Species Diversity and Distribution of Fish in Lake Nicaragua

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INTRODUCTION

The results of a preliminary study of the abundance, diversity and distribution of some of the fish species in Lake Nicaragua are presented here. These parameters have received little attention from investigators working on the lake.

A frequently used measure of species diversity is the Shannon-Weiner diversity index. It measures the degree of uncertainty of predicting the species identity of a randomly selected individual (Pielou, 1966). Lloyd and Ghelardi (1964) indicated that species diversity indices are influenced by both the species number, or "richness", and the species "evenness", or relative number of individuals of a species in a given habitat. They proposed a measure of species evenness to facilitate comparisons between habitats for which species diversity indices have been calculated. Horn (1966) proposed an index to measure the "overlap" between samples taken from different habitats. This index is an objective measure of the dissimilarity, or heterogeneity, of a set of samples.

In this study the indices of species diversity, evenness and overlap of trawl samples obtained along the depth gradient in Lake Nicaragua are compared. The indices were computed on the proportions of biomass of each species in the samples from a specified depth.

METHODS

Between March and May, 1972, samples were collected at 92 trawling stations in Lake Nicaragua. The stations were separated from each other by a distance of 5 nautical miles. Samples were collected by towing a 45-foot semi-balloon shrimp trawl for 30 minutes at a speed of approximately 3 knots. Depths were obtained at each station by a Simrad echo-sounder mounted in the collecting vessel.

The total catch of the trawl at each station was evenly divided among a number of fish baskets depending on the size of the total catch. One basket was then randomly designated the sample for that station. Each sample was first weighed, then all the fish were identified and sorted to species. Finally the weight of each species in the sample was obtained. Large fish such as gar, *Lepisosteus tropicus*, and snook, *Centropomus parallelus*, were removed from the total catch prior to dividing it among the baskets, since they often did not fit inside the baskets. They were weighed individually and these figures were then added to the total catch and sample figures to assure their proper proportions of biomass in the study. The single incidence of a sawfish, *Pristis perotteti*, was ignored since no estimate of its weight was obtained. Individuals of the genus *Rhamdia* (Pimelodidae) were considered as being members of a single species due to difficulties in rapid identification in the field.[1]

The total catches of the trawl varied from 40 to 280 pounds ($\bar{x}$ = 170 pounds). The weights of the samples ranged from 10 to 45 pounds ($\bar{x}$ = 30 pounds) and normally represented 10 to 15% of the total catch for each station.

There was a substantial amount of sampling error introduced in both the sample and individual species weights at some stations due to vessel instability during periods of inclement weather. Other sources of error such as the presence of twigs, clam shells and excess water in the samples, were minimized but not totally eliminated. Because trawling equipment and strategies are selective of the size and type of fish captured, the results of this study do not present a completely accurate description of the fish community of the lake. It is most likely that both small fish (*e.g.*, Characidae, Poeciliidae) and large fish (*e.g.*, Carcharhinidae, Pristidae, Lepisostidae, etc.) were not adequately represented in the samples due to trawl selectivity. In addition, the type of trawl used is designed to operate in benthic areas free of rock outcroppings and similar obstructions. Approximately 10% of the lake's bottom area could not be sampled due to these limitations. Based on the soundings taken during this study the lake has an estimated mean depth of 40 feet and a soft mud bottom with few breaks in relief.

CALCULATIONS

The Shannon-Weiner diversity index, H', is an estimate of the average diversity of a sample where:

$$H' = -\sum_{i=1}^{s} p_i \log p_i;$$

p_i = proportion of biomass of the ith species in the population; s = total number of species in the sample (Pielou, 1966).

The species evenness ratio (J') is the ratio of the observed species diversity (H') to the maximum possible for the same number of species in the sample (log S). It is expressed as:

$$J' = H'/\log S.$$

If J' = 1, the biomasses of the individual species are evenly distributed among all of the species in the sample.

[1]Two species of *Rhamdia* were present in samples taken from previous trawling operations at a variety of depths in the lake (W. Bussing, pers. comm.).

