ABUNDANCE INDEX FOR YOUNG-OF-THE-YEAR FISH IN WESTERN LAKE ERIE

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ADMINISTRATIVE REPORT No. 80-8

January 1980

Presented at the Great Lakes Fishery Commission Lake Erie Committee Meeting, Erie, Pennsylvania, February 28, 1978.

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ABSTRACT

This report discusses and presents statistical techniques used to estimate abundance index AI which is expressed as $\log_{10}$ ((catch/10-minute tow) + 1.). Data analyzed are catches of young-of-the-year walleyes, yellow perch, white, bass, freshwater drum, and emerald shiner taken with small mesh 26-ft bottom trawls during 1967-74. A Model II nested ANOVA, with subsampling consisting of replicate tows within visits within stations, is recommended to find AI and its error, even for a coordinated interagency sampling program. A graph and equations are provided to arrive at a reasonable mix of numbers of visits and stations, given relative mean difference, α, (1-β), two replicate tows, and coefficient of variation CV.

INTRODUCTION

The U.S. Fish and Wildlife Service (FWS) assessment program on the abundance of young-of-the-year (YOY) fish in the Western Basin of Lake Erie was initiated in 1959. A YOY abundance index for a species was defined as the arithmetic mean catch/hour computed from all the 10-minute tows with bottom trawls made during a year. The observed trend in yearly index values was used to help judge the status of species, strength of oncoming year classes, and effects of environmental factors on reproductive success. Neither standard error nor confidence interval were computed to measure the uncertainty of an estimated index.

Responsibility for this assessment program was assumed early in the summer of 1975 by the Ohio Department of Wildlife (ODW). Biologists of both agencies met several times during the transition period to refine and standardize the assessment program conducted by the ODW and other agencies. Data collected by all contributing agencies would then be compatible and additive, and consistent interpretations could be made by all users.

As a basis for developing additional guidelines, the Great Lakes Fishery Laboratory (GLFL) has analytically examined the catches of YOY walleyes, yellow perch, white bass, freshwater drum, and emerald shiners for 1967-74. The objectives were:

1. To describe and evaluate the method that has been used by the FWS; compute the error for the estimated mean catch for each species and year by this method.

2. To describe and evaluate a preferred method of estimating the mean catch and its error using the same data base as in Objective No. 1.

3. To develop and recommend guidelines for sampling and data analysis for future estimates of mean catch and its error.

SAMPLING CONCEPTS

Ideally, sampling is planned to fulfill one of these two conditions:

1. A desired statistic is to be estimated with a specified allowable error AE at lowest cost (i.e., fewest number of sample units).

2. A desired statistic is to be estimated with the lowest possible allowable error at a fixed cost (i.e., a given number of sample units).

Applicable variations of these two statements include:

1. How many sample units must be taken if an index of abundance is to be reliable as specified?

2. What is the reliability of an index of abundance as determined from a set number of sample units?

3. How many sample units must be taken in each group or treatment to estimate the difference between their indices of abundance with a specified reliability?

4. How many sample units must be taken in each group or treatment to estimate a set difference between indices with a specified reliability?

5. With what reliability can the difference between indices be stated by taking a set number of sample units?

6. What coefficient of variation CV (a relative index of variability) can be expected for a set number of sample units and specified difference between indices of abundance?

Implicit in the above statements and questions are: (1) the significance level α, or probability of wrongly rejecting a null hypothesis of no difference; (2) whether α is one-tail or two-tail, i.e., whether a statistic is always judged only larger than > (or only smaller than <) a test statistic, or whether it can be > or < the test statistic; (3) the probability β of not detecting a difference if one exists; (4) a measure of variability of the data, such as variance s^2 or coefficient of variation CV; (5) the applicable assumptions for parametric analyses of data including randomness, independence, normality, homogeneity of variance, and additivity; and (6) the reasonable control of technique errors and confounding. Sample size estimates for nested designs can be optimized by also including information on costs such as that for locating sample units, procuring test material, and measuring characteristics of interest.

The sampling specifications given above are not as complex and restrictive as they might appear. Typically the investigator couples specified values of AE, α, and $1-\beta$ (the power function, or power of the test) with an estimate of s^2 or CV (derived from a metameter which is reasonably normal, has homogeneous variance, etc.) to estimate sample size. Theoretically, this procedure involves specific equations for commonly used sampling and experimental designs. In practice, the complete information needed to apply these equations is often lacking or too costly to obtain. Fortunately, reasonably good, conservative approximations can be obtained using a general equation which is the basis for Figure 1. The actual form of this equation will depend upon the application, as illustrated below.

Application 1

Determine the number of sample units needed in each of k groups to be P% (or $1-\beta$) sure of detecting a relative difference of d% between any two of the means at the 5% level of significance (α.05, 2-tail) and an approximate coefficient of variance of CV%. Note: (a) data or error assumed normally distributed, and technique errors controlled; and (b) if k>2, equation is a better estimator than Figure 1.

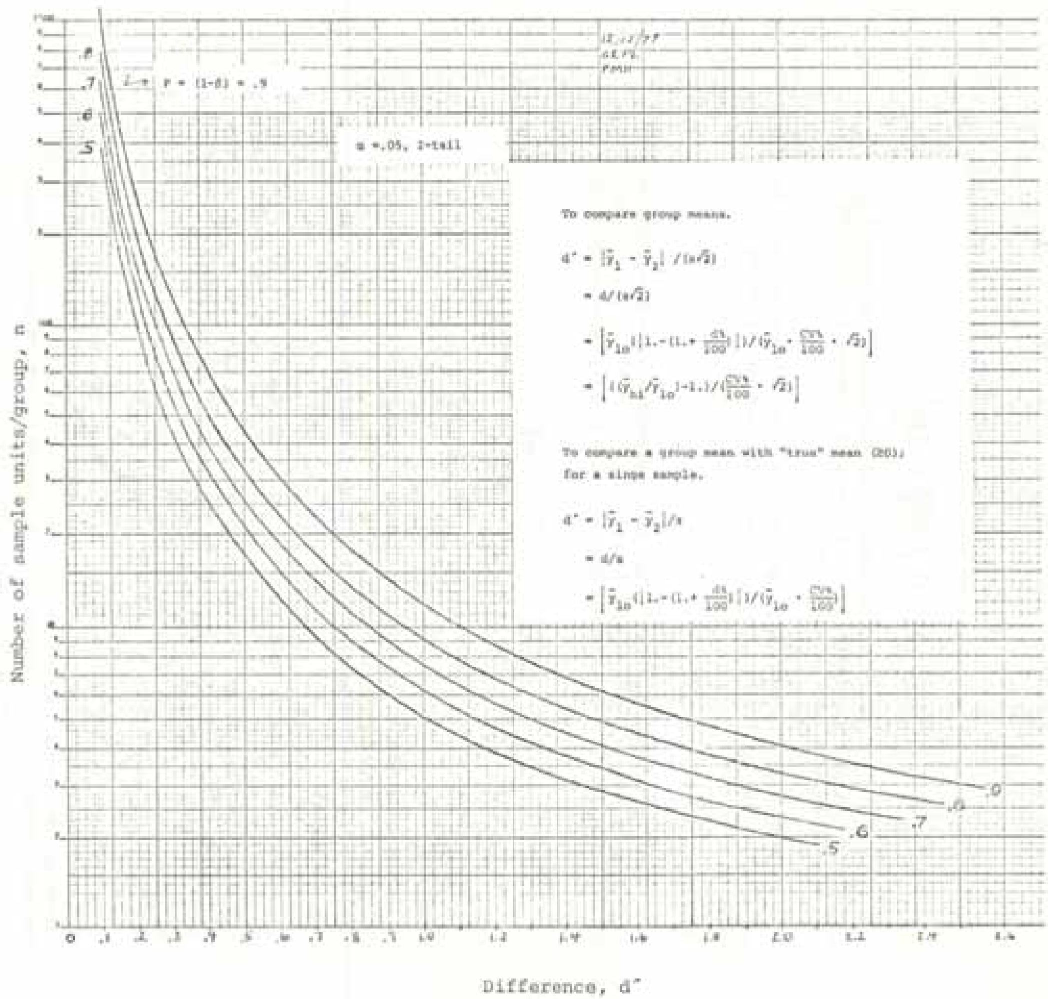

Figure 1. Sample size estimates.

$$n \geq \frac{T^2}{(d')^2} = \frac{\left[t_{.05,\ k(n-1)df} + t_{2\ (1 - \frac{P\%}{100}),\ k(n-1)df}\right]^2}{\left[\bar{y}_{lo}\left(\left|1 - (1 + \frac{d\%}{100})\right|\right) / (\bar{y}_{lo} \cdot \frac{CV\%}{100} \cdot \sqrt{2})\right]^2} \quad [1]$$

$$= \frac{T^2}{\left[((\bar{y}_{hi}/\bar{y}_{lo}) - 1) / (\frac{CV\%}{100} \cdot \sqrt{2})\right]^2} \quad [2]$$

Note: d' is a "relative standardized difference" because $\bar{y}_{lo}$ drops out and the relative difference is related to standard deviation s by the unitless CV.

