MULTIPLE REGRESSION ANALYSIS OF YELLOW PERCH YIELDS NEAR THE LUDINGTON PUMPED - STORAGE RESERVOIR

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ABSTRACT

MULTIPLE REGRESSION ANALYSIS OF YELLOW PERCH YIELDS NEAR THE LUDINGTON PUMPED-STORAGE RESERVOIR

By

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This investigation determined the parameters that affect the concentration and the activity patterns of adult, yellow perch. Yellow perch were collected by gill net at six sampling sites during 1973 in the inshore Lake Michigan waters near the Ludington Pumped-Storage Power Plant. The yield was examined by a step-wise deletion multiple regression program that utilized climatic and water condition parameters and gonadal development.

The independent climatic variables are barometric pressure, wind direction and velocity, and air temperature. Water condition parameters include water temperature, light penetration, and turbidity. Factors that affect gonadal development and spawning, such as photoperiod and the gonad: body weight ratio, were also incorporated in the regressions.

The results show that the independent variables explain 77 to 99 percent of the variation in yield of males, and 45 to 95 percent of the variation in yield of female yellow perch.

The information reveals the importance of barometric pressure at the stations most affected by the power plant. The male and female yield response to barometric pressure was quite different. Complex climatic interrelationships that influence activity were prevalent at all sampling sites. Photoperiod and water temperature are significant as they may affect seasonal migration patterns. Depth, although not an independent variable, is important.

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INTRODUCTION

The demand for electrical energy is accelerating. Coupled with this growing demand is a change from conventional fossil fuel generating plants to nuclear power plants and large pumped-storage reservoirs. Each new power generating facility is required by the Federal government to conduct a pre and post-operational environmental impact study. Michigan State University, Department of Fisheries and Wildlife, contracted with Consumer Powers and Detroit Edison Companies in 1971 to evaluate the effects of the Ludington Pumped-Storage Power Plant on the fish, physical-chemical conditions, benthic and plankton populations of an inshore area of Lake Michigan.

Questions under study relating to local fish species include:

1. Do the currents produced by the power plant attract or repel or in some other fashion affect the concentrations of fish species near the plant?

2. Do the pumping and generating modes physically harm individual fish through mechanical damage or pressure change?

3. What are the effects of fish entrainment in the reservoir?

This research represents an attempt to answer questions about fish concentration and movement in Lake Michigan, by using multiple regression analysis.

Use of multiple regression analysis by fisheries biologists has been minimal and of a limited nature. Generally, few independent variables are chosen and these are linear variables only. Walburg (1972) used four independent variables to examine sauger year class strength. Lewis (1969) attempted to explain the number of trout per stream pool using seven independent variables. A more comprehensive study related amphipod numbers to ten linear variables and one quadratic variable (Alley, 1968).

This investigation has utilized various climatic parameters, water condition variables and factors that affect gonadal development to explain the numbers of fish and their movements near the power plant. Yellow perch, *Perca flavescens*, (Mitchill) was chosen for study because of its importance as a sports fish and its localized abundance. The ultimate goal is to determine under what conditions yellow perch were most affected by the Ludington Pumped-Storage Reservoir.

DESCRIPTION OF SAMPLING AREA

The inshore sampling area of Lake Michigan was 6.4 km (4.0 mi) south of Ludington, Michigan, adjacent to the pumped-storage hydro-electric plant (Figure 1). Station one was 4.8 km (3 mi) south of the breakwall (Table 1). Station one served as the control station as this site was considered to be unaffected by currents from the power plant. Station two was 1.6 km (1 mi) south-southeast of the southern jetty. Station three was .8 km (.5 mi) south of the breakwall. Station four was about 2.4 km (1.5 mi) west-southwest of the breakwall. Station five was .8 km (.5 mi) north-northwest of the breakwall. Station six was 1.6 km (1 mi) north of the northern jetty. Sampling station depths and bottom sediment composition are shown (Table 1).

These stations were chosen so as to gauge the magnitude of the effects of the currents created by the pumping and generating cycles of the power plant. Current velocities and directions were not obtained for 1973. Although current velocities were not measured, they have been calculated to be about .7m/sec (2.3 ft./sec) between the jetties when all six units are generating (Liston and Tack, 1973). The volume

Figure 1.--Map and location of sampling sites near the Consumers Power Pumped-Storage Reservoir.