To calculate the amount of overlap of biomass of a given number of species between samples, that is, to determine the habitat preference of different species, the index of heterogeneity (R_h)is utilized, where:

$$R_h = 1 - \frac{\sum_{i=1}^{s} (x_i + y_i)\log(x_i + y_i) - \sum_{i=1}^{s} x_i \log x_i - \sum_{i=1}^{s} y_i \log y_i}{(X + Y)\log(X + Y) - X \log X - Y \log Y},$$

x_i = proportion of biomass of species i in sample X; y_i = proportion of biomass of species i in sample Y. Where data are in the form of frequencies, X = Y = 1, x_i and y_i represent the proportions of the respective samples composed of species i (Horn, 1966). When two samples are from the same habitat, R_h = O.

H′ and J′ were calculated for each sample, all samples were grouped by depth to the nearest fathom and the mean values of H′ and J′ were obtained for each fathom. R_h was calculated by pairing the mean proportions of biomass for each species as grouped by depth to the nearest fathom.

Results

Species diversity and evenness

In total, thirteen species were identified from the trawl samples. They are listed in Table 1 with their respective family names.

Table 1. Family and species of fish identified from trawl catches in Lake Nicaragua, March to May, 1972.

Family	Species
Clupeidae	*Dorosoma chavesi*
Pimelodidae	*Rhamdia* spp.
Cichlidae	*Cichlasoma nicaraguense*
	Cichlasoma longimanus
	Cichlasoma citrinellum
	Cichlasoma centrarchus
	Neetroplus nematopus
Characidae	*Roeboides guatemalensis*
	Bramocharax bransfordi
	Brycon guatemalensis
Eleotridae	*Gobiomorus dormitor*
Lepisostidae	*Lepisosteus tropicus*
Centropomidae	*Centropomus parallelus*

For the 92 samples, species diversity ranged from 0.61 to 2.06 ($\bar{x}$ = 1.43; S.D. = 0.23). The mean species diversity indices by depth are presented in Figure 1 and Table 2. Analysis of variance shows the difference among sample means to be significant ($F_{H'} = 20 > F_{0.95} = 1.35$). In the bottom half of Table 3 the results of Duncan's multiple comparison test for the means of H′ are presented. The means from the samples 2 through 6 fathoms are not significantly different from each other. Sample means from 7 and 8 fathoms are significantly different from the means of the sets of samples from less than 6 fathoms in all cases, but they are not significantly different from each other. The mean of H′ from 9 fathoms is significantly different from the means of all other sets of samples.

The computed indices of species eveness, J′, ranged from 0.35 to 0.91 ($\bar{x}$ = 0.68; S.D. = 0.13). Figure 2 is a graph of the mean species eveness for all depths. Analysis of variance indicates that the difference among sample means is significant ($F_{J'} = 4.63 > F_{0.95} = 1.35$).

Species overlap of the samples by depth

Table 4 is a tabulation of the mean percentage of biomass of each species in the set of samples for each given depth. In the top half of Table 3 the values of sample heterogeneity, R_h, are presented. These were calculated from the mean proportions of biomass for paired samples as presented in Table 4. The final column in Table 3 presents the total heterogeneity of the samples from the indicated depth against all other samples.

Discussion

Evidence of different habitats

The species diversity index H′, as used in this study, is a measure of the uncertainty of predicting the species identity of a biomass within a given sample. If a set of samples is taken from habitats which are identical in the number of species and the distribution of biomasses among the species, the uncertainty of prediction, or H′, would be nearly the same for each sample. Conversely, a set of samples from habitats with dissimilar numbers of species or distributions would most likely have significantly different indices of H′. As presented in Tables 2 and 3, the species diversity indices of the sets of samples from depths greater than 6 fathoms

Table 2. Values of H′ and J′ for sets of samples from 8 depths.