Alternatively, estimate n from Figure 1 by reading up from the X-axis value d' to the desired curve for P(or $1-\beta$), and then left to the Y-axis value n.

Application 2

Similar to Application 1, but the comparison is between the sample mean and $\bar{Y}$, the true or accepted mean. Note that if $\bar{Y} = 0$, the solution of Equation (2) is simply that for an individual (simple random) sample.

$$n > \frac{T^2}{\left[\bar{y}_{lo}\ \left(\left|1 - (1 + \frac{d\%}{100})\right|\right) / (\bar{y}_{lo} \cdot \frac{CV\%}{100})\right]^2} \quad [3]$$

Application 3

For different α, or for the one-tail test, appropriate values for "$t_{.05}$" are substituted in Equation (1) or (2).

Application 4

If one prefers to make no adjustment for a Type II error (failure to detect a difference if one really exists), the curve for P = 50% (i.e., $1-\beta = .5$) is used in all these applications. In general, as the chance of making a Type I error lessens (α set smaller), the chance of making a Type II error increases, and vice versa. The probability β of a Type II error is related to α, s^2, n, and the difference being tested, so the specified value of β is an obvious generalization for practical purposes.

Figure 1 is not the only way to estimate sample size by coupling information on α, β, s^2 or CV, n, and the difference between means or the ratio of the means (Natrella 1963; Pella and Myren 1974; Thomas 1977). However, Figure 1 is a useful way of presenting these relationships in terms of the information commonly available or predictable. Unquestionably, n is just a reasonable, though generally conservative, estimate of the number of sample units to take in a group. This is because CV is an approximation of the variability found under the conditions or factors that prevail.

Thus, CV might even be a function of the mean square error MS_e in an analysis of variance ANOVA. As was mentioned earlier, the alternative to using an approximate CV is to spend a considerable amount of money and time gathering detailed data on variance and cost and using these values in specific equations suitable for the study design.

POPULATION

Representation of fish abundance in western Lake Erie was obtained from four primary (1, 4, 5, 7) and five secondary (16, 24, 31, 41, 43) sampling stations (Figure 2 and Table 1). Year, season, depth, location, weather, and biological or behavioral factors all influence the variability (variance, s^2).

Over the years these nine stations were consistently most productive of all those sampled in U.S. waters of western Lake Erie. They are centrally located in the zone of commercial fishing which extends from just east of Toledo to about 15 miles east of Station 1. The principal out-flow currents of the St. Clair/Detroit River system pass through the area.

ASSESSMENT TRAWLING

During the FWS assessment program, usually two 10-minute tows or sample units were taken biweekly from mid-June until early November at each station and depth. The assessment included catches made at East Harbor (Station 4) at 10-, 15-, and 20-feet during the 2-day-night series in August and October. Four of the 12 hours trawled each year for this series were after dark. A small mesh 26-foot bottom trawl was used.

ANALYSIS

Method Used to Date (Objective 1)

Yearly indices of abundance for 14 species were computed from 22-32.5 hours of trawl tow data as catch/hour based on individual 10-minute tows. All locations, depths, and sampling periods were used. Arithmetic (i.e., untransformed) catches were analyzed, and no error was computed. Tables 2-6 list the indices by species, station group, and year. The minimum and maximum catches given in column 4 are clues to variability and likely right skew (nonnormality) of the data. Note that when the minimum values of zero are prevalent, there is a good chance that the distribution can not be described for a data set, especially when sample size is small (column 3).

If, indeed, catch/hour was reasonably normally distributed so that parametric statistics for the computation of standard error of the mean applied, the 0.95 confidence limits about the mean are as shown in column 5.

Improved Method, Complete Data Base (Objective 2)

In an attempt to normalize the catch data, the transformation $\log_{10}$ ((catch/hour) + 1) was applied. This metameter is a good approximation of the negative binomial distribution--a random distribution of "rare" events, the occurrence of which are unequally dispersed (i.e., clumpy). The likelihood of a catch, and the magnitude of such a catch, are typical attributes

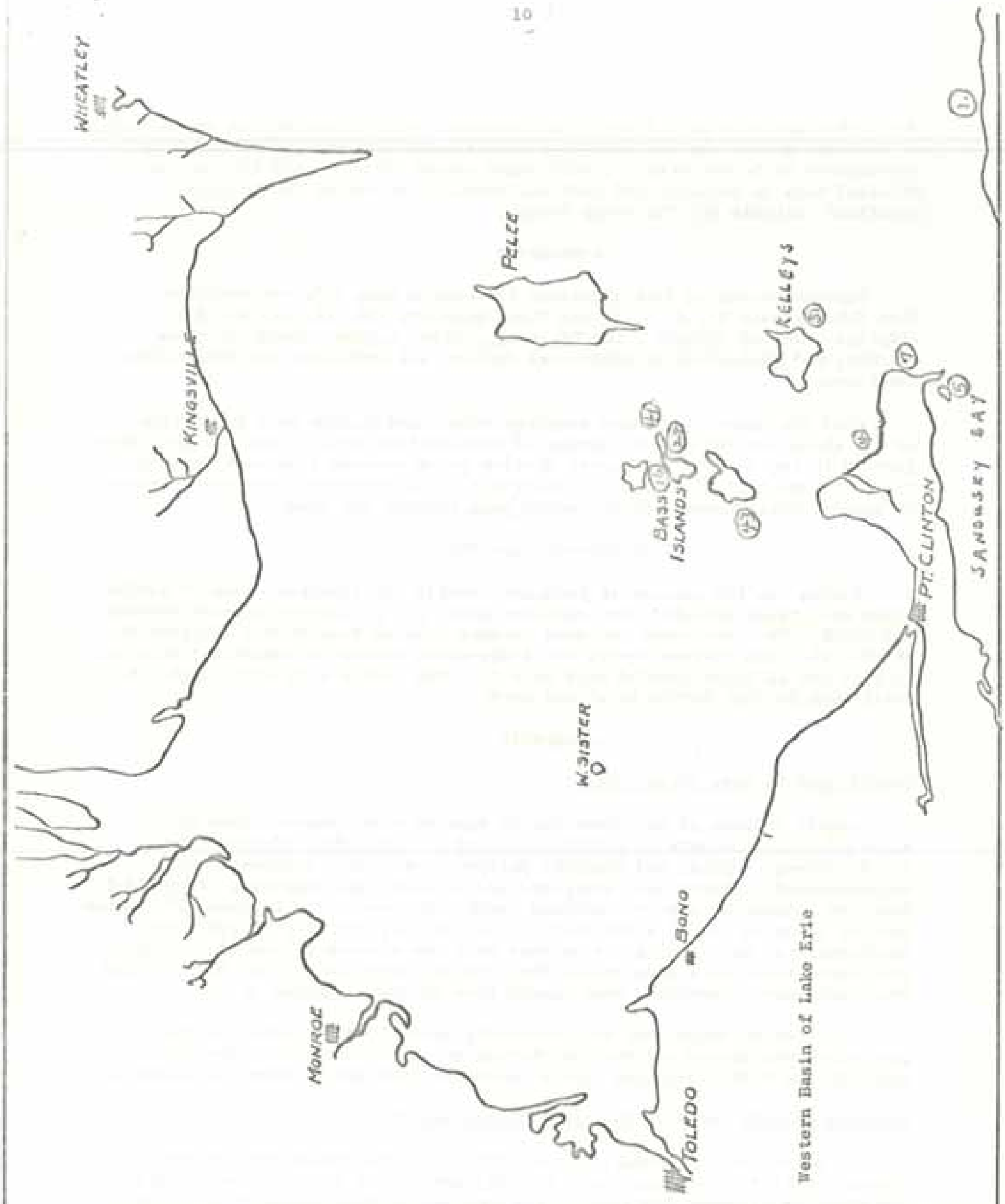

Figure 2. FWS sampling stations (circled) in western Lake Erie.