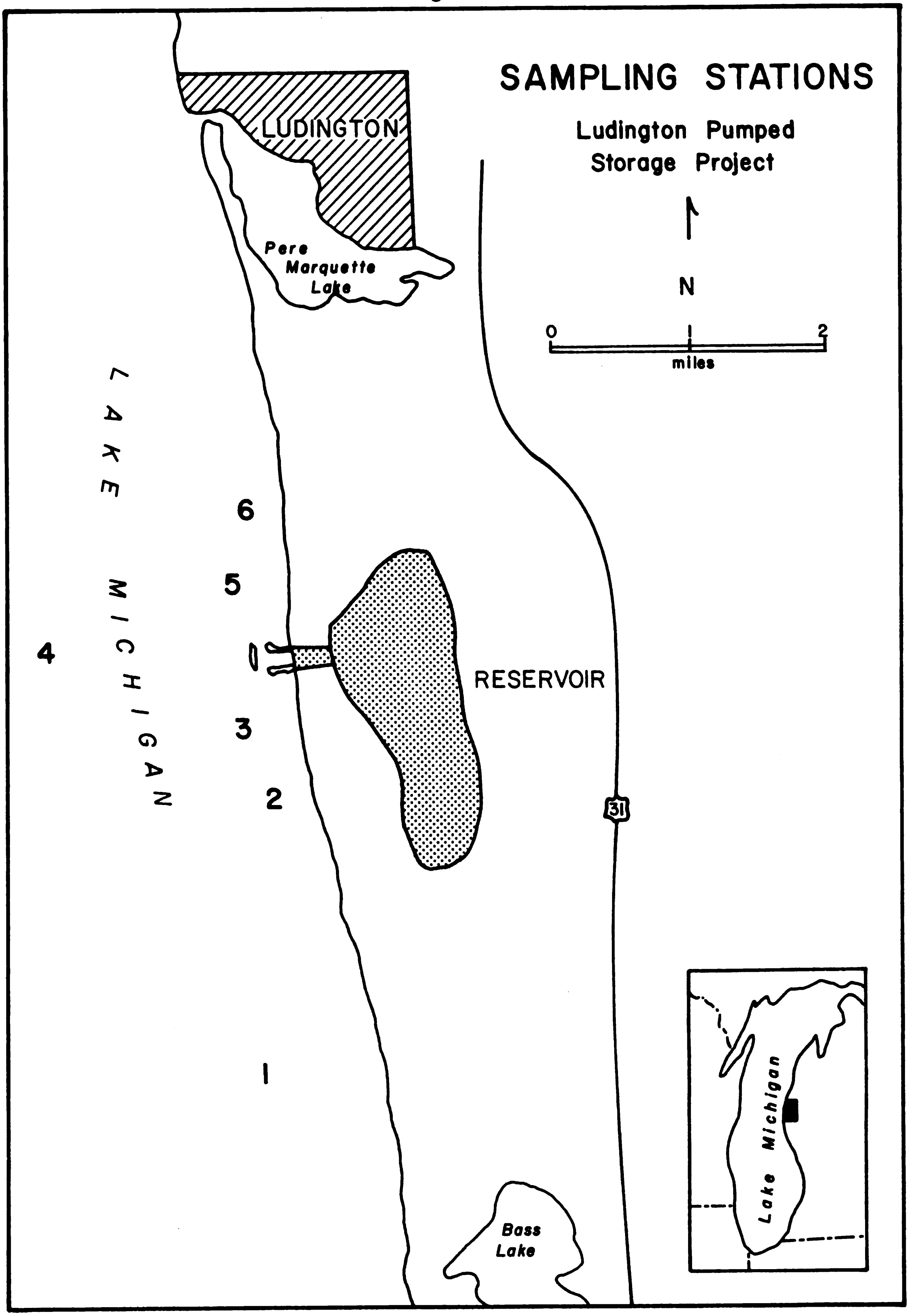
SAMPLING STATIONS
Ludington Pumped
Storage Project
N
0
1
2
miles
LUDINGTON
Pere
Marquette
Lake
LAKE MICHIGAN
6
5
4
3
2
1
RESERVOIR
31
Bass
Lake
Lake Michigan

TABLE 1.--Location of sampling sites, their depths and bottom sediment description.

Station	N Lat.	W Long.	Depth (m)	Type*
1	43° 51' 00"	86° 27' 20"	12	sand
2	43° 52' 45"	86° 26' 50"	8	sand
3	43° 53' 5"	86° 27' 20"	14	sand, gravel
4	43° 53' 30"	86° 29' 00"	24	silty sand and clayey silt
5	43° 54' 20"	86° 27' 35"	12	sand, gravel, rocks
6	43° 54' 50"	86° 27' 10"	6	sand, rocks

*Olson, 1974.

of water will be 75,960 cfs. A more detailed description of the power plant's facilities and the reservoir can be found in Liston and Tack (1973).