Depth (fathoms)	No. of samples (n)	H′ $\bar{x}$	H′ s^2	J′ $\bar{x}$	J′ s^2
2	10	1.50	0.11	0.67	0.017
3	10	1.55	0.24	0.67	0.005
4	13	1.61	0.02	0.73	0.010
5	15	1.52	0.07	0.72	0.017
6	19	1.52	0.04	0.73	0.009
7	10	1.25	0.04	0.65	0.007
8	11	1.15	0.08	0.57	0.010
9	4	0.84	0.03	0.50	0.007
	92	1.43	0.06	0.68	0.014

Analysis of variance

Source	SS	df	MS	F	p	SS	df	MS	F	p
Between depths	3.5	7	0.500	20.	<.01	0.35	7	0.050	4.63	<.01
Within depths	2.1	84	0.025			0.91	84	0.0108		
Total	5.6	91				1.26	91			

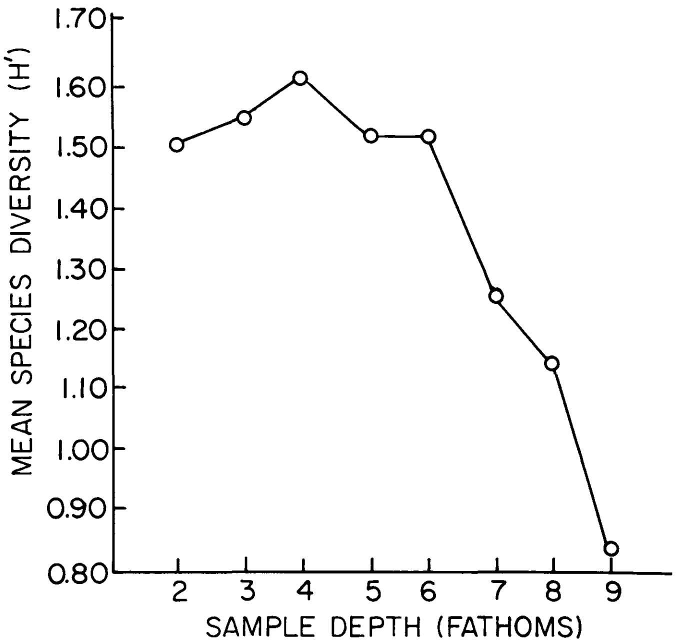

FIG 1. Mean species diversity of sets of samples from 8 depths.

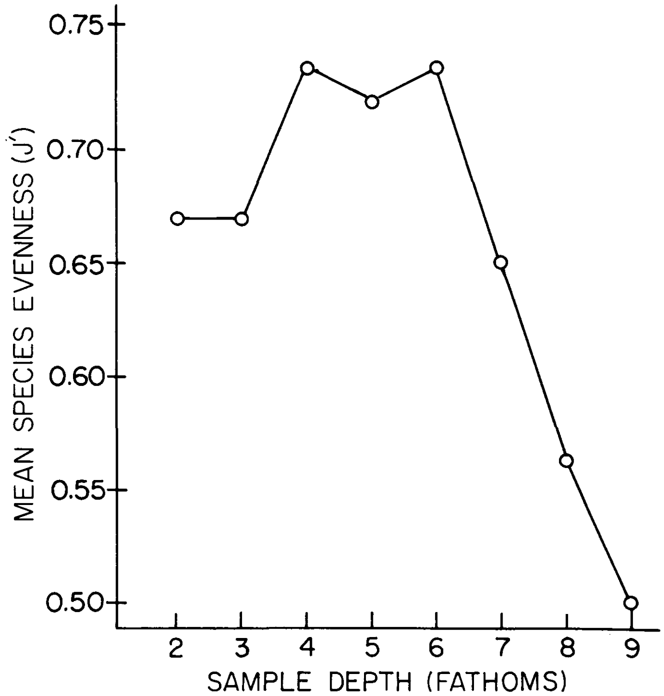

FIG 2. Mean species evenness of sets of samples from 8 depths.

