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Predicting the Standing Crop of Fish in Michigan Lakes

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PREDICTING THE STANDING CROP OF FISH IN MICHIGAN LAKES[1]

By James C. Schneider

Abstract

Data on the standing crop of fish in Michigan lakes were reanalyzed using multiple correlation and regression techniques. A model previously used to successfully predict fish harvest rates also gave improved predictions of fish standing crops. However, the best model tested, explaining 56% of the variation in fish crops, included these parameters: panfish index, climate index, $1 \div \log_{10}$ Secchi disk transparency, $\log_{10}$ vegetation index, $\log_{10}$ area, and rough fish index. This model is much better than the first, and appears to give reasonable and useful predictions.

Introduction

In an earlier report (Schneider 1973) I summarized information collected by research personnel on the standing crops of fish in Michigan lakes. I also attempted to correlate the total biomass of fish with certain simple physical-chemical indices of lake productivity: alkalinity, mean depth, area, and alkalinity ÷ mean depth (a correlate of the morphoedaphic index). The correlation was found to be poor ($R^2 = 0.25$; i.e., 25% of the variation in fish biomass was accounted for by the physical-chemical indices) unless the statistical requirements were "strained" and the data were

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[1] Contribution from Dingell-Johnson Project F-35-R, Michigan.

stratified according to type of fish population and type of habitat; consequently, the predictive equations were of limited value.

Subsequently, data from Michigan lakes on fish harvest rates were summarized and analyzed (Schneider 1975). These data were highly correlated (R^2 = 0.78 to 0.88) with panfish index, climate index, Secchi disk transparency, vegetation index, mean depth, and area--but principally with the first four of these. The biological significance of the first four of these parameters was conceived as follows: Secchi disk transparency and vegetation index reflect the standing crops of plankton and higher aquatic vegetation, respectively; the climate index reflects length of growing season and turnover rate; and the panfish index reflects the trophic structure of the fish population and the efficiency with which limnological production is converted into fish. Thus the improved model applied to the data on fish harvest was not only statistically sound, but also biologically meaningful. The purpose of this report is to test the improved model on the fish standing crop data.

Methods

Schneider (1973) listed the study lakes and populations, and gave the methods used for deriving adjusted estimates of fish standing crops in pounds per acre. One population, Jewett Lake, 1958 (Patriarche 1968), was added to the list and small corrections were made to three other estimates (Table 1). Schneider (1973) also gave data on lake area (acres), mean depth (feet), alkalinity (ppm), and alkalinity ÷ mean depth which will not be repeated here. Additional parameters used in the reanalysis were panfish index, climate index, Secchi disk transparency (in feet), vegetation index, oxygen-thermal type, and rough fish index (Table 1). Information on these parameters was obtained from publications, Michigan Department of Natural Resources surveys on file, or a general knowledge of the waters. A complete set of data was obtained for 61 populations in 55 different lakes and a partial set of data was available for 65 populations.

All of the additional parameters except the rough fish index were defined and discussed by Schneider (1975). Briefly, the panfish index was the fraction of the total fish standing crop (instead of total fish harvest, as used in the 1975 analysis) comprised of bluegills (*Lepomis macrochirus*), pumpkinseeds (*Lepomis gibbosus*), crappies (*Pomoxis* spp.), or hybrid sunfish;[2] the climate index was the average cumulative growing-degree-days above a base of 55 F (Van Den Brink et al. 1971); the vegetation index was the relative abundance of submerged vegetation (ranked 1 through 5 for sparse through abundant); and the oxygen-thermal type classified lakes according to stratification and dissolved oxygen (typed 1 through 6 for lakes with at least 2 ppm dissolved oxygen at the bottom of the hypolimnion in midsummer through unstratified lakes experiencing fish kills due to oxygen deficits). The new parameter, the rough fish index, was defined as the fraction of the total fish biomass comprised of bullheads (*Ictalurus* spp.), carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), and suckers (*Catostomus* spp.). These species are low on the food chain and developed very high standing crops in some of the study lakes. The rough fish index was not used in the 1975 analysis because those species contributed little to the sport fish harvest.

The values for fish standing crop and for some of the parameters were transformed by $\log_{10}$ because previous experience indicated this tended to normalize and linearize the data for statistical analysis. The reciprocal of $\log_{10}$ Secchi was used so that a positive, rather than a negative, correlation would result. Multiple linear correlations and regressions were performed with the assistance of an Amdol 360 computer to determine which parameters were most strongly related to $\log_{10}$ fish standing crop and to derive predictive equations.

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[2] For all practical purposes the abundance of bluegill is the only important part of the panfish index. Pumpkinseeds, crappies, and hybrid sunfish were included because they had been combined with bluegill in the catch estimates derived from the mail survey.