Table 1. Sampling stations in western Lake Erie for the assessment of YOY fishes.

Number	Approximate location	Sampling depth (ft.)	Sampling period
Primary station			
1	Cedar Point	10 & 20	Biweekly
4	East Harbor	10,15, & 20	Biweekly
5	Johnson Island (Sandusky Bay)	10	Biweekly
7	Sand Point (Marblehead)	10 & 17	Biweekly
Secondary station			
16	Rattlesnake Island	32	1 or 2 visits
24	East Bay, Middle Bass	32	1 or 2 visits
31	East, Kelly's Island	42	1 or 2 visits
41	East Bay, Middle Bass	22	1 or 2 visits
43	S.E., Green Island	25	1 or 2 visits

Table 2. YOY index of abundance for Lake Erie white bass.

①	②	③	④		⑤	⑥	⑦
Stations	Year	No. 10-min. tows, n	Catch/hour		Mean catch/hr, $\bar{x}$, & 95 C.L. $= \bar{x} \pm t s_{\bar{x}}$	Mean(log(C/hr+1)), $\bar{y}$, & 95 C.L. $= \bar{y} \pm t s_{\bar{y}}$	Retransformed from logs
			Min.	Max.			
All: 1, 4, 5, 7, 16, 24, 31, 41, 43. Includes 2-day-night at Sta. 4.	1967	169	0	880	35.4 < 53.6 < 71.8	0.960 < 1.083 < 1.205	8.1 < 11.1 < 15.0
	1968	162	0	456	20.6 < 32.7 < 44.9	0.638 < 0.761 < 0.884	3.3 < 4.8 < 6.7
	1969	169	0	640	17.5 < 29.2 < 40.9	0.582 < 0.703 < 0.824	2.8 < 4.0 < 5.7
	1970	153	0	1,680	48.0 < 83.3 < 118.5	0.985 < 1.124 < 1.264	8.7 < 12.3 < 17.4
	1971	137	0	472	28.2 < 39.5 < 50.7	1.031 < 1.147 < 1.264	9.7 < 13.0 < 17.4
	1972	161	0	448	56.3 < 71.7 < 87.2	1.131 < 1.269 < 1.408	12.5 < 17.6 < 24.6
	1973	207	0	2,560	79.2 < 130.2 < 181.3	0.994 < 1.124 < 1.254	8.7 < 12.3 < 16.9
	1974	173	0	524	32.1 < 46.1 < 60.0	0.867 < 0.990 < 1.112	6.4 < 8.8 < 11.9
Primary: 1, 4, 5, 7, but no 2-day-night at Sta. 4.	1967	89	0	572	26.8 < 49.6 < 72.4	0.826 < 1.003 < 1.180	5.7 < 9.1 < 14.1
	1968	76	0	416	5.3 < 19.9 < 38.5	0.386 < 0.551 < 0.715	1.4 < 2.6 < 4.2
	1969	85	0	152	8.0 < 17.6 < 19.3	0.469 < 0.618 < 0.767	1.9 < 3.1 < 4.8
	1970	74	0	1,680	69.4 < 141.2 < 213.0	1.077 < 1.294 < 1.511	10.9 < 18.7 < 31.4
	1971	62	0	472	23.8 < 45.3 < 66.8	0.792 < 1.003 < 1.214	5.2 < 9.1 < 15.4
	1972	81	0	368	20.8 < 36.9 < 53.0	0.569 < 0.762 < 0.954	2.7 < 4.8 < 8.0
	1973	112	0	920	42.7 < 76.1 < 109.5	0.815 < 0.987 < 1.159	5.5 < 8.7 < 13.4
	1974	84	0	500	10.7 < 26.6 < 42.4	0.559 < 0.721 < 0.882	2.6 < 4.3 < 6.6
Secondary: 16, 24, 31, 41, 43	1967	8	0	3	-1.5 < 0.4 < 1.3	-0.103 < 0.075 < 0.253	includes 0
	1968	14	0	22	-0.9 < 2.4 < 5.8	0.037 < 0.274 < 0.511	0.1 < 1.9 < 2.2
	1969	12	0	0	0	0	0
	1970	7	0	0	0	0	0
	1971	3	0	11	-8.3 < 5.3 < 19.0	-0.764 < 0.619 < 2.002	includes 0
	1972	8	0	448	20.4 < 151.4 < 282.4	0.972 < 1.616 < 2.519	4.4 < 41.3 < 329.4
	1973	23	0	450	3.6 < 47.0 < 90.5	0.607 < 0.967 < 1.327	3.0 < 8.3 < 20.2
	1974	17	0	524	-13.6 < 65.6 < 144.9	0.519 < 0.963 < 1.406	2.3 < 8.2 < 24.5
4: 2-day-night; AM, PM, Dark	1967	72	0	880	32.0 < 62.6 < 96.8	1.128 < 1.253 < 1.459	12.4 < 18.6 < 27.6
	1968	72	0	456	30.0 < 52.1 < 74.3	0.888 < 1.077 < 1.266	6.7 < 10.9 < 17.5
	1969	72	0	640	26.5 < 52.3 < 78.2	0.710 < 0.920 < 1.131	4.1 < 7.3 < 12.5
	1970	72	0	164	25.0 < 36.8 < 48.7	0.882 < 1.058 < 1.237	6.6 < 10.4 < 16.3
	1971	72	0	224	24.8 < 35.9 < 47.1	1.174 < 1.293 < 1.413	13.9 < 18.6 < 24.9
	1972	72	8	424	79.6 < 102.1 < 126.6	1.694 < 1.800 < 1.906	48.4 < 62.1 < 79.5
	1973	72	0	2560	106.1 < 240.9 < 375.8	1.154 < 1.387 < 1.620	13.3 < 23.4 < 40.7
	1974	72	0	416	42.5 < 64.2 < 85.9	1.129 < 1.310 < 1.492	12.4 < 19.4 < 30.0
4: 2-day-night; Dark only	1967	24	0	68	9.9 < 18.1 < 26.5	0.669 < 0.942 < 1.214	3.5 < 7.7 < 15.4
	1968	24	0	114	3.4 < 14.6 < 25.8	0.447 < 0.726 < 1.004	1.8 < 4.3 < 9.1
	1969	24	0	424	3.5 < 55.4 < 107.3	0.320 < 0.718 < 1.115	1.1 < 4.2 < 12.0
	1970	24	0	104	9.6 < 20.9 < 32.2	0.603 < 0.906 < 1.210	3.0 < 7.1 < 15.2
	1971	24	1	216	16.4 < 36.9 < 57.3	1.056 < 1.286 < 1.516	10.4 < 18.3 < 31.8
	1972	24	8	92	32.5 < 44.1 < 55.8	1.425 < 1.559 < 1.692	25.6 < 35.2 < 48.2
	1973	24	0	264	9.6 < 36.8 < 63.5	0.726 < 1.048 < 1.370	4.3 < 10.2 < 22.4
	1974	24	0	88	13.9 < 27.2 < 40.6	0.754 < 1.050 < 1.345	4.7 < 10.2 < 21.1
4: 2-day-night; AM & PM only	1967	48	0	880	39.9 < 87.5 < 135.1	1.274 < 1.468 < 1.662	17.8 < 28.4 < 44.9
	1968	48	0	456	39.1 < 70.9 < 102.7	1.014 < 1.252 < 1.490	9.3 < 16.9 < 29.9
	1969	48	0	640	20.6 < 51.0 < 81.4	0.771 < 1.022 < 1.273	4.9 < 9.5 < 17.8
	1970	48	0	164	25.2 < 38.8 < 52.4	0.912 < 1.136 < 1.359	7.2 < 12.7 < 21.9
	1971	48	0	224	21.6 < 35.4 < 49.2	1.153 < 1.297 < 1.442	13.2 < 18.8 < 26.7
	1972	48	8	424	99.3 < 131.0 < 164.7	1.787 < 1.921 < 2.055	60.2 < 82.4 < 112.5
	1973	48	0	2960	145.3 < 343.0 < 540.7	1.250 < 1.556 < 1.862	16.8 < 35.0 < 71.8
	1974	48	0	416	51.9 < 82.7 < 113.6	1.212 < 1.435 < 1.659	15.3 < 26.2 < 45.5