have significantly lower values than the sets of samples from less than 6 fathoms. This is an indication that at least two different habitats were sampled in Lake Nicaragua. As used in this paper, the evenness index, J', is sensitive to differences in the distribution of biomass among the species in a sample. The values of J' calculated for the samples at depths greater than 7 fathoms are lower than those of the samples from less than 7 fathoms. This is, therefore, another indication that at least two different habitats were sampled. In a set of samples of unequally distributed populations, the calculated values of J' would always vary greatly, and not always in direct relationship with H'. Pielou (1966), however, has shown that a direct relationship commonly exists between H' and J'. Comparison of Figures 1 and 2 shows that H' and J' are directly related in the samples taken from Lake Nicaragua.

As shown in Table 3, the value of R_h for paired samples varies from 0.00 to 0.61, an indication that not all the samples are from the same homogeneous habitat. From the final column of Table 3, it can be seen that the samples from 2 and 9 fathoms are the most dissimilar to all others, and, therefore, represent the extremes of the two habitats in terms of species distribution. This, furthermore, indicates that the lower values of H' are not simply caused by a decrease in the evenness component of species diversity, but rather that the samples from 2 and 9 fathoms, among others, have distinct species compositions.

The samples taken at 6 fathoms appear to represent a transition zone between the two distinct habitats. In these samples there is less total heterogeneity than in all other samples from a given depth. The dominants from both habitats show changes in their patterns of biomass distribution at 6 fathoms, and two of the rare species from both habitats are represented in higher proportions of biomass.

It will be necessary to obtain additional samples at smaller intervals of depth to conclusively state whether the samples from 7 and 8 fathoms represent a broadening of the transition zone or a third discrete habitat. The intermediate values of H' and J' for the samples may be interpreted as evidence that the transition zone extends into deeper waters. However, the rather sharp rise in the total heterogeneity of these samples can be cited as evidence for the existence of a discrete third habitat. Further sampling of the fish community of the lake will make possible the

TABLE 3. Results of Duncan's multiple comparison test for the means of H' from 8 depths. Values of R_h obtained by pairing samples.

Sample depth → (fathoms) ↓	2	3	4	5	6	7	8	9	Total heterogeneity
2		0.00	0.08	0.09	0.21	0.35	0.40	0.61	1.74
3	n.s.		0.00	0.02	0.10	0.26	0.25	0.60	1.23
4	n.s.	n.s.		0.04	0.11	0.23	0.30	0.56	1.32
5	n.s.	n.s.	n.s.		0.09	0.19	0.23	0.50	1.14
6	n.s.	n.s.	n.s.	n.s.		0.08	0.11	0.36	1.06
7	sig.	sig.	sig.	sig.	sig.		0.03	0.19	1.33
8	sig.	sig.	sig.	sig.	sig.	n.s.		0.14	1.46
9	sig.	sig.	sig.	sig.	sig.	sig.	sig.		2.96

TABLE 4. Mean percentage of species biomass in sets of samples from 8 depths. P = species present but less than 0.1%.

	Depth (fathoms)							
Species	2	3	4	5	6	7	8	9
D. chavesi	32.7	32.5	36.2	39.1	31.9	30.4	26.7	18.7
C. longimanus	27.5	27.9	18.4	15.8	5.9	2.3	0.9	0.2
C. citrinellum	12.5	12.3	8.6	9.0	8.4	7.2	3.3	P
C. centrarchus	1.5	3.1	6.6	4.3	3.8	0.4	0.5	--
B. bransfordi	2.1	1.9	0.9	0.2	0.1	P	0.3	--
B. guatemalensis	0.2	--	P	--	0.1	--	P	--
N. nematopus	0.4	0.5	0.6	P	P	--	--	--
L. tropicus	8.1	4.8	1.4	1.2	--	0.2	--	--
C. nicaraguense	8.6	9.9	17.9	18.6	25.0	18.3	18.5	2.8
R. guatemalensis	2.3	2.3	2.0	2.7	4.3	0.6	0.5	--
Rhamdia spp.	1.8	2.5	3.8	7.5	17.9	39.2	46.6	69.8
G. dormitor	1.3	0.7	0.5	0.4	0.9	1.5	1.8	4.9
C. parallelus	1.0	1.8	3.2	1.3	1.7	0.3	1.0	3.1

description of additional habitats which lie beyond the boundaries already delineated. In particular, the shoreline, midwater and rocky zones of the lake probably represent habitats distinct from that of the open water, which was sampled in this study.

