FACTORS AFFECTING FISH POPULATIONS IN FLOOD PREVENTION LAKES OF NORTH-CENTRAL TEXAS

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Abstract: During summer, 1976, limnological and fish population data were obtained from 56 flood prevention lakes of the Trinity River watershed. Fish samples obtained by gillnetting, electrofishing, and seining indicated that the principal fishes were largemouth bass *Micropterus salmoides),* bluegill *(Lepomis macrochirus),* black bullheads *(Ictalurus melas),* white crappie *(Pomoxis annularis),* green sunfish *(Lepomis cyanellus),* channel catfish *(Ictalarus punctatus),* golden shiner *(Notemigonus crysoleucas),* and redear sunfish *(Lepomis microlophus).* Analysis of fish data was performed by simple and multiple correlation techniques in relation to physical, limnological, and biological variables. Variation in fish biomass, as indicated by gill net catch, was explained by a combination of biological and physical characteristics, whereas species composition was a more important factor in largemouth bass models. Channel catfish characteristics, in contrast, were highly affected by physical and limnological variables. Although models explaining variation in white crappie characteristics were generally imprecise, sunfish models were typically highly significant due to strong influence of physical and limnological factors. These results emphasize the need for management objectives directed toward a single species or group of species in flood prevention lakes.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 34:292-306

Over 13,200 floodwater retarding structures have been constructed by the Soil Conservation Service under authorization of the 1944 Flood Control Act and the 1954 Watershed Protection and Flood Prevention Act. The primary purpose for the construction of these flood prevention lakes is to reduce flooding by retarding excess runoff in upper watersheds and by releasing it slowly over a period of days. These flood prevention lakes vary greatly in size, but the majority have a maximum volume of less than 2.5×10^5 m^3 at principal spillway level. After construction, ownership of the lakes reverts to the local property owner. Consequently, they have received little attention from fisheries researchers.

Because these lakes are intermediate in size between small farm ponds and larger multipurpose reservoirs, very little information is available on the management of these lakes. The effects of environmental factors on fish production in lakes and reservoirs has been widely studied (Moyle 1946, Carlander 1955, Jenkins and Morais 1971, Aggus and Lewis 1976, Jenkins 1976); however, very little information has been obtained on small watershed lakes. Since flood prevention lakes differ in size and are operationally different from farm ponds or large multipurpose reservoirs, the accepted fisheries management procedures may need modification to be effective for flood prevention lakes (Noble et al. 1979). Hatcher (1973) discussed these structures as fish and wildlife habitat, stating that excessive watershed to lake area ratio is the most common limitation to fish populations.

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According to Dillon and Marriage (1973) there is some evidence that periodic overflow causes floodwater retarding lakes to maintain better fishing than do ponds with static water levels. No other literature on fish populations or management in flood prevention lakes has apparently been published.

During the summer of 1976, 56 flood prevention lakes of the Trinity River watershed of North Central Texas were sampled to determine the variations in fish population parameters in existing flood prevention lakes. The objective of this paper is to relate the variations in selected fish population parameters to biological, limnological and structural differences among the lakes.

This study was conducted as a part of Texas Agricultural Experiment Station Project S-6206, supported through a grant from the Soil Conservation Service. We particularly extend our appreciation to William C. Hobaugh for his assistance in data collection, to Larry R. Aggus for his comments on the manuscript, and to the landowners and SCS personnel of the study area for their cooperation and assistance.

METHODS

Chambers, Grays, and Richland Creek watersheds in the Trinity River drainage contain approximately 250 flood prevention lakes. Of these, 56 lakes in Ellis, Hill, Johnson, Limestone, and Navarro Counties were chosen to give a wide range of physical lake parameters.