Table 3. YOY index of abundance for Lake Erie freshwater drum.

① Stations	② Year	③ No. 10-min. tows, n	④ Catch/hour Min.	Max.	⑤ Mean catch/hr, $\bar{x}$, & 95 C.L. $= \bar{x} \pm t s_{\bar{x}}$	⑥ Mean (log (c/hr + 1)), $\bar{y}$, & 95 C.L. $= \bar{y} \pm t s_{\bar{y}}$	⑦ Retransformed from logs
All: 1, 4, 5, 7; 16, 24, 31, 41, 43 Includes 2-day-night at Sta. 4	1967	169	0	1960	58.8<94.9<131.0	0.901<1.050<1.200	7.0<10.2<14.8
	68	162	0	848	58.5<79.9<100.5	1.087<1.230<1.372	11.2<16.0<22.6
	69	169	0	566	59.6<78.7<97.8	0.883<1.038<1.194	6.6<9.9<14.6
	70	153	0	584	60.9<80.6<99.6	1.156<1.299<1.443	13.3<18.9<26.7
	71	139	0	228	20.4<28.1<35.8	0.732<0.864<0.996	4.4<6.3<8.9
	72	161	0	352	19.1<29.1<39.2	0.527<0.656<0.784	2.4<3.5<5.1
	73	209	0	224	14.6<20.3<26.0	0.572<0.669<0.766	2.6<3.6<4.8
	74	173	0	1848	63.3<92.1<120.9	1.028<1.176<1.324	9.7<14.0<20.1
Primary: 1, 4, 5, 7, but no 2-day-night at Sta. 4	67	89	0	564	20.7<41.0<61.4	0.509<0.698<0.887	2.2<4.0<6.7
	68	76	0	454	46.8<71.0<95.3	0.862<1.089<1.316	6.3<11.3<19.7
	69	85	0	448	27.4<48.5<69.6	0.583<0.792<1.000	2.8<5.2<9.0
	70	74	0	508	32.6<55.9<79.2	0.782<0.991<1.201	5.1<8.8<14.9
	71	62	0	171	10.1<21.1<32.1	0.482<0.695<0.869	2.0<3.9<6.4
	72	81	0	186	5.8<13.4<21.1	0.276<0.428<0.579	.9<1.7<2.8
	73	112	0	224	9.5<16.6<23.7	0.425<0.558<0.692	1.7<2.6<3.9
	74	84	0	1848	31.1<81.2<131.3	0.922<1.042<1.162	4.3<9.9<13.5
Secondary: 16, 24, 31, 41, 43	67	8	0	3	-0.5<0.4<1.3	-0.103<0.075<0.253	Includes 0
	68	14	0	556	32.1<147.9<263.8	0.327<1.073<1.819	1.1<10.8<64.9
	69	12	0	0	0	0	0
	70	7	0	0	0	0	0
	71	3	0	1	-1.1<0.3<1.8	-0.331<0.100<0.532	Includes 0
	72	8	0	4	-0.5<0.8<2.0	-0.056<0.147<0.350	Includes 0
	73	23	0	12	0.9<2.6<4.3	0.146<0.331<0.516	.4<1.1<2.3
	74	17	0	204	4.6<36.9<69.2	0.258<0.749<1.240	.8<4.6<16.4
4: 2-day-night; AM, PM, Dark	67	72	0	1960	93.5<172.0<250.5	1.335<1.554<1.773	23.3<38.3<61.1
	68	72	0	848	42.0<75.6<109.2	1.242<1.408<1.574	16.5<24.6<36.5
	69	72	0	566	91.4<127.5<163.7	1.280<1.503<1.726	18.1<30.8<57.2
	70	72	0	584	42.0<107.6<133.1	1.588<1.742<1.897	30.9<54.2<77.9
	71	72	0	228	24.1<35.3<46.5	0.879<1.058<1.237	6.6<10.4<16.3
	72	72	0	352	25.9<50.0<70.0	0.756<0.968<1.181	4.7<8.3<14.2
	73	72	0	224	20.1<31.7<43.3	0.747<0.934<1.122	4.6<7.6<12.2
	74	72	0	700	80.2<119.8<154.6	1.355<1.550<1.745	21.6<34.5<54.6
4: 2-day-night; Dark only	67	24	18	1960	196.2<406.9<619.1	1.957<2.223<2.496	88.3<166.1<312.3
	68	24	2	848	65.5<159.5<253.6	1.481<1.772<2.063	29.3<58.2<114.6
	69	24	19	566	108.0<170.0<232.0	1.913<2.079<2.244	80.8<119.0<174.4
	70	24	25	584	98.9<158.5<218.0	1.922<2.068<2.215	82.6<116.0<163.1
	71	24	40	228	74.7<92.3<110.0	1.862<1.935<2.008	71.8<85.1<100.9
	72	24	6	352	81.8<127.7<173.6	1.708<1.909<2.110	50.1<80.1<127.8
	73	24	16	224	59.6<83.4<107.2	1.691<1.825<1.959	48.1<65.8<90.0
	74	24	81	700	210.5<280.9<351.2	2.278<2.382<2.487	188.7<240.0<306.0
4: 2-day-night; AM & PM only	67	48	0	250	34.3<54.9<96.1	1.059<1.280<1.500	10.5<18.1<30.6
	68	48	0	159	23.7<33.6<43.6	1.039<1.226<1.414	10.0<15.8<24.9
	69	48	0	532	61.5<106.3<151.1	0.920<1.215<1.510	7.3<15.4<31.4
	70	48	0	292	59.4<82.1<104.8	1.371<1.579<1.787	22.5<36.9<60.2
	71	48	0	27	4.5<6.8<9.1	0.462<0.619<0.771	1.9<3.2<4.9
	72	48	0	129	4.2<11.1<18.0	0.303<0.498<0.693	1.0<2.1<3.9
	73	48	0	44	3.1<5.8<8.4	0.330<0.489<0.648	1.1<2.1<3.4
	74	48	0	264	19.6<36.2<52.8	0.933<1.134<1.336	7.6<12.6<20.7

Table 4. YOY index of abundance for Lake Erie emerald shiner.