Species associations of the two habitats

The two habitats, hereafter designated "shallow benthic" and "deep benthic," extend from 2 to 5 fathoms and 7 to 9 fathoms, respectively. A summary of the species associations by habitat inferred from the relative proportions of biomass in the samples is as follows:

(1) The shallow benthic habitat is dominated by *Dorosoma chavesi.* In decreasing order of biomass are *Cichlasoma longimanus, Cichlasoma citrinellum, Lepisosteus tropicus, Cichlasoma centrarchus, Bramocharax bransfordi, Neetroplus nematopus* and *Brycon guatemalensis.*

(2) *Cichlasoma nicaraguense* and *Roeboides guatemalensis* are present in both habitats as rare species. In the transition zone at 6 fathoms they are present at their greatest proportions of biomass.

(3) The deep benthic habitat is dominated by *Rhamdia* spp., especially at 9 fathoms. *D. chavesi* is abundant, but in decreasing proportions with increased depth. Surprisingly, *Gobiomorus dormitor*, often seen at night at the surface of shallow waters, is increasingly abundant with depth. *C. citrinellum* is present in the deep benthic, but in smaller proportions than in the shallow benthic. *C. longimanus* and *C. centrarchus* are of minimal importance in the deep benthic.

(4) In the samples taken, *Centropomus parallelus* shows no distinct pattern of biomass proportions with respect to depth.

Conclusions

Significant differences in the species diversity, evenness and species overlap indices for trawl samples from Lake Nicaragua indicate that the samples were taken from at least two different habitats with distinct fish associations.

The shallow benthic habitat has a higher index of species diversity. The proportion of species biomass is more evenly divided among the total number of species in this habitat. Samples from this habitat are dominated by *D. chavesi.* The deep benthic habitat has a very low species diversity and evenness index. The samples from the deepest waters are composed almost exclusively of fish of the genus *Rhamdia.* It is postulated that a transition zone exists between the two habitats.

A more extensive and intensive sampling program along the depth gradient of the lake and including the shoreline, mid-water and rocky zones of the lake would make possible a more complete description of the structure of the fish community of the lake.

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Summary

Indices of species diversity, species evenness and overlap of species composition were calculated for 92 samples of fish along the depth gradient of the benthic zone of Lake Nicaragua. The indices were computed on the proportion of biomass of each species in the samples. The results indicate that two different habitats were sampled in the study. Samples from the "shallow benthic" habitat, between 2 and 5 fathoms, are dominated by *Dorosoma chavesi.* Samples from the "deep benthic" habitat, which extends from 7 to 9 fathoms, are dominated by *Rhamdia* spp. A transition zone between the two habitats is evidenced in the samples from 6 fathoms. Further sampling is necessary to describe adequately the other major habitats of the lake.

Resumen

Se estudiaron 92 muestras de pescado a lo largo de una gradiente de profundidad en la zona bentónica del lago de Nicaragua y se obtuvieron índices de diversidad, uniformidad y traslape en la composición de las especies en las muestras. Los índices se calcularon en proporción a la biomasa de cada especie en las muestras. Los resultados indican que se tomaron muestras de dos hábitats distintos. Las muestras del hábitat "bentónico poco profundo", de 2 a 5 brazas de profundidad, tienen a *Dorosoma chavesi* como especie dominante, mientras que en las del "bentónico profundo" (de 7 a 9 brazas) domina *Rhamdia* spp. Las muestras de 6 brazas indican una zona de transición entre ambos hábitats. Será necesario un programa de muestreo mas amplio para describir adecuadamente los otros ambientes del lago.

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