The lakes ranged in surface area at principal spillway level from 2.4-26.4 ha, with the majority of the lakes in the 4-10 ha range. Shoreline development varied due to changing topography within the region, ranging from 1.08 to 4.45, with the majority being less than 2.0. Only 3 lakes had a shoreline development greater than 3.0. Mean depths were evenly distributed throughout the range of 0.54-2.75 m. The drainage area to surface area ratios (watershed ratios) ranged from 17.7 to 174.0 ha of watershed per hectare of water, with the majority being less than 20.0. Age of the lakes varied from 3-23 years.

Five of the lakes had been partially drawn down for maintenance of the dam since their construction. In 18 lakes, water levels had risen above the crest of the emergency spillway at least once since construction of the structure.

Sampling of limnological conditions and fish populations was conducted once in each lake during the summer of 1976. Sampling was done from 15 May to 15 August, the period when the most stable weather conditions and water levels were anticipated.

Limnological conditions measured at each lake included alkalinity, hardness, oxygen-temperature profile, pH, and Secchi disk transparency. Water samples for alkalinity, hardness, and pH were taken from the limnetic zone at 1 location. Hardness and alkalinity were determined by titration using a 50 ml water sample; pH was measured by colorimetry. Oxygen and temperature profiles were taken at 0.5 m intervals from the surface to the bottom at 1 site near the dam using an oxygen-temperature meter. All limnological samples were taken between 0900 and 1500 hr CDT.

The fish populations in each lake were sampled over a 2-day period using 3 techniques. Two experimental multifilament gill nets, 45.5 m by 2.4 m, consisting of 6 equal panels with bar meshes of 25.4, 38.1, 50.8, 60.5, 76.2, and 88.9 mm, were set for 24 hours in each lake. In each case the nets were set perpendicular to the shore beginning in water 1-2 m deep. One net was set at the dam near the principal spillway and the other was set on the side of the lake. Two daytime electrofishing transects were run on each lake using a 250 volt, non-pulsed D.C. electrofishing apparatus operated from a small boat. Transects were approximately 100 m in length, 1 along the dam and the other along the side, and approximately followed the 0.75 m contour. When feasible, all fish stunned were collected on each run. Three quadrant seine hauls were made at each lake with a 6.6 m long, 6 mm mesh seine. All large fish were weighed to the nearest gram, and total lengths (TL) to the nearest millimeter were taken to the field. Smaller fish were preserved in 10 percent formalin and later measured to the nearest millimeter TL and weighed to the nearest 0.1 gram in the laboratory. Coefficients of condition (K_{TL}) were calculated following Carlander (1977).

Data were analyzed using simple linear correlation and stepwise multiple regression (Steel and Torrie 1960). Simple linear correlations were run between all variables, including catch data, condition factors, physical parameters, and limnological parameters. Using stepwise variable selection, fish population variables for selected species were regressed against all physical and limnological variables to produce a physical-limnological model for each fish population variable. Then those physical, limnological, and biological parameters which were significant ($P \leq 0.10$) in the simple correlations, were selected as independent variables to produce a stepwise comprehensive model. Those parameters which directly contributed to the values of certain dependent variables were excluded as independent variables, e.g., catches of any species in a particular gear were not used to explain total catch in that gear. For both models, only those variables with significant ($P \leq 0.10$) partial correlation coefficients were included by the stepwise selection procedure. The α 0.05 level of probability was accepted in tests of significance for the multiple correlation coefficient.

RESULTS

Physical and Chemical Conditions

The temperature-oxygen profiles showed that most lakes were stratified at 1.5-2.5 m, if at all. Since the average depth of all study lakes was 1.5 m, the majority of the water was above the thermocline in most lakes. Only in the deep channels and areas where excavation for dam construction had taken place was stratification generally observed. Large surface areas, shallow water, and surface winds apparently kept 22 of the lakes from stratifying. In contrast, small ponds in the area typically stratify in April at shallower depths.

All lakes had acceptable pH, hardness, and alkalinity values for fish populations. Values of pH ranged from 7.8 to 9.0. Alkalinity values ranged from 10 to 214 mg/liter and hardness values ranged from 28 to 204 mg/liter.