①	②	③	④		⑤	⑥	⑦
Stations	Year	No. 10-min. tows, n	Catch/hour Min.	Max.	Mean catch/hr, $\bar{x}$, & 95% C.L. = $\bar{x} \pm t s_{\bar{x}}$	Mean(log(C/hr+1)), $\bar{y}$, & 95% C.L. = $\bar{y} \pm t s_{\bar{y}}$	Detransformed from logs
All: 1, 4, 5, 7; 14, 24, 31, 41, 43. Includes 2-day-night at Sta. 4	1967	169	0	1376	1.7<20.1<38.6	0.208<0.302<0.399	.6<1.0<1.5
	68	162	0	1198	10.8<32.1<53.4	0.327<0.441<0.554	1.1<1.8<2.6
	69	169	0	106	2.4<4.6<6.9	0.194<0.294<0.393	.6<.9<1.2
	70	153	0	1008	6.7<21.5<36.4	0.331<0.444<0.556	1.1<1.8<2.6
	71	137	0	1104	19.1<39.8<62.4	0.453<0.586<0.720	1.8<2.9<4.2
	72	161	0	140	5.4<8.5<11.5	0.365<0.460<0.554	1.3<1.9<2.6
	73	207	0	1252	19.2<37.8<56.4	0.399<0.511<0.623	1.5<2.2<3.2
	74	173	0	1272	19.2<42.1<64.0	0.352<0.474<0.596	1.2<2.0<3.0
Primary: 1, 4, 5, 7, but no 2-day-night at Sta. 4	67	89	0	1376	-8.1<26.1<60.3	0.094<0.218<0.343	0.2<.9<1.2
	68	76	0	52	1.1<3.3<5.5	0.113<0.218<0.323	0.3<0.7<1.1
	69	85	0	18	0.4<1.0<1.7	0.063<0.130<0.196	0.2<0.3<0.6
	70	74	0	1008	-8.9<18.8<46.3	0.107<0.243<0.378	0.3<0.9<1.3
	71	62	0	1104	-2.0<40.3<82.6	0.191<0.381<0.571	0.6<1.4<2.7
	72	81	0	47	1.4<3.4<5.3	0.141<0.246<0.350	0.4<0.8<1.2
	73	112	0	992	-3.2<14.6<32.5	0.151<0.255<0.359	0.4<0.8<1.2
	74	84	0	40	0.7<2.1<3.5	0.070<0.177<0.263	0.2<0.5<0.8
Secondary: 14, 24, 31, 41, 43	67	8	0	0	0	0	0
	68	14	0	12	-0.3<1.7<3.9	0.005<0.229<0.454	0.0<0.7<1.8
	69	12	0	0	0	0	0
	70	7	0	0	0	0	0
	71	3	0	5	-5.5<1.7<8.3	-0.837<0.255<1.395	includes 0
	72	8	0	54	3.4<27.0<50.6	0.486<1.102<1.719	2.1<11.6<51.1
	73	23	0	1252	-7.5<113.5<235.9	0.275<0.759<1.243	0.9<4.7<16.5
	74	17	0	32	-1.2<2.7<6.7	0.035<0.253<0.471	0.1<0.8<2.0
4: 2-day-night; AM, PM, Dark	67	72	0	228	4.4<15.0<25.6	0.283<0.440<0.596	0.9<1.8<2.9
	68	72	0	1198	21.4<65.5<115.6	0.503<0.717<0.930	2.2<4.2<7.5
	69	72	0	106	4.7<8.5<14.3	0.344<0.490<0.635	1.2<2.1<3.3
	70	72	0	312	11.6<26.5<41.4	0.514<0.654<0.803	2.3<3.5<6.5
	71	72	0	592	16.7<40.8<65.0	0.535<0.796<0.963	2.5<5.0<8.2
	72	72	0	140	6.3<12.1<18.0	0.481<0.629<0.777	2.0<3.3<5.0
	73	72	0	586	24.2<49.5<74.9	0.614<0.829<1.045	3.1<5.0<10.1
	74	72	0	1272	45.2<98.1<151.0	0.626<0.873<1.121	3.2<6.5<12.2
4: 2-day-night; Dark only	67	24	0	228	8.4<39.1<69.7	0.344<0.731<1.119	1.2<4.4<12.2
	68	24	0	1198	49.3<183.8<318.3	0.705<1.204<1.703	4.1<15.0<49.5
	69	24	0	70	9.7<19.9<30.1	0.570<0.877<1.184	2.7<6.5<14.3
	70	24	0	312	21.1<62.8<104.5	0.793<1.149<1.505	5.2<13.1<31.0
	71	24	0	592	48.0<113.7<179.4	1.063<1.439<1.815	10.6<26.5<64.3
	72	24	0	140	10.5<25.3<40.1	0.742<1.025<1.309	4.5<9.6<19.4
	73	24	0	556	34.2<100.2<166.3	0.830<1.253<1.696	5.8<16.9<46.4
	74	24	10	1272	154.8<288.2<421.6	1.752<2.185<2.418	58.5<152.1<160.8
4: 2-day-night; AM & PM only	67	48	0	46	0.8<3.0<5.2	0.166<0.294<0.422	0.5<1.0<1.6
	68	48	0	147	2.3<10.8<19.3	0.294<0.473<0.651	1.0<2.0<3.5
	69	48	0	106	-2.4<4.3<8.9	0.165<0.296<0.427	0.5<1.0<1.7
	70	48	0	66	3.5<8.3<13.2	0.288<0.466<0.644	0.9<1.9<3.4
	71	48	0	26	2.4<4.4<6.5	0.304<0.445<0.585	1.0<1.8<2.8
	72	48	0	88	1.4<5.5<9.6	0.284<0.431<0.578	0.9<1.7<2.8
	73	48	0	352	6.6<24.2<41.9	0.385<0.618<0.851	1.4<3.1<6.1
	74	48	0	42	0.5<3.0<5.6	0.053<0.217<0.350	0.0<0.6<1.2

Table 5. YOY index of abundance for Lake Erie yellow perch.