Results

Simple correlations indicated that fish standing crop was moderately related to all the parameters except area and rough fish index (Table 2). However, multiple correlations indicated that these two parameters were important and that mean depth, oxygen-thermal type, alkalinity, and alkalinity ÷ mean depth could be deleted with very little loss. When these four parameters were deleted, R^2 only declined from 0.59 to 0.56. Unexpectedly, the analysis indicated that Secchi disk transparency was unimportant also (compare multiple correlations 3 and 4 in Table 2). Thus equation 4, Tables 2 and 3, includes only the statistically significant parameters. However, considering the importance of Secchi disk transparency for predicting fish harvest rates and its logical basis, it seems best to retain it in the model. Thus equation 3, Table 3, is judged to be the best, overall, for predicting fish standing crops.

Considering only the parameters most useful for predicting fish harvest rates (multiple correlations 1 and 2), 44 to 48% of the variation in fish standing crops was explained. This is a considerable improvement over the 25% (for pooled data) obtained in the 1973 model but is not as satisfactory as the 78 to 88% obtained in the 1975 analysis of fish harvest rates.

Addition of the rough fish index improved the fit of the model to the fish biomass data by about 8%, and was a worthwhile addition on both statistical and biological grounds. The total amount of variation accounted for, 56%, is probably as good as can be expected considering the quality of the input data, the naturally high variation in fish standing crops from year to year, and the complexity and diversity of aquatic ecosystems.

The best model developed (equation 3, Table 3) includes panfish index, climate index, $1 \div \log_{10}$ Secchi disk transparency, $\log_{10}$ vegetation index, $\log_{10}$ area, and rough fish index. It seems to provide reasonable rough estimates of fish standing crops under a wide variety of conditions and is superior to the earlier model in utility, statistics, and concept.

The metric system (kilograms, hectares, meters) equivalent of equation 3 is:

$$\log_{10} \text{standing crop} = 1.1039 + 0.3595 \text{ panfish index} + 0.0336 (1 \div \log_{10} \text{Secchi}) + 0.4520 \log_{10} \text{vegetation index} + 0.000292 \text{ climate index} - 0.1107 \log_{10} \text{area} + 0.5336 \text{ rough fish index.}$$

Literature cited

Patriarche, Mercer H. 1968. Development and management of bluegill populations in warmwater lakes. Michigan Department of Natural Resources Dingell-Johnson Project F-27-R-4, Work Plan 6, Job 8, Final Report, 6 pp.

Schneider, James C. 1973. The standing crop of fish in Michigan lakes. Michigan Department of Natural Resources, Fisheries Research Report 1794, 35 pp.

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Table 1.--Fish standing crops (pounds per acre), observed (adjusted estimates of Schneider 1973) and predicted (Table 3, equation 3), with Secchi disk transparencies vegetation abundance indices, climate indices, oxygen-thermal types, panfish indices, and rough fish indices for Michigan lakes, ponds, and reservoirs used in the analysis. Additional data given in Schneider (1973).

Lake[a]	Secchi disk (feet)	Vegetation index	Climate index	Oxygen-thermal type	Fish indices[b]		Fish standing crop	
					Panfish	Rough fish	Observed	Predicted
Airport	17	1	1100	3	0.01	0.01	24	25
Cassidy (1966-68)	9	3	2000	5	0.01	0.01	35	67
Ford (1936)	18	3	1300	5	0.01	0.01	86[c]	43
Jewett (1969)	12	3	1300	4	0.01	0.01	62	45
Sand No. 2 (1969)	12	2	1500	3	0.01	0.01	28	42
Section Four	36	1	1300	1	0.01	0.01	47	29
South Twin	13	2	1300	3	0.01	0.01	58	42
Big Bear	13	3	1300	5	0.05	0.50	60[c]	58
Booth	14	2	1300	5	0.01	0.25	36	48
Clear	6	3	1300	5	0.21	0.76	191	155
Cub	10	3	1250	5	0.01	0.35	62	62
De Bruin's			2200		0.27	0.71	301	
Devoe	16	1	1300	3	0.03	0.82	57	56
Dix Pond	10	3	2000	5	0.01	0.01	128	97
East Fish	16	3	1300	3	0.01	0.30	50	61
East Twin	13	3	1300	5	0.08	0.07	48	32
Fitzek			1300	2	0.01	0.09	32	
Ford (1971)	18	3	1300	5	1.00	0.01	40	99
Grebe	9	5	1300	4	0.18	0.46	192	98
Holland	13	3	1000	3	0.18	0.48	137	80
Katherine	10	1	1250	2	0.01	0.01	10	24
Kimes No. 3	13	2	1600	3	0.51	0.26	228	100
Linnbeck	9	3	1200	2	0.08	0.09	48	57
Lodge	6	4	1300	6	0.67	0.18	121	124
Lower Loch Alpine	8	4	2000	5	0.27	0.49	190	198
Marsh	10	3	1250	3	0.01	0.01	52	38
North Basin Twin	27	3	1300	3	0.91	0.01	87	91
North Twin	12	2	1300	5	0.78	0.03	36	68