Secchi disk transparency varied markedly. Transparencies as low as 5 cm occurred in 2 lakes, but reached or exceeded 100 cm in 6 lakes. A complete list of physical and chemical data is presented in Farquhar (1977).

Fish Samples

In the 56 lakes sampled, 23 species of fishes, including hybrid sunfish, were found (Table 1). The number of species found per lake ranged from 3 to 12. Largemouth bass were present most frequently, occurring in 52 of the lakes, followed by bluegill in 51, black bullheads in 46, white crappie and green sunfish in 42, channel catfish in 40, golden shiner in 36, and redear sunfish in 33. These species dominated the samples from most of the lakes with the other species occurring in less than 50 percent of the lakes and generally in smaller numbers when present. With the exception of black bullheads, rough fish such as carp *(Cyprinus carpio)*, river carpsucker *(Carpiodes carpio)*, and yellow bullhead *(Ictalurus natalis)* occurred in less than 15 percent of the lakes and in relatively small numbers compared to sport fish.

Biomass Indices

Since all lakes were sampled with uniform gill net effort, gill net catch data were used as an index of biomass of fishes present in the lakes. Using the total weight of all species caught in the 2 gill nets as a relative index of biomass, simple linear correlations and multiple regression equations were calculated to investigate which factors were affecting fish standing crop.

Table 1. Number of lakes in which fish species were collected.

Scientific Name	Common Name	Frequency
Campostoma anomalum	Stoneroller	1
Carpiodes carpio	River carpsucker	8
Cyprinus carpio	Carp	5
Dorosoma cepedianum	Gizzard shad	8
Etheostoma gracile	Slough darter	1
Fundulus olivaceus	Blackspotted topminnow	4
Gambusia affinis	Mosquitofish	17
Ictalurus melas	Black bullhead	46
Ictalurus natalis	Yellow bullhead	6
Ictalurus punctatus	Channel catfish	40
Lepomis cyanellus	Green sunfish	42
Lepomis gulosus	Warmouth	9
Lepomis humilis	Orangespotted sunfish	7
Lepomis macrochirus	Bluegill	51
Lepomis megalotis	Longear sunfish	13
Lepomis microlophus	Redear sunfish	33
Lepomis spp.	Hybrid sunfish	11
Micropterus salmoides	Largemouth bass	52
Notemigonus crysoleucas	Golden shiner	36
Notropis lutrensis	Red shiner	17
Pimephales vigilax	Bullhead minnow	4
Pomoxis annularis	White crappie	42
Pomoxis nigromaculatus	Black crappie	1

Analysis of simple linear correlations between total biomass in gill nets and physical, limnological, and biological variables (excluding gill net catches of individual species) revealed 8 significant correlations. Of the 12 non-biological variables, surface area, watershed ratio, hardness, and stratification depth were positively related to fish biomass (Table 2). Three biological variables—numbers of electrofished red shiners *(Notropis lutrensis)*, gizzard shad *(Dorsoma cepedianum)*, and largemouth bass—were positively correlated to total gill net weight. Total biomass was negatively correlated with the percent of largemouth bass in the gill nets.

Multiple regression analysis using only physical and limnological parameters as independent variables resulted in the inclusion of 2 significant variables: surface area and stratification depth. This model explained only 24 percent of the variation ($R^2=0.24$) in total gill net biomass, but was highly significant ($P < 0.002$). Logarithmic transformation of the dependent variable, total biomass in gill nets, was employed in an attempt to improve precision, but resulted in a smaller R^2 value even though the variables selected were similar.

The comprehensive model explained approximately 44 percent of the variation in the biomass index ($P < 0.001$). The comprehensive model contained number of red shiners and largemouth bass caught electrofishing, the percent of largemouth bass in the gill nets, and 2 physical characteristics—watershed ratio and surface area.