①	②	③	④		⑤	⑥	⑦
Stations	Year	No. 10-min. tows, n	Catch/hour Min.	Catch/hour Max.	Mean catch/hr, $\bar{x}$, & .95 c.l. $= \bar{x} \pm t s_{\bar{x}}$	Mean (log (c/hr+1)), $\bar{y}$, & .95 c.l. $= \bar{y} \pm t s_{\bar{y}}$	Retransformed from logs
All: 1, 4, 5, 7; 14, 24, 31, 41, 43. Includes 2-day-night at Sta. 4	1967	169	0	1560	25.1<50.7<76.2	0.995<1.085<1.202	8.9<11.2<14.9
	68	162	0	104	9.3<12.0<14.6	0.711<0.799<0.884	4.1<5.3<6.7
	69	169	0	388	11.2<19.1<27.1	0.585<0.685<0.786	2.8<3.8<5.1
	70	157	0	960	57.4<77.5<97.7	1.400<1.503<1.606	24.1<30.8<39.4
	71	137	0	344	29.9<41.7<53.5	0.952<1.116<1.280	8.0<12.1<18.1
	72	161	0	880	22.6<35.1<47.7	1.054<1.152<1.251	10.3<13.2<16.8
	73	207	0	436	15.8<22.2<28.5	0.780<0.852<0.964	5.0<6.4<8.2
	74	173	0	668	33.3<44.6<55.9	1.156<1.255<1.353	13.3<17.0<21.5
Primary: 1, 4, 5, 7, but no 2-day-night at Sta. 4	67	59	0	1560	22.9<71.1<119.2	0.882<1.057<1.231	6.6<10.4<16.0
	68	76	0	95	5.7<9.7<13.4	0.540<0.669<0.799	2.5<3.7<5.3
	69	85	0	209	5.0<11.1<17.2	0.460<0.589<0.719	1.9<2.9<4.2
	70	74	0	960	34.4<64.5<94.6	1.196<1.354<1.512	14.7<21.6<31.5
	71	62	0	344	34.0<56.7<79.4	0.851<1.111<1.371	6.8<11.9<20.4
	72	81	0	880	13.6<36.6<59.7	0.896<1.049<1.203	6.9<10.2<15.0
	73	112	0	436	10.6<20.9<31.2	0.613<0.743<0.872	3.1<4.5<6.4
	74	54	0	668	12.0<53.8<95.7	0.990<1.153<1.326	8.8<13.4<20.2
Secondary: 14, 24, 31, 41, 43	67	8	0	9	-0.9<1.1<3.2	-0.111<0.173<0.456	INCLUDES 0
	68	14	0	104	3.8<20.2<36.6	0.693<1.012<1.331	3.9<9.3<20.4
	69	12	0	3	-0.2<0.3<0.9	-0.084<0.045<0.174	INCLUDES 0
	70	7	18	820	-28.9<229.9<488.2	1.583<2.090<2.597	38.3<120.0<393.3
	71	3	52	169	-73.4<92.0<257.9	1.192<1.901<2.610	14.6<78.6<406.4
	72	8	1	292	-11.9<81.8<175.4	0.658<1.376<2.094	3.5<22.8<123.2
	73	23	0	156	5.8<20.6<35.4	0.636<0.917<1.198	3.3<7.3<14.8
	74	17	3	96	17.3<31.8<46.2	1.131<1.347<1.563	12.5<21.2<35.6
4: 2-day-night; AM, PM, Dark	67	72	0	128	23.5<31.0<38.5	1.081<1.225<1.369	11.3<15.9<22.3
	68	72	0	72	9.5<12.8<16.2	0.768<0.892<1.016	4.9<6.8<9.4
	69	72	0	388	14.8<31.8<48.8	0.738<0.900<1.063	4.5<6.9<10.6
	70	72	0	384	55.4<76.3<97.2	1.467<1.600<1.732	28.3<38.8<53.0
	71	72	0	238	16.5<26.6<36.8	0.948<1.088<1.228	7.9<11.2<15.9
	72	72	0	152	21.4<28.3<35.1	1.125<1.244<1.363	12.3<16.5<22.1
	73	72	0	136	16.9<24.7<32.5	0.917<1.059<1.201	7.3<10.5<14.9
	74	72	0	196	27.9<36.8<45.7	1.223<1.346<1.468	15.7<21.2<28.4
4: 2-day-night; Dark only	67	24	0	105	15.5<27.6<39.8	0.856<1.139<1.419	6.2<12.7<25.2
	68	24	0	34	7.4<11.5<15.6	0.702<0.909<1.115	4.0<7.1<12.0
	69	24	0	388	11.9<49.6<87.4	0.784<1.114<1.443	5.1<12.0<26.7
	70	24	0	384	43.3<86.5<129.6	1.278<1.571<1.864	18.0<36.2<72.1
	71	24	0	238	13.0<38.2<63.4	0.947<1.213<1.479	7.9<15.3<29.1
	72	24	0	94	15.9<24.7<33.5	1.096<1.267<1.438	11.5<17.5<26.4
	73	24	4	136	15.6<29.4<43.2	1.080<1.268<1.456	11.0<17.5<27.6
	74	24	0	84	14.9<24.9<34.9	0.938<1.170<1.402	7.8<13.8<24.2
4: 2-day-night; AM & PM only	67	48	0	128	23.0<32.7<42.4	1.117<1.275<1.433	12.1<17.8<26.1
	68	48	0	72	8.8<13.5<18.3	0.723<0.883<1.043	4.3<6.6<10.0
	69	48	0	292	5.1<22.9<40.6	0.612<0.754<0.896	3.1<5.2<8.5
	70	48	2	288	47.4<71.2<95.0	1.471<1.614<1.756	28.6<40.1<56.0
	71	48	0	184	11.8<20.9<29.9	0.859<1.026<1.192	6.2<9.6<14.6
	72	48	0	152	20.7<30.1<39.6	1.072<1.232<1.393	10.8<16.1<23.7
	73	48	0	131	12.6<22.4<32.1	0.765<0.954<1.143	4.8<8.0<12.9
	74	48	0	196	30.5<42.8<55.1	1.251<1.434<1.596	18.5<26.2<34.7

Table 6. YOY index of abundance for Lake Erie walleyes.

①	②	③	④		⑤	⑥	⑦
Stations	Year	No. 10-min. tows, n	Catch/hour		Mean catch/hr, $\bar{x}$, & .95 C.L. $= \bar{x} \pm t s_{\bar{x}}$	Mean(log(C/hr + 1)), $\bar{y}$, & .95 C.L. $= \bar{y} \pm t s_{\bar{y}}$	Detransformed from logs
			Min.	Max.			
All: 1, 4, 5, 7; 16, 24, 31, 41, 43 Includes 2-day-night at Sta. 4	1967	169	0	8	0.3<0.5<0.7	0.064<0.102<0.139	0.2<0.3<0.4
	68	162	0	4	0.2<0.3<0.4	0.043<0.067<0.092	0.1<0.2<0.2
	69	169	0	36	0.4<0.8<1.3	0.095<0.139<0.182	0.2<0.4<0.5
	70	153	0	98	3.0<4.6<6.3	0.377<0.451<0.525	1.4<1.8<2.3
	71	137	0	4	0.4<0.5<0.7	0.093<0.128<0.163	0.2<0.3<0.5
	72	161	0	44	2.5<3.7<5.0	0.347<0.413<0.480	1.2<1.6<2.0
	73	207	0	17	0.8<1.1<1.4	0.145<0.185<0.225	0.4<0.5<0.7
	74	193	0	204	5.1<8.9<12.8	0.409<0.491<0.575	1.6<2.1<2.8
Primary: 1, 4, 5, 7, but no 2-day-night at Sta. 4	67	89	0	8	0.3<0.6<0.9	0.066<0.114<0.163	0.2<0.3<0.5
	68	76	0	2	0.1<0.3<0.4	0.039<0.072<0.105	0.1<0.2<0.3
	69	85	0	36	0.4<1.3<2.1	0.135<0.198<0.260	0.4<0.6<0.8
	70	74	0	98	3.7<6.9<10.0	0.450<0.583<0.707	0.2<2.5<4.0
	71	62	0	4	0.4<0.7<1.0	0.099<0.159<0.218	0.0<0.4<0.7
	72	81	0	44	2.9<5.1<7.4	0.369<0.473<0.577	1.3<2.0<2.8
	73	112	0	17	0.8<1.4<1.9	0.160<0.220<0.280	0.4<0.7<0.9
	74	84	0	204	6.9<14.5<22.0	0.439<0.578<0.718	1.5<2.8<4.2
Secondary: 16, 24, 31, 41, 43	67	8	0	0	0	0	0
	68	14	0	2	-.2<0.1<0.5	-0.040<0.034<0.108	includes 0
	69	12	0	0	0	0	0
	70	7	0	8	-.4<2.1<4.7	0.115<0.394<0.674	0.3<1.5<3.7
	71	3	0	1	-1.1<0.3<1.8	-0.331<0.100<0.531	includes 0
	72	8	0	2	0.0<0.6<1.2	0.011<0.193<0.336	0.0<0.5<1.2
	73	23	0	4	0.0<0.4<0.8	0.019<0.103<0.188	0.0<0.3<0.5
	74	17	0	5	0.6<1.6<2.6	0.136<0.301<0.466	0.4<1.0<1.9
4: 2-day-night; AM, PM, Dark	67	72	0	6	0.2<0.4<0.7	0.050<0.097<0.145	0.1<0.3<0.4
	68	72	0	4	0.1<0.3<0.5	0.028<0.070<0.112	0.1<0.2<0.3
	69	72	0	9	0.1<0.4<0.8	0.050<0.094<0.145	0.1<0.2<0.3
	70	72	0	30	1.3<2.6<3.9	0.215<0.311<0.406	0.6<1.0<1.5
	71	72	0	3	0.2<0.4<0.6	0.062<0.102<0.143	0.2<0.3<0.4
	72	72	0	17	1.7<2.5<3.4	0.283<0.372<0.462	0.9<1.4<1.9
	73	72	0	7	0.4<0.8<1.2	0.094<0.156<0.218	0.0<0.4<0.7
	74	72	0	54	2.4<4.3<6.2	0.325<0.435<0.545	1.1<1.9<2.5
4: 2-day-night; Dark only	67	24	0	3	-0.1<0.2<0.5	-0.011<0.050<0.111	includes 0
	68	24	0	0	0	0	0
	69	24	0	9	-0.2<0.8<1.7	-0.019<0.099<0.218	includes 0
	70	24	0	1	0.0<0.2<0.3	0.002<0.050<0.099	0.0<0.1<0.3
	71	24	0	3	0.0<0.4<0.7	0.024<0.095<0.171	0.0<0.2<0.5
	72	24	0	4	0.4<1.1<1.7	0.109<0.226<0.343	0.3<0.7<1.2
	73	24	0	2	0.4<0.2<0.5	-0.003<0.062<0.128	includes 0
	74	24	0	4	0.1<0.5<0.9	0.041<0.124<0.207	0.1<0.3<0.6
4: 2-day-night; AM & PM only	67	48	0	6	0.2<0.6<0.9	0.059<0.121<0.185	0.0<0.3<0.5
	68	48	0	4	0.2<0.5<0.8	0.044<0.105<0.166	0.0<0.3<0.5
	69	48	0	4	0.1<0.3<0.5	0.021<0.069<0.118	0.0<0.2<0.3
	70	48	0	30	2.0<3.9<5.7	0.314<0.441<0.569	1.1<1.8<2.7
	71	48	0	2	0.2<0.4<0.6	0.056<0.106<0.156	0.1<0.3<0.4
	72	48	0	17	2.1<3.3<4.5	0.328<0.446<0.563	1.1<1.8<2.7
	73	48	0	7	0.6<1.1<1.7	0.019<0.204<0.290	0.0<0.6<0.9
	74	48	0	54	3.4<6.1<8.9	0.449<0.590<0.732	1.8<2.9<4.4

