Fishermen

The States reported nearly 12 million salt-water fishermen for 1965. This figure includes nonresidents so there is some duplication. Some 6 million or nearly half of the marine fishermen were reported from Florida. The data were based on a comprehensive survey by the Governor's Committee on Recreational Development (1963). The survey contains projections to the year 2000. By 2000, the number of marine fishermen will increase by 125 percent and reach 29.4 million.

Stocking

Excluding anadromous species, no marine fish were stocked in the oceans in 1965. During the latter part of the 19th century and until about 1950, billions of marine fishes were stocked annually along the Atlantic Coast. During 1936, the U. S. Bureau of Fisheries stocked 2.2 billion fry including Atlantic cod, flounder, haddock, herring, mackerel, pollock, and American shad. At least 8 of the 23 coastal States are considering stocking marine and additional anadromous fishes. The States which are considering stocking of striped bass include Delaware, Louisiana, Maryland, Massachusetts, and Virginia. Louisiana is considering stocking croaker, pompano, redfish, sleeper, snook, and spotted sea trout. Maryland and Virginia are also considering species other than striped bass. The State of Washington plans to stock chinook and coho salmon in marine waters.

Fishery biologists are confronted with two problems with respect to stocking hatchery fish in the oceans.

First are the problems associated with the culture of marine species. New hatchery and rearing facilities would be required. The rearing of marine species to fingerling or yearling size would probably involve new methods of feeding, handling, and disease control.

The second major problem would be evaluation of the stockings. This would involve marking of most of the fish initially stocked and periodic recovery of marked fish to determine growth and survival rates.

SPECIES DIVERSITY SPECIES ABUNDANCE OF FISH POPULATIONS: AN EXAMINATION OF VARIOUS METHODS

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ABSTRACT

Twenty sets of fish collection data were used to compare seven diversity indices. The data sets were chosen to represent the wide variation in habitat, ecologic condition, salinity, as well as other factors, encountered in fishery work.

Cross comparisons of several index rankings were made and the dependencies of the various indices discussed. Variation of index score with number of species and with sample size was examined. Results indicate four indices may be applied to fishery work.

INTRODUCTION

Although many diversity indices have been suggested scant attention has been paid to the application of these measures to fish populations and assemblages. The fishery worker is at a disadvantage in this regard and historically has relied on species lists to report his findings. This paper examines and compares seven such indices and evaluates the potential usefullness to the fishery scientist.

Diversity indices have been shown to be useful measures of natural populations (ex. Menhinick, 1964; Wilhm, 1967; Preston, 1948; Fisher et al. 1943). In most instances, a value (d) is derived from the relationship of number of species (S) available and total number of individuals (N) collected. Gleason (1922) proposed the following as a measure:

$$d = \frac{S}{\log N} \qquad (a)$$

Margalef (1951) modified the above to the following form:

$$d = \frac{S-1}{\text{Natural Log } N} \qquad (b)$$

Margalef (1956) in a latter paper used a measure derived from information theory.

$$d = \frac{1}{N} \text{ Natural log } \left(\frac{N!}{(N_1!, N_2! \ldots N_n!)} \right) \qquad (c)$$

Menhinick (1964) proposed two indices as given below:

$$d = \frac{\text{Log } S}{\text{Log } N} \qquad (d)$$

and

$$d = \frac{S}{(N)^{1/2}} \qquad (e)$$

Williams (1944, 1947, 1953) found that collection data could be fit to a logarithmic series and that diversity could be measured as "alpha" in the following equation:

$$S = a \text{ Natural log } \left(1 + \frac{N}{a}\right) \qquad (f)$$

McErlean & Mihursky (1968) equate diversity with the slope in the equation:

$$\text{Log } N = d \text{ (Species Rank)} + K \qquad (g)$$

METHODS

These seven indices were calculated for 20 sets of fish collection data obtained from a wide variety of sources. (see table 1 of McErlean & Mihursky, 1968). The 20 sets were chosen to reflect the wide variety of collecting gears, habitats, salinity conditions and to represent differing ecologic conditions including index variation with pollutional addition. The number of species in a given sample ranged from 8 to 44 whereas the total number collected ranged from about 200 to 45,000. For a given index the 20 sets were arranged from most to least abundant for the purpose of cross correlation (Rank correlation) and assessing variation in ordering. Also, for each set of data, normal regressions were run pairing index value with both number of species and number of individuals. In this manner index value may be viewed as a function of sample size or number of species present.

RESULTS

Index scores for the seven formulations are given in Table 1 along with assigned ranks in parenthesis. Variation of ranks assigned to a given set of data was measured by coefficient of variation (C.V.). The least variable was #9, an estuarine otter trawl series; the most variable was #18, a fresh water control station used in a pollution study. Ranks 1 and 2 were somewhat constant throughout as was rank 20.