Table 2. Variables correlated with total biomass of fishes caught in gill nets in 56 flood prevention lakes.

Models	Variables	Significance of simple correlation	Significance of partial correlation coefficient in final model	R^2
Physical-Limnological	Shoreline Development(-)[1]	0.539	---	0.241 ($P < 0.001$)
	Surface Area(+)	0.012	0.090	
	Age(-)	0.982	---	
	Mean Depth(-)	0.911	---	
	Watershed Ratio(+)	0.027	---	
	Spillway Function(-)	0.365	---	
	pH(+)	0.569	---	
	Alkalinity(+)	0.119	---	
	Total Hardness(+)	0.063	---	
	Stratification Depth(+)	0.001	0.005	
	Secchi Disk Depth(+)	0.944	---	
	Drawdown(-)	0.842	---	
Comprehensive	Surface Area(+)	0.012	0.021	0.440 ($P < 0.001$)
	Watershed Ratio(+)	0.027	0.012	
	Total Hardness(+)	0.063	---	
	Stratification Depth(+)	0.001	---	
	EF[2] Red Shiners(+)	0.006	0.032	
	EF Gizzard Shad(+)	0.062	---	
	GN[3] Largemouth Bass%(-)	0.031	0.016	
	EF Largemouth Bass(+)	0.077	0.002	

[1]Sign indicates direction of simple correlation [2]Sampling by electrofishing (EF) [3]Sampling by gill net (GN)

Similarity of the significant variables in these models with those included in the channel catfish models presented later, indicates that the contribution of channel catfish to the total biomass in gill nets strongly influenced this analysis. This effect indicated the need to analyze biomass data from each species of interest individually.

Largemouth Bass

To determine what factors were affecting largemouth bass populations in flood prevention lakes, several bass population parameters were examined as dependent variables. These factors included number of bass caught in the gill nets, biomass of bass caught in the gill nets, percent of gill net catch comprised of bass, number of young bass (TL $<$ 150 mm) caught seining and electrofishing, condition of young bass, and condition of bass 150-320 mm TL.

Significant physical-limnological models were formulated for each bass parameter except gill net number and condition of young bass, but R^2 values were typically low (Table 3). Shoreline development, watershed ratio, pH, hardness, and stratification depth emerged as significant in these models; however, none appeared in more than 1 model. In addition to these variables, significant, simple negative correlations were found between surface area and number of young bass and between mean depth and condition of adult bass.

The comprehensive models for all largemouth bass parameters indicated significant partial correlations with 1 or more biological variables (Table 3). These biological variables were entirely characteristics of prey species—red shiner, golden shiner, and gizzard shad. Only 1 physical-limnological variable, shoreline development, was significant in any comprehensive model, that for condition of adult bass.

Adult largemouth bass catch parameters appear to be positively related to golden shiners, represented by numbers caught by seining. Number of young bass, used as an indication of reproductive success, was also related to golden shiner abundance, and additionally to gizzard shad abundance. Condition models for both young and adult bass also included prey species variables. Multiple regression models explained from 25 to 55 percent of the variation. The R^2 values were all highly significant ($P < 0.010$) except that for condition of young bass ($P < 0.023$).

In general, these analyses show that the species composition is much more important in determining largemouth bass success than physical or limnological conditions. Presence of golden shiners generally was indicative of large populations of bass. Abundance of gizzard shad, while often considered undesirable due to overabundance of large fish, was positively correlated to young largemouth bass numbers.

Channel Catfish

Overall analyses of the channel catfish data indicated a strong relationship with some physical parameters (Table 4). Shoreline development was negatively correlated with channel catfish numbers, biomass, and percent gill net composition. Significant simple correlations of percent gill net composition also occurred with Secchi disk depth, watershed ratio, alkalinity, and average depth, all of which were negative. Number and biomass were also positively correlated with surface area and stratification depth. Condition of channel catfish, however, was not significantly correlated with any physical or limnological variable.