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Table 1.--continued

Lake[a]	Secchi disk (feet)	Vegetation index	Climate index	Oxygen-thermal type	Fish indices[b]: Pan-fish	Fish indices[b]: Rough fish	Fish standing crop: Observed	Fish standing crop: Predicted
O'Brien	22	3	1300	3	0.04	0.26	45	59
Pike No. 4			1300		0.15	0.27	73	
Pond No. 4			1300		0.01	0.40	113	
Pond No. 24	6	3	2200	5	0.54	0.19	184	171
Rash Pond	6	2	2000	5	0.01	0.01	96	112
Sand No. 2 (1971)	12	2	1500	3	1.00	0.01	12	96
Sand No. 3 (1971)	12	2	1500	5	1.00	0.01	243	97
Scaup	8	4	1300	4	0.18	0.53	45	130
Swanzy	15	2	1100	2	0.06	0.01	52	32
Twin	15	1	1100	2	0.01	0.01	17	22
Upper Loch Alpine	8	4	2000	5	0.17	0.70	301	238
Bear	10	3	2150	4	0.58	0.03	90	109
Cadillac	5	3	1400	4	0.12	0.08	25	45
Cassidy (1964)	9	3	2000	5	0.57	0.13	145	124
Craig	5	5	2100	4	0.71	0.01	350	173
Deep	22	3	1900	2	0.59	0.01	63	100
Fife (1950)	10	4	1500	3	0.63	0.03	95[c]	69
Howe	12	1	1300	5	0.05	0.60	63	58
South Pond	14	1	1300	4	0.81	0.07	58	73
Sugarloaf	11	5	2000	4	0.36	0.05	95	98
Third Sister	8	3	2000	4	0.66	0.03	145	143
Walsh	11	5	2000	4	0.65	0.08	153	175
Whitmore	10	5	1900	3	0.32	0.32	57	108
Wintergreen	4	3	2200	4	0.70	0.02	360	187
Belmont No. 1	8	4	1900	5	1.00	0.01	305	214
Belmont No. 2	8	4	1900	5	1.00	0.01	239	206
Belmont No. 3	8	4	1900	5	1.00	0.01	233	228
Burke	13	2	1800	3	0.36	0.45	100	147
Center	14	1	1400	3	0.90	0.01	284	55
Daggett (1962)	8	3	2100	4	0.84	0.01	151	166
Daggett (1966)	8	3	2100	4	0.99	0.01	198	189
Emerald	9	3	2000	5	0.99	0.01	159	190

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Table 1.--concluded

Lake[a]	Secchi disk (feet)	Vegetation index	Climate index	Oxygen-thermal type	Fish indices[b] Pan-fish	Rough fish	Fish standing crop Observed	Predicted
Ford (1946)	18	3	1300	5	0.99	0.01	204	99
Jewett (1958)	5	3	1300	4	0.77	0.02	100	108
Jewett (1965)	5	3	1300	4	1.00	0.01	93	130
Mill	12	4	2000	4	0.53	0.04	116	103
Sand No. 3 (1969)	17	2	1500	5	1.00	0.01	73	93

[a] Lakes considered more than once are identified by year of fish standing crop estimate.

[b] In lakes where no "panfish" or "rough fish" were present, the indices were set at 0.01 to avoid statistical problems caused by 0.00.

[c] A revision of the observed adjusted standing crop estimate of Schneider (1973).

Table 2.--Simple correlation coefficients between $\log_{10}$ fish standing crop and nine parameters, and partial correlation coefficients and coefficients of determination (R^2) from four multiple correlations of $\log_{10}$ fish standing crop on selected parameters. Sample size was 61 to 65.

Parameter	Simple correlation coefficients	Partial correlation coefficients from multiple correlations			
		No. 1	No. 2	No. 3	No. 4
Panfish index	+0.45	+0.35	+0.32	+0.46	+0.46
Climate index	+0.55	0.30	+0.29	+0.35	+0.39
$1 \div \log_{10}$ Secchi	+0.38	NS	NS	NS	--
Log_{10} vegetation index	+0.46	NS	+0.29	+0.29	+0.32
Mean depth	-0.40	--	NS	--	--
Log_{10} area	NS	--	NS	-0.29	-0.28
Rough fish index	NS	--	--	+0.40	+0.40
Oxygen-thermal type	+0.44	--	--	--	--
Alkalinity	+0.32	--	--	--	--
$\text{Log}_{10} \frac{\text{Alkalinity}}{\text{Mean depth}}$	+0.41	--	--	--	--
R^2		0.44	0.48	0.56	0.55

NS = not statistically significant at the 0.05 level.

-- = the parameter was not included in the multiple correlation.

Table 3.--Regression coefficients for four multiple regression equations relating $\log_{10}$ fish standing crop (pounds per acre) to selected parameters.

Lake characteristic	Equation			
	No. 1	No. 2	No. 3 "Best"	No. 4
Constant	+0.9823	+1.1163	+0.9840	+1.1062
Panfish index	+0.2760	+0.2481	+0.3632	+0.3714
Climate index	+0.00028	+0.00026	+0.00030	0.00033
$1 \div \log_{10}$ Secchi	+0.2144	+0.2289	+0.1990	--
Log_{10} vegetation index	+0.3974	+0.4907	+0.4342	+0.4810
Mean depth	--	-0.00101	--	--
Log_{10} area	--	-0.1039	-0.1065	-0.1032
Rough fish index	--	--	+0.5204	+0.5329