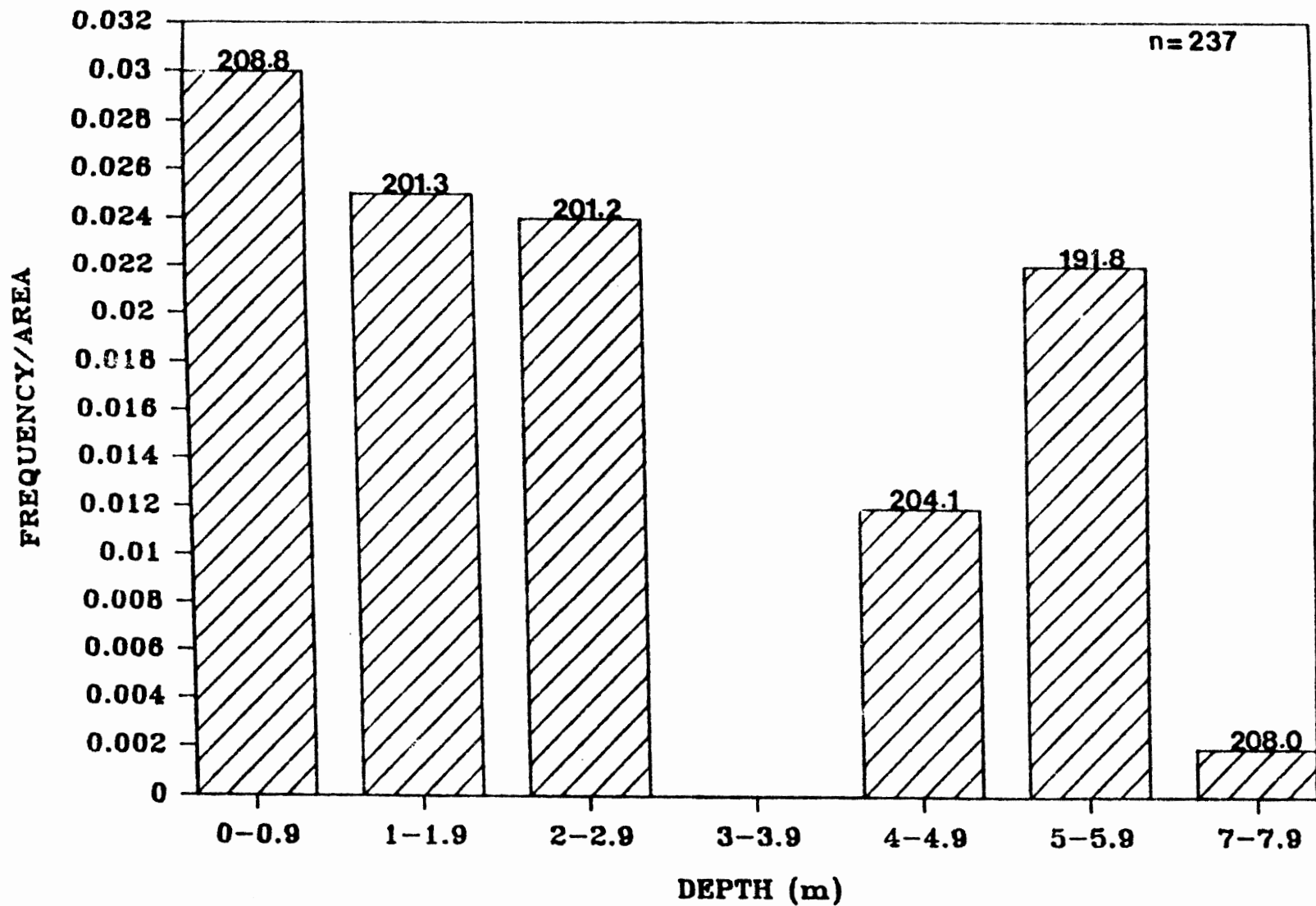


Figure 46. Fall 1984 relative density estimates in relation to depth for black bullhead. Mean total length is indicated above each depth category.

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