Significant regression models were calculated for channel catfish numbers, weight, and percent of gill net catch. R^2 values were highest for channel catfish numbers (0.39) and weight (0.37), both based on 3 physical-limnological variables—shoreline development, surface area, and stratification depth.

The comprehensive models for all channel catfish population parameters indicated significant partial correlations, all positive, with 1 or more biological variables (Table 4). Each model, except that for channel catfish condition, also included 1 or more physical-

Table 3. Variables included by stepwise multiple regression of the physical-limnological and comprehensive models from largemouth bass parameters.

Models	Variables	Gill net Number	Gill net Biomass	Gill net % Composition	Number Young	K of Young	K of Adult
Physical-Limnological	Shoreline Development						-
	Watershed Ratio		+[1]				
	pH				+		
	Total Hardness		-				
	Stratification Depth			-			
	R^2	0.05	0.10	0.11	0.26	0.03	0.15
	p of larger R^2	0.115	0.078	0.019	0.011	0.429	0.011
Comprehensive	Shoreline Development						-
	SN Golden Shiners	+	+	+			
	EF[2] Golden Shiners				+	+	
	GN[3] Golden Shiners					-	
	GN Gizzard Shad				+		
	SN[4] Red Shiners						+
	R^2	0.31	0.35	0.27	0.55	0.34	0.25
	p of larger R^2	0.001	0.001	0.001	0.003	0.023	0.010

[1]Signs indicate direction of correlation

[2]Sampling by electrofishing (EF)

[3]Sampling by gill net (GN)

[4]Sampling by seine (SN)

Table 4. Variables included by stepwise multiple regression in the physical-limnological and comprehensive models for channel catfish parameters.

Models	Variables	Gill net Number	Gill net Biomass	Gill net % Composition	Condition
Physical-Limnological	Shoreline Development	-[1]	-	-	
	Surface Area	+	+		
	Stratification Depth	+	+		
	R^2	0.39	0.37	0.16	0.07
	p of larger R^2	0.001	0.001	0.003	0.132
Comprehensive	Shoreline Development	-		-	
	Stratification Depth	+	+		
	Secchi Disk Depth	-			
	SN[2] Longear Sunfish	+			
	EF[3] Green Sunfish			+	
	EF Red Shiners		+		
	SN Red Shiners			+	
	GN[4] Golden Shiners				+
	R^2	0.47	0.53	0.42	0.20
	p of larger R^2	0.001	0.001	0.001	0.010

[1]Signs indicate direction of correlation
[2]Sampling by seine (SN)
[3]Sampling by electrofishing (EF)
[4]Sampling by gill net (GN)

limnological variables. R^2 values increased markedly over those for the physical-limnological models, ranging from 0.42 to 0.53 for the 3 catch parameters.

These analyses indicated the importance of physical-limnological variables in determining abundance of channel catfish. Large, turbid lakes with little shoreline development and deep stratification appear to favor channel catfish. Abundance of certain forage species appears to increase the predictability of channel catfish parameters.

Crappie

Two species of crappie were found in the 56 lakes sampled. Black crappie occurred in only 1 of the lakes and are, therefore, relatively unimportant in the management of these lakes. White crappie, however, occurred in 42 lakes. While some lakes had populations of catchable-size crappie, at least 25 percent of those lakes in which they occurred appeared to have serious overpopulation and stunting.

Analysis of 4 dependent variables revealed a possible relationship between white crappie and water level fluctuations in the physical-limnological models (Table 5). Positive correlations of number, weight, and percent of crappie with spillway function and negative correlations of condition with spillway function and drawdown would tend to indicate that fluctuations are conducive to white crappie numbers. A high simple correlation coefficient (r=-0.33, P 0.059) indicated that with increasing crappie numbers, the condition of white crappie over 150 mm TL tended to decrease. Biomass of crappie also had a significant, simple, positive correlation with surface area. R^2 values for all 4 models were very low, indicating low predictability for these parameters based on physical and limnological variables.