Since the power plant is located on the eastern side of Lake Michigan, it is constantly exposed to winds from the southwest, west, and northwest. These onshore winds may affect the sampling areas through an increase in turbidity, and water column mixing. Also, high water levels eroding large sandy bluffs add large amounts of particulate matter to the water column. These prevailing winds also bring in new weather systems which affect these sampling sites.

Prevailing winds are also partially responsible for water temperature change. Continual onshore winds that shift offshore suddenly, due to a passing weather system, push warm epilimnetic waters offshore forcing the cold hypolimnetic waters to the surface.

MATERIALS AND METHODS

Samples of adult yellow perch (age 3 and greater) were collected using experimental gill nets set on the bottom at each of six stations. Twenty-one 24-hour collections were made between 25 April and 02 October, 1973, at stations 1, 2, 3, 5, and 6, and 20 collections at station 4. The nets were of 25.4 mm (1 in), 50.8 mm (2 in), 63.5 mm (2.5 in), 76.2 mm (3 in), 101.6 mm (4 in), 114.3 mm (4.5 in), 177.8 mm (7 in) stretched nylon mesh. Each mesh size was 50 feet (15.24 m) in length until 10 July. At that time each 50-foot panel was decreased to a 25-foot (7.62 m) panel because of manpower demands in the reservoir. All yields of perch after 10 July were doubled for direct comparison with earlier data.

The parameters and units used to compute regression equations are given in Table 2. All parameters were measured and recorded on the day the gill nets were set.

Barometric pressure, wind direction and velocity were obtained from the Ludington Coast Guard Station approximately 6.4 km (4 mi) north-northeast of the breakwall. This information was recorded at 1000 hours for stations 4, 5, and 6 and at 1300 hours for stations 1, 2, and 3. Bottom water

TABLE 2.--Parameters measured to compute regression equations.

Parameter	Units
Atmospheric Pressure	Inches of Mercury
Wind Direction	22 Degree Intervals
Wind Velocity	Knots
Bottom Water Temperature	Degrees Celsius
Air Temperature	Degrees Celsius
Photoperiod	Hours From Sunrise to Sunset
Light Penetration	Secchi Disk (meters)
Bottom Turbidity	Formazon Turbidity Units
Gonad:Body Weight	Ratio

temperature was measured with a Yellow Springs Instruments thermistor. Light penetration was measured by a Secchi disk. Turbidity was determined by a Hach turbidimeter. Values for these three parameters were recorded at each station. Therefore, barometric pressure, wind direction, and velocity were constant for stations 4, 5, and 6 and for stations 1, 2, and 3, but water and air temperature, light penetration and turbidity varied from station to station. Sunrise and sunset was recorded for Muskegon, Michigan (43° 10' NLat, 86° 14' WLong) approximately 89 km (55 mi) south of the breakwall. For the gonad to body weight ratio, a random sample of ten yellow perch was selected from each station. Each fish was weighed, the gonads were removed and weighed, and the ratios were determined. A mean gonad to body weight ratio was then determined for each 24-hour gill net lift by station.

Yields were also determined from this random sample of ten perch. The proportion of males to females was found and then compared to the total yield at that station.

The above information was keypunched onto standard Hollerith computer cards and parameters were assigned variable names to be entered into the regression equations (Table 3).

The parameters were chosen because of their possible effects on the inshore fisheries of this area. The values for similar parameters from 1972 data were graphed against the dependent variable, yellow perch yield, as a preliminary exercise (graphs not shown). In this way relationships concerning linearity were established between yield and these various parameters. Interactions were also graphically depicted. The climatic interactions were deemed important in that they influence inshore water temperature, current direction and velocity, turbidity, and food availability. The various gonad:body weight interactions involving water temperature and photoperiod were believed to be important because the inshore areas were used for spawning by yellow perch (Liston and Tack, 1973). Temperature and daylength have been shown to be determinants of gonad maturation in

TABLE 3.--Variable names assigned to the recorded parameters.

Linear Terms	Quadratic Terms	Interaction Terms
X1=Barometric Pressure	$X14=(X1)^2$	X23=X1 x X2
X2=Wind Direction	$X15=(X2)^2$	X24=X3 x X6
X3=Water Temperature	$X16=(X3)^2$	X25=X2 x X6
X5=Photoperiod	$X18=(X5)^2$	X26=X1 x X6
X6=Air Temperature	$X19=(X6)^2$	X27=X5 x X6
X7=Light Penetration	$X20=(X7)^2$	X29=X7 x X8
X8=Turbidity	$X21=(X8)^2$	X35=X2 x X3
X9=Wind Velocity	$X22=(X9)^2$	X36=X3 x X5
X13=Yellow Perch Yield	$X42=(X41)^2$	X43=X41 x X3
X41=Gonad: Body Weight		X44=X41 x X5
		X45=X41 x X3 x X5

many species of fishes (Hoover, 1937, Burger, 1939, Kaya and Hasler, 1972, and Burrows, 1958).

On the basis of the preliminary graphs, a statistical model was postulated. Preliminary attempts using the control station to utilize this regressional model were abandoned as relationships concerning the graphical linearity of the dependent to independent variables had apparently changed from 1972 to 1973.

The regressions were calculated using a least squares stepwise deletion program from the Michigan State University Computer Center. In vector notation, the normal equations to be solved are: $\underline{X}'\underline{X}\underline{\hat{b}}=\underline{X}'\underline{y}$. Solving, one obtains the vector of regression coefficients $\underline{\hat{b}}=(\underline{X}'\underline{X})^{-1}\underline{X}'\underline{y}$.

The matrix $\underline{X}'\underline{X}$ is symmetric of the form:

$$\begin{bmatrix} n & X._1 & X._2 & \cdot & \cdot & \cdot & X._k \\ X._1 & \Sigma X_{i1}^2 & \Sigma X_{i1}X_{i2} & \cdot & \cdot & \cdot & \Sigma X_{i1}X_{ik} \\ X._2 & \Sigma X_{i1}X_{i2} & \Sigma X_{i2}^2 & & & & \\ \cdot & \cdot & & \cdot & & & \\ \cdot & \cdot & & & \cdot & & \\ \cdot & \cdot & & & & \cdot & \\ X._k & \Sigma X_{i1}X_{ik} & & & & & \Sigma X_{ik}^2 \end{bmatrix}$$

where: n = number of observations

$X.k$ = sum of all observations of variable k

ΣX_{ik}^2 = sum of squares of independent variable k

$\Sigma X_{i1}X_{ik}$ = sum of cross-products of variable 1 and variable k

$\underline{X}'\underline{y}$ is a vector of the form:

$$\begin{bmatrix} y. \\ \Sigma X_{i1}Y_i \\ \cdot \\ \cdot \\ \cdot \\ \Sigma X_{ik}Y_i \end{bmatrix}$$

where: $y.$ = sum of all observations of the dependent variable

$\Sigma X_{ik}Y_i$ = sum of cross-product of independent variable k and dependent variable i.

By finding the inverse of $\underline{X}'\underline{X}$, one can solve for the predicted regression coefficients, $\underline{\hat{b}}$ (Searle, 1971).

In stepwise deletion regression, the initial least squares equation is obtained using all independent variables available. The least significant variable is deleted and the equation is recalculated. This is continued until certain stopping criteria are met. Possible criteria include the following: (1) largest significance probability; (2) smallest sequential test-statistic (F_{bi}); (3) smallest independent test-statistic (t_{bi}); (4) smallest highest order partial correlation coefficient; (5) the variable that will reduce the square of the multiple correlation coefficient the least; or, (6) the variable that increases the error sum of squares the least (Ruble et al., 1969). A five percent significance level was chosen for all tests of significance and as a stopping criteron. A variable, therefore, was deleted if there was less than ninety-five percent confidence that the corresponding regression coefficient was nonzero.

Before the equations were calculated the catch data were transformed to more closely approximate the normal distribution. Yields from gill nets are not normally distributed but are probably best represented by a negative binomial distribution (Moyle and Lound, 1960). The negative binomial is best explained by examining the assumptions of its close relative, the Poisson distribution. The Poisson assumes the following: (1) there is a low probability of any given point being occupied; (2) the number of individuals in a sampling unit must be very small compared to the maximum possible; (3) individuals act as a discrete unit; and, (4) the samples must be small compared to the present population (Elliott, 1971). The yields of this study violate assumption number three because yellow perch form schools and cannot be considered a discrete unit (Hasler and Villemonte, 1953). Also, the variance is much greater than the mean and increases with the mean (Elliott, 1971). A transformation of the form, log (yield + 0.5) was thought to be adequate