These results are not as instructive as the data given in Table 2. This table gives rank correlations of both Margalef indices and McErlean and Mihursky to all others. The highest rank correlations occur between these three with each other and with Gleason's index; itself a generic form of Margalef (1951). Williams alpha is poorly correlated with these three and both Menhinick formulations are also low in comparison. These data suggest that the following are somewhat equivalent in rank

TABLE 1

Data Set	Total Number Collected: Species	Total Number Collected: Individuals	Gleason $\frac{S}{\text{Log } N}$ (a)	Margalef $\frac{S-1}{\ln N}$ (b)	Margalef Information (c)	Menhinick $\frac{\text{Log } S}{\text{Log } N}$ (d)	Menhinick $\frac{S}{(N)1/2}$ (e)	Williams Alpha (f)	McErlean & Mihursky Slope (g)	Coefficient of Variation (CV)
1	20	12,159	4.90 (10)	2.02 (12)	1.02 (15)	.319 (14)	.181 (16)	2.43 (11)	-.195 (10.0)	.194
2	16	45,825	3.43 (16)	1.40 (16)	1.24 (11)	.258 (19)	.075 (19)	4.58 (5)	-.301 (19.0)	.284
3	22	7,817	5.66 (7)	3.15 (7)	1.87 (5)	.344 (12)	.249 (12)	2.35 (12)	-.121 (6.0)	.360
4	17	2,808	4.93 (9)	2.84 (8)	1.78 (6)	.357 (9)	.321 (11)	2.81 (9)	-.191 (8.0)	.176
5	10	219	4.27 (11)	1.67 (13)	1.07 (13)	.427 (4)	.676 (4)	2.21 (13)	-.251 (16.5)	.453
6	9	213	3.86 (14)	1.49 (15)	.80 (18)	.408 (5)	.617 (6)	2.15 (14)	-.251 (16.5)	.402
7	9	480	3.36 (17)	1.30 (19)	.19 (19)	.354 (10)	.411 (8)	1.93 (15)	-.260 (18.0)	.294
8	21	2,587	6.16 (5)	3.59 (5)	1.68 (8)	.387 (8)	.413 (9)	5.18 (4)	-.157 (7.0)	.289
9	16	17,766	3.76 (15)	1.53 (14)	.82 (16)	.282 (17)	.120 (17)	1.76 (16)	-.248 (14.5)	.076
10	14	16,650	3.32 (18)	1.34 (18)	.81 (17)	.273 (18)	.109 (18)	1.67 (19)	-.248 (14.5)	.083
11	9	35,156	1.98 (20)	.76 (20)	.13 (20)	.209 (20)	.048 (20)	3.52 (7)	-.497 (20.0)	.271
12	18	1,587	5.63 (8)	3.39 (6)	1.67 (9)	.394 (7)	.452 (7)	3.18 (8)	-.194 (9.0)	.144
13	15	5,621	4.00 (12)	2.21 (11)	1.09 (12)	.315 (15)	.200 (14)	1.69 (17)	-.204 (13.0)	.126
14	12	1,230	3.88 (13)	2.30 (10)	1.39 (10)	.350 (11)	.342 (10)	2.46 (10)	-.240 (11.0)	.104
15	36	2,340	10.71 (2)	6.43 (2)	2.13 (3)	.464 (2)	.744 (3)	5.86 (3)	-.072 (2.0)	.218
16	25	1,603	7.81 (3)	4.72 (3)	1.75 (7)	.438 (3)	.625 (5)	4.02 (6)	-.114 (5.0)	.354
17	44	2,614	12.87 (1)	7.72 (1)	2.51 (1)	.480 (1)	.861 (2)	6.55 (1)	-.066 (1.0)	.342
18	24	16,646	5.69 (6)	2.37 (9)	2.41 (2)	.327 (13)	.186 (15)	1.67 (18)	-.112 (4.0)	.624
19	8	1,512	2.52 (19)	1.39 (17)	1.04 (14)	.283 (16)	.206 (13)	1.06 (20)	-.230 (12.0)	.205
20	21	203	6.34 (4)	3.77 (4)	2.08 (4)	.399 (6)	1.470 (1)	6.28 (2)	-.105 (3.0)	.472