In the comprehensive models, high simple correlations between the number and weight of white crappie in gill nets and number of mosquitofish *(Gambusia affinis)* in seines resulted in exclusion of all physical-limnological variables from these 2 models. This relationship was likely fortuitous, since mosquitofish were seined from only 15 lakes, and this variable was not highly correlated with any other meaningful variable. In contrast, the comprehensive models for percent composition of crappie indicated an inverse relationship with 2 predator species—largemouth bass and green sunfish. The comprehensive model for crappie condition was substantially more precise (R^2=0.61). It included 2 physical variables—spillway function and lake age, plus 1 biological variable, number of seined longear sunfish.

The generally low R^2 values for white crappie models indicate that the conditions affecting this species are probably quite complex. Few biological variables had significant simple correlations with white crappie variables, consequently few were available for possible inclusion in the model.

Sunfish

Six species of sunfish, plus hybrid sunfish, occurred in the 56 lakes. Bluegill was the dominant species, followed by green sunfish and redear sunfish. These species represent an important sport fish resource as well as an important forage source for predatory fishes.

Analysis of sunfish data was performed on 4 bluegill population parameters and 3 parameters including all sunfish (Table 6). Number of bluegills in gill nets, number of bluegills in seine samples, and the condition of young (TL $<$ 100 mm) and adult (100-180 mm TL) bluegills were used as dependent variables. In addition, total sunfish biomass, number, and percent were used. These 3 parameters included only gill net data and consisted of all species of sunfish, except orangespotted sunfish which were not caught in gill nets.

Overall analyses of the sunfish data revealed that the physical and limnological conditions were important in determining the sunfish characteristics, as indicated by the

Table 5. Variables included by stepwise multiple regression in the physical-limnological and comprehensive models for white crappie parameters.

Models	Variables	Gill net Number	Gill net Biomass	Gill net % Composition	K of Adult
Physical-Limnological	Spillway Function	+[1]	+	+	-
	Hardness	+	+		
	Drawdown				-
	R^2	0.14	0.11	0.06	0.30
	p of larger R^2	0.028	0.058	0.084	0.002
Comprehensive	Spillway Function				-
	Age				-
	SN[2] Mosquitofish	+	+		
	EF[3] Largemouth Bass			-	
	EF Green Sunfish			-	
	SN Longear Sunfish				-
	R^2	0.26	0.25	0.19	0.61
	p of larger R^2	0.001	0.001	0.009	0.001

[1]Signs indicate direction of correlation

[2]Sampling by seine (SN)

[3]Sampling by electrofishing (EF)

Table 6. Variables included by stepwise multiple regression in the physical-limnological and comprehensive models for sunfish parameters.

		Bluegill				Gill net Sunfish		
Models	Variables	GN[1]	SN[2]	K(Young)	K(Adult)	No.	Wt.	%
Physical-Limnological	Alkalinity	+[3]			-	-		
	Secchi Disk Depth	+		-		+	+	+
	Watershed Ratio			+			+	
	Hardness			-				
	Area				+			
	Spillway Function				-			
	pH				-			
	Shoreline Development							+
	R^2	0.29	0.05	0.53	0.34	0.29	0.38	0.45
	p of larger R^2	0.001	0.143	0.001	0.003	0.001	0.001	0.001
Comprehensive	Stratification Depth	+				+	+	
	Alkalinity	+		-	-	+		
	pH				-			
	Secchi Disk Depth						+	+
	Shoreline Development							+
	Total Largemouth Bass				+			
	Largemouth Bass Weight		+					
	Total Redear Sunfish		+					
	GN Redear Sunfish	+						
	SN Redear Sunfish		+					
	SN Bluegills	+				+	+	+

Table 6. Cont.