of the negative binomial. Used with data of such type, the logarithmic transformation generally has the added ability to reduce variance and its tendency to be positively correlated with the mean catch/hour. Furthermore, it generally restores additivity to the data (factors such as depth, season, and population-regulating factors usually have an adverse multiplicative effect). The improvement in logs was evident from scatter diagrams of residuals on predicted (mean) counts and from histograms of residuals.

The mean catch/hour and 0.95 confidence limits in terms of logs are presented in column 6. These values, detransformed into arithmetic units, are given in column 7. Note that the confidence limits (or corresponding interval) are no longer symmetrical about the mean. Also, the resultant geometric mean is typically less than the corresponding untransformed mean (column 5).

Recommended Method (Objective 3)

Before considering a new assessment procedure, we had to estimate the variances resulting from readily controllable factors. We used the two-day-night series conducted at East Harbor (Station 4) because it had the most complete data, larger (and less variable) indices, and involved the most factors. (A preliminary report of the GLFL, August 1977, covers in more detail the material condensed in the next three paragraphs.)

A partially nested factorial design was utilized in the statistical analysis of catches which included 8 years x 2 seasons x 2 days x 3 daily periods x 3 depths x 2 tows. Catch data were transformed to $\log_{10}$ (count +1) to help normalize the generally negative bionomial distribution. Significant differences in catches were determined in an analysis of variance (ANOVA) utilizing the F test at the 5% level. The Duncan k-ratio t test was used to evaluate main factor and two and three factor interactions. Table 7 summarizes the ANOVA of the catches of YOY yellow perch, walleyes, white bass, freshwater drum, and emerald shiners at East Harbor. The multiple comparison tests further indicated that:

1. Trawling along the 15- and 20-ft depth contours is most productive.

2. Trawling during August can be limited to morning and/or afternoon periods for walleyes, yellow perch, and white bass, while night trawling during October is necessary to adequately sample shiners and drums.

3. Two 10-minute tows along each depth contour provide sampling replicates for increased reliability in abundance estimates and probably at no great increase in operating costs.

Separate one-way ANOVA for the two most important species, walleyes and yellow perch, disclosed no significant difference in the log mean catch on consecutive days. So trawl catches could be considered independent for days 1 and 2 (at least at East Harbor during the daylight in August at 15- and 20-feet). On this basis, and to gain more individual sample units, catches from replicate tows were also considered independent.

Table 7. Significance levels for analysis of variance of catches of five species of YOY fish from western Lake Erie, 1967-74, for the variable year, season, period of day, depth, and interactions.[1]

Source of variance		White bass	Freshwater drum	Emerald shiner	Yellow perch	Walleye
Year	(Y)	**	**	NS	**	**
Season	(S)	**	**	**	**	**
Period	(P)	**	**	**	NS	**
Depth	(D)	**	**	*	**	NS
YS		**	**	**	NS	**
YP		NS	**	**	NS	*
SP		*	**	**	NS	**
YD		*	NS	*	**	**
SD		NS	NS	NS	**	*
PD		NS	**	NS	NS	NS
Days	(YS)	**	**	**	**	**
YSP		NS	**	NS	NS	NS
YSD		*	NS	NS	**	**
YPD		NS	NS	NS	NS	NS
SPD		NS	NS	NS	NS	NS

[1]Significance levels: NS = difference not significant at P.05; * = significant at P.05; ** = significant at P.01.

Insight on variability associated with trawling area is obtainable from column 7 of Tables 2-6. With few exceptions, the mean catches computed for the 2-day-night series at East Harbor were larger and more stable than corresponding catches based on the primary or secondary stations. Interestingly, earlier studies have shown that the YOY abundance index from this series correlated best with the year class estimates determined from sampling commercial catches. Regardless of the few sample units taken at the five secondary stations, mean catches have been variable and low (except yellow perch) or not significantly different from zero. One can only assume that catches at 15 to 20 feet would have been larger and more stable, since trawling only took place between 22 and 42 feet at these five stations.

Coefficient of variation CV is a relative measure of dispersion or variability for a data set. It can be found by simple algebra from column 7 (or from columns 5 or 6 for those metameters) as follows:

$$CV = \frac{\sqrt{n}\ (CL_{hi} - CL_{lo})}{4\bar{y}} \qquad [4]$$

$$= \frac{\sqrt{n}\ (CI_{av})}{2\bar{y}}$$

where CI_{av} = average confidence interval = $(CL_{hi} - CL_{lo})/2$

For example, the CV for white bass sampled in 1973 at primary stations 1, 4, 5 and 7 (excluding data from the 2-day-night series at station 4) is

$$CV = \frac{\sqrt{112}\ (13.4-5.5)}{4(8.7)}$$

= 2.40 or 240%, which indicates very high variance.

The relative, standardized difference d′ has four basic forms depending on use (see also Applications 1 and 2 under SAMPLING CONCEPTS).

Comparing sample means (Application 1)

$$d' = \frac{CI_{av}\sqrt{\bar{y}}}{CV\sqrt{2}} \qquad [5]$$

$$\text{or} \quad = \frac{d}{CV\sqrt{2}} \qquad [6]$$

where d = some specified difference between 2 means expressed as a proportion.

Example 1: Assume the information given under (4) is considered representative for white bass. Then, by (5):

$$d' = \frac{(13.4-5.5)/2/8.7}{2.4\sqrt{2}} = \frac{0.454}{3.394}$$

$$= 0.134$$

The number of sample units n needed in each group to be 50% sure of detecting a difference between means of 45.4% at α = 0.05 and a CV of 240% is 210 (Enter X-axis of Figure 1 at d' = 0.134; read up to the $1-\beta$ = 0.5 curve; then left to the Y-axis = 210).

Example 2: Assume that d = 0.5 and CV = 1.5 are more reasonable for a species. Then, by (6):

$$d' = \frac{0.5}{1.5\sqrt{2}} = 0.236$$

and n = 64, using Figure 1.

Comparing a sample mean with the population mean $\bar{Y}$, including $\bar{Y}$ = 0 (Application 2)

$$d' = \frac{CI_{a}\sqrt{\bar{y}}}{CV} \qquad [7]$$

or

$$= \frac{d}{CV} \qquad [8]$$

Example 1: Assume the information given under (4) is considered representative. Then, using (7) and Figure 1, the number of sample units n to take in a group to be 50% sure of detecting a difference of 45.4% between that group's mean and the population mean (say zero) at α = 0.05 and a CV of 240% is about 100 since

$$d' = \frac{0.454}{2.4} = 0.189$$

Example 2: Assume that d = 0.5 and CV = 1.5 are more reasonable for a species. Then, by (8):

$$d' = \frac{0.5}{1.5} = 0.333$$

and n = 34

Note that to be 80% sure of detecting this difference, n = 70.