TABLE 2

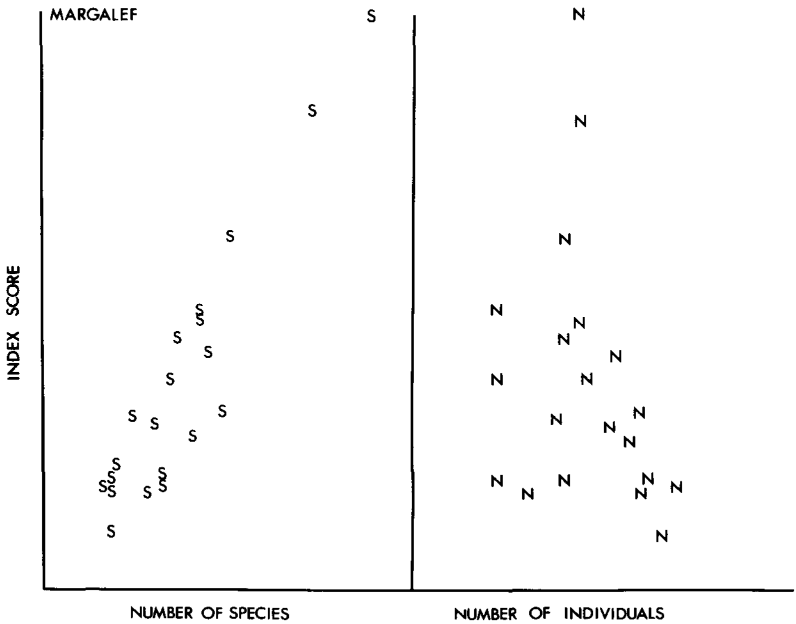
	Gleason	Margalef	Margalef	Menhinick	Menhinick	Williams	McErlean & Mihursky
	$\frac{S}{\text{Log } N}$	$\frac{S-1}{\text{Log } N}$	Information	$\frac{\text{Log } S}{\text{Log } N}$	$\frac{S}{(N)1/2}$	Alpha	Slope
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
RANK CORRELATION WITH							
Margalef (c)	.88	.89		.55	.88	.52	.90
Margalef (b)	.97		.89	.73	.76	.64	.92
McErlean & Mihursky (g)	.91	.92	.90	.59	.55	.46	
CORRELATION OF INDEX VALUES AND							
Number of Species	.96	.93	.80	.60	.41	.69	-.77
Log Number of Individuals	-.27	-.19	.29	-.69	-.56	.02	.07

assignment: Margalef information (c), Margalef (b), McErlean-Mihursky (g), and Gleason (a).

Table 2 gives correlation coefficients of the seven indices with total number collected and total number of species for the 20 sets of data. Gleason's index (a) is most highly correlated with number of species followed by Margalef (b). It is interesting that the formula derived from information theory (c) is so highly correlated with number of species. Both Menhinick (d,e) formulations and Williams (f) are less highly correlated than with the number of species collected.

In respect to the number of individuals collected both (d) and (e) appear somewhat linear although negative in sign. Only Margalef (c) and Williams (f) yield positive correlation coefficients but these may not be significant. Until more data have been examined it is probably better to list (c), (b), (g), (f) and (a) as independent of sample size.

Scatter diagrams of index value (Figures 1-7) and N and S suggest that regression analysis (ie. linear) may be inappropriate in some cases. This is particularly true of (g) values (Fig. 7) correlated with number of species. The plot suggests a negative hyperbola.



DISCUSSION AND CONCLUSIONS

Of the seven indices computed four [(c), (b), (g), (a)] agree well with each other. Presumably these are equivalent and could be used interchangeably. Each is well correlated with number of species and tentatively independent of sample size at least with the 20 data sets tested. That Margalef information index is highly correlated with number of species appears disparate since the arrangement of numbers within a species is supposed to override a simple species-number effect. That is, low index values should result if the numbers collected are clustered within a few species even though many species are present.

If the four indices mentioned above are compared on the basis of ease of calculation a and b would be equivalent followed by g and then c. For these data and unless other factors are to be computed (ie, D max., D min. etc.) the extra effort does not seem necessary. Margalef's other index (b) emerges as possibly the best for these data. It is simple to calculate and interpret, is highly correlated with number of species present and apparently independent of sample size.

Mc Erlean and Mihursky's index (b) is highly correlated with both Margalef indices and with number of species; it also appears to be independent of sample size. It is also a graphic method and this may be an advantage, with fish data, over the other formulations studied. Where computer assistance is not available it might be an alternate to information theory analysis.

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LITERATURE CITED

Fisher, R. A., A. S. Corbet and C. B. Williams, 1943. The relation between the number of species and the number of individuals in a random sample from an animal population. J. Animal Ecol. 12:42-58.

Gleason, H. A., 1922. On the relation between species and area. Ecology 3:158-162.

Margalef, R., 1951. Diversidad de Especies en Comunidades Naturales. Pro. Ins. Biol. Apl. 9,5.

_________. 1956. Information y Diversidad Especies en las Comunidades de Organisms. Inv. Pesq. 3,99.

McErlean, A. J. and J. A. Nihursky, 1969. (Mimeo). Graphical and Mathematical Analysis of Species Diversity-Species Abundance of Fish Populations. U of Md., Natural Resources Inst. Hallowing Point Station, Prince Frederick, Md. Natural Resources Inst. Ref. No. 69-103.

Menhinick, E.F., 1964. A comparison of some species-individuals diversity indices applied to samples of field insects. Ecology 45:859-861.

Preston, F. W., 1948. The commonness, and rarity, of species. Ecology 29: 254-283.

Wilhm, J. L., 1967. Comparison of some diversity indices applied to populations of benthic macroinvertebrates in a stream receiving organic wastes. J. Water Pollut. Control Fed. 39(10) Part I:1673-1683.

Williams, C. B., 1944. Some applications of the logarithmic series and the index of diversity to ecological problems. Jour. Ecol. 32:1-44.

_________. 1947. The logarithmic series and its application to biological problems. Jour. Ecol. 34:253-272.

_________. 1953. The relative abundance of different species in a wild animal population. J. Animal Ecol. 22:14-31.