		Bluegill				Gill net Sunfish		
Models	Variables	GN[1]	SN[2]	K(Young)	K(Adult)	No.	Wt.	%
	SN Red Shiners	-			+	-		
	Sunfish Weight		+					
	EF[4] Golden Shiners		+					
	SN Black Bullhead		+					
	EF Orangespotted Sunfish				+			
	GN Yellow Bullhead					+	+	
	R^2	0.53	0.72	0.28	0.59	0.57	0.76	0.45
	p of larger R^2	0.001	0.001	0.002	0.001	0.001	0.001	0.001

[1]Sampling by gill net (GN)
[2]Sampling by seine (SN)
[3]Signs indicate direction of correlation
[4]Sampling by electrofishing (EF)

inclusion of at least 2 physical-limnological variables in most of the models (Table 6). Clarity of water, as measured by Secchi disk transparency, was directly related to adult sunfish parameters. Other physical variables such as watershed ratio and shoreline development were correlated to sunfish populations; however, correlations between these factors and water clarity makes determination of the role of these factors in the populations of sunfish difficult. Marked increases in R^2 values were obtained in the comprehensive models. Although a large number of physical-limnological variables were retained, R^2 values for sunfish comprehensive models were frequently high because of the inclusion of the independent variable, number of bluegills seined. Inclusion of other biological variables was erratic.

Bullheads

Two species of bullhead catfish were found. Yellow bullheads occurred in only 6 lakes and were not abundant in any. Therefore, yellow bullhead data were not analyzed. To determine what factors were affecting black bullhead populations, 2 black bullhead population parameters, gill net biomass and number, were examined as dependent variables.

A significant physical-limnological model was formulated for biomass of black bullheads (R^2=0.10, $P < 0.023$). Surface area, which was negatively correlated to biomass, was the only variable found to be significant in this model. No significant physical-limnological model was calculated for black bullhead numbers (R^2=0.06, $P < 0.086$).

Comprehensive models for the 2 black bullhead population parameters indicated significant partial correlations with only 1 biological variable. Numbers of redear sunfish collected by electrofishing were positively correlated to biomass (R^2=0.30, $P < 0.001$) and numbers (R^2=0.18, $P < 0.002$) of black bullheads.

The black bullhead, although generally considered an undesirable species, is utilized by some area fishermen. Overpopulation of bullheads, which often occurs in smaller ponds of the area, seemed to occur rarely in flood prevention lakes. Only 3 of the lakes sampled had an apparent overpopulation of bullhead catfish. Although significant models were formulated, our analyses found few meaningful relationships between black bullheads and other variables.

DISCUSSION

Several general trends are apparent from this analysis, but certain limitations arise from the extensive nature of the study. Since all lakes were sampled only once and the sampling was likely affected by water clarity, time of the day, time of the season, and weather conditions, these results should be used to indicate general relationships and not for exact predictive purposes. Inter-correlations between independent variables also make precise determination of those factors affecting fish populations very difficult. More intensive sampling of each lake would be necessary to better determine what factors are most important in fish production.

Several physical parameters were closely related to fish production. Surface area and stratification depth were positively correlated to channel catfish numbers and biomass, and total weight of all species caught in the gill nets; however, channel catfish often made up the majority of the gill net catch by weight. The relationships to physical parameters agree with the findings of Aggus and Lewis (1976) in larger reservoirs. In contrast Carlander (1955) found no correlations between the area of a body of water and the standing crops of fish in midwest lakes. His results agree with those of Jenkins (1957) for Oklahoma ponds. Shoreline development was negatively correlated to channel catfish population parameters, while Secchi disk transparency was positively correlated to sunfish abundance. Aggus and Lewis (1976) found a positive relationship between shoreline development and sunfish weight. Channel catfish were probably not directly affected by shoreline development, but rather those lakes which had a low shoreline development were generally more turbid ($r=0.37$, $P < 0.005$) and shallower ($r=0.37$, $P < 0.006$). These conditions were often associated with the larger channel catfish populations. High watershed ratios and alkalinity values were positively correlated with sunfish data. These conditions were generally associated with the deeper, clearer lakes, with high shoreline development and high numbers of large sunfish. No significant effect of age or average depth could be determined. Thus the physical parameters seem to have a pronounced effect on channel catfish and sunfish species. The deeper, clearer lakes are better suited to sunfish while the shallow, turbid lakes seem to be better for catfish.