DISCUSSION AND RECOMMENDATIONS

Recommendation 1

Though the statistical distribution of catch/hr will never be known exactly, there is sufficient evidence from the foregoing analyses and the literature to recommend the transformation $\log_{10}$ ((catch/hr + 1). For such count data, $\log_{10}$ helps to normalize the data and improve homogeneity of variance and additivity. Thus the abundance indices in column 7 of Tables 2-6 are statistically more reliable than those in column 5.

Recommendation 2

An index of abundance will be less variable when computed from sample units (tows) wherein catches/hr are large and rarely are zero. Under such conditions, the normal distribution would be approached. Ideally, this could happen when population levels are very high, especially if the tow duration is considerably lengthened. From a practical standpoint, tows of 10 minutes are less likely to sample diverse conditions, clog, snag, or lose part of the catch. Such catches can also be counted easier and more accurately. Two 10-minute tows made with small mesh 26-foot bottom trawls for assessing YOY fishes at each visit to a station are recommended.

Recommendation 3

It would be too costly to develop a sampling scheme for each species, so a compromise is needed. Walleyes, yellow perch, and white bass ideally should be sampled in August during the daytime at a depth of about 15 to 20 feet, and at primary stations such as 1, 4, 5, and 7 in Ohio waters. For the other two species examined, freshwater drum and emerald shiner, a better index can be had by sampling at these same stations and depths in October at night.

Records should be kept of the walleyes, yellow perch, and white bass caught in October, and of freshwater drum and emerald shiner taken in August, but should not be used to compute the respective abundance indices. To do so will increase variance unnecessarily.

Preferred primary stations are those that are consistent producers of YOY fish, representative of important nearby fishing areas, in a major water current pathway, and easily accessible. Even though station 4 has been the most productive of these, additional locations are needed for a more conservative and reliable index (see also Recommendation 4).

Catches at the secondary stations have been too low or sporadic to recommend their retention in the sampling scheme. Furthermore, depths sampled at these stations are not optimum for the five species considered in this paper based on evidence from the 2-day-night series at East Harbor.

Variance components can be used to compute the best "mix" of S, V, and T. Yearly checks of CV, d, d′ and n should be made for each species using (4), (5), and Figure 1. The nested sampling technique should lead to higher precision of the abundance index and subsequent reduction of CV and n. The investigators would then have two choices: (1) make fewer visits at each station to maintain the approximate ratio d/CV = 0.33; or (2) maintain the current effort, gaining a more precise or reliable abundance index.

Statistical package for computers such as BMD8V are written for balanced designs like the one recommended. If there are unequal numbers of tows per visit, BMDX64 can be used. An unbalanced design (not the same number of visits at each station) requires a more complicated computer routine.

All of this has direct application for any new coordinated interagency program. Based on the high variability shown in Tables 2-6, start with CV = 150% and two tows at each visit of a station. (More than two tows could well cause technique problems such as net avoidance, chasing YOY out of area, and limiting the number of visits one could take under "similar" weather conditions at additional stations that same day.) The investigator must specify a difference that he wants to be able to detect, α, and $(1-\beta)$ to estimate n. Granted, sv = n/t, leaving s and v "unknown." Do not initially set s and v entirely on statistical analyses. Equally important are such things as trying to visit all sampling stations s on the same day (the assumption being similar weather prevails.) Also, more than 10 visits/station in about a month might soon spook or reduce fish abundance. The concept of "a reasonable day's work" must be woven into the design. Ideally, in nested sampling the variance decreases from S to V to T, so more stations than visits/station are preferred, especially if all the stations assigned to an agency can be visited in a day.

The investigators conducting such a joint venture would proceed as follows:

1. Set d, $\alpha = 0.05$, $(1-\beta)$, t = 2, and CV = 1.5; compute d′ using Equation (6); and find n from Figure 1 (a two-way table could be prepared to show n for various combinations of these variables).

2. Arbitrarily set s equal to, or slightly larger than, v such that $sv \doteq n/t$.

3. Assign the participating agencies i the number of stations s_i (and their locations) agreeable to them such that $s = \sum_{i=1} s_i$.

4. Have each participating agency take two tows T at each of their s_i stations S on v visits V during daylight in August (for species similar in behavior to walleye, yellow perch, and white bass), and after dark in October (for species similar in behavior to freshwater drum and emerald shiner).

Recommendation 4

Further gains in the precision of the abundance indices are possible with a new sampling design and analysis. Instead of using a simple random sample design as in the past, a nested or balanced repeated subsampling scheme is recommended. Computations should be in units of $\log_{10}$ ((catch/hr)+1).

Station, visit at a station, and replicate tow during a visit at a station can be considered random or representative factors, making this a Model II ANOVA. Assume four primary stations S and two replicate tows per visit T are reasonable choices. For these, the visits per station V can be conservatively estimated from the relationship $v = n/(s \cdot t)$. Referring to the discussion under ANALYSIS, especially that pertaining to Equation (6), conservative estimates of d = 0.5 and CV = 1.5 lead to d′ = 0.24, n = 64 from Figure 1, and v = 8. This form of d′ is recommended because the most likely use of the log mean catch/hr will be its comparison with the corresponding value for other years. Note the impact of the ratio d/CV in the calculations.

Continuing with this example, every effort should be made to visit each of the four primary stations on eight days in August and eight days in October, and to make two 10-minute tows per day. By eliminating the secondary stations and the two-day-night series, the proposed assessment program will cost less and undoubtedly lead to more reliable abundance indices than formerly.

The MODEL II nested ANOVA and computations leading to the mean catch/hr and its error are as follows:

Model	Source of variation	Degrees of freedom	Sum of squares	Variance, or mean square	F	Variance component
II	Station, S	(s-1)=3	SS_S	$MS_S=SS_S/3$	MS_S/MS_V	$\sigma_S^2 = (MS_S-MS_V)/(t \cdot v)$
II	Visit, V	s(v-1)=28	SS_V	$MS_V=SS_V/28$	MS_V/MS_T	$\sigma_V^2 = (MS_V-MS_T)/t$
II	Tow, T	sv(t-1)=32	SS_T	$MS_T=SS_T/32$	-	$\sigma_T^2 = MS_T$
	Total	(n-1)=63				σ^2 Total

Mean, $\bar{y} = \sum_{i=1}^{64} y/64$

Standard error, $s_{\bar{y}} = \sqrt{(\sigma_T^2/svt) + (\sigma_V^2/sv) + (\sigma_S^2/s)}$

Sampling error or confidence interval, $D_{\bar{y},\,0.05} = \pm\ 2s_{\bar{y}}$

Confidence limits, in logarithms, $(\bar{y} - D_{\bar{y}}) < \bar{y} < (\bar{y} + D_{\bar{y}})$

Confidence limits, detransformed,

$(\text{antilog } (\bar{y} - D_{\bar{y}}) - 1) < (\text{antilog } (\bar{y}) - 1) < (\text{antilog } (\bar{y} + D_{\bar{y}}) - 1)$

For example, let

$$d = 0.2,\ \alpha = .05,\ (1-\beta) = 0.5,\ t = 2,\ CV = 1.5,\ \text{so } d' = 0.09$$

and $n \doteq 370$. Then a reasonable combination will be $s = 18$, $v = 10$, $t = 2$, $n = 360$. If the investigators want to be 80% sure $(1-\beta)$ of detecting a difference of 20% ($d = .2$) between abundance indices, $n \doteq 800$, and likely mixes are $s = 40$, $v = 10$, $t = 2$, $n = 800$.

Using Figure 1 backwards, let's assume that 370 sample units was the most effort we could mount and still not reduce the stocks appreciably. At $1-\beta = 0.5$, $d' = 0.09$. If ability to detect a 20% difference d between abundance indices year to year is reasonable, then

$$d' = d/CV\sqrt{2}$$
$$0.09 = 0.2/CV\sqrt{2}$$
and $CV = 150\%$ as before

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