Bennett (1943) found that white crappie stunting was most pronounced in shallow muddy lakes, however, in our study, no significant relationships emerged between average depth and number ($r=0.03$, $P > 0.840$) or condition ($r=0.02$, $P > 0.889$) of adult white crappie, or between Secchi disk transparency and number ($r=0.09$, $P > 0.495$) or condition ($r=0.12$, $P > 0.478$) of adult white crappie. Crappie catches were correlated with spillway function and total hardness, but mechanisms for this relationship are unclear. Condition of adult white crappie was negatively correlated to both spillway function and drawdown, probably an indirect result of the above correlation with crappie numbers. Extreme water level fluctuations appear to increase crappie numbers, but adversely affect their condition. In contrast, Cichra and Noble (1980) indicated that extended summer drawdown tended to diversify size composition of white crappie populations and increased condition of adults.

Largemouth bass populations appeared to be least influenced by physical and limnological conditions. Five variables were included in the physical-limnological models, but no variable ever appeared in more than 1 model. For 2 of the largemouth bass characteristics, number caught in gill nets and condition of young, no significant models were formulated.

For most fish population characteristics, combinations of biological variables overshadowed the effects of physical or limnological conditions. In lakes whose white crappie populations were dominated by intermediate size fish (100-199 mm TL), the numbers were low for both adult bass ($r=-0.62$, $P < 0.001$) and adult sunfish ($r=-0.37$, $P < 0.043$). Several forage species were indicators of abundant sport fish populations. Contrary to the findings of Bennett (1943), significant positive correlations were found between golden shiners and both bass and sunfish parameters. Our data agree with Jenkins (1957) who found in Oklahoma ponds that golden shiners were associated with larger bass crops. This species was most likely serving as a forage base for largemouth bass and increasing bass production in those lakes where they were numerous. Red shiner catches were highly correlated with condition of adult bass and dominance of channel catfish. Red shiner abundance was low in lakes which maintained large populations of bluegill and other sunfish. Condition of small bluegills was higher in lakes having large red shiner populations. In all these cases involving the red shiner, cause-and-effect relationships are not clearly evident. Although often considered an undesirable species, gizzard shad catches were significantly correlated to high populations of young bass. This could be a result of reduced intraspecific predation on young bass due to high shad numbers, or the shad might be serving as a forage source for the young bass. The apparent importance of such forage species as golden shiners, red shiners, gizzard shad, and several sunfish species indicates that management of game fish could be accomplished indirectly through the management of these forage species.

Since, in most cases, biological variables were more important than physical or limnological conditions, management of flood prevention lakes should be most successful through manipulation of the biological parameters. Population manipulation through stocking or selective removal of certain species could be an effective means of improving the size and species composition. Certain habitat manipulations would favor some species, e.g., management to decrease turbidity would likely favor largemouth bass and sunfish.

Management of flood prevention lakes would also be most successful when techniques are directed toward 1 species or group of species. This study revealed that sunfish and bass are most adapted to, and should be best managed, in deep, clear lakes with high shoreline development. In contrast, catfish will be most successful in the shallower, more turbid lakes. White crappie management, however, would most likely be accomplished through management of bass and sunfish, since stabilization of water levels is virtually impossible in flood prevention lakes. While each of these species occurred in lakes of all types, management efforts should be directed towards the species that are best adapted to the conditions of a particular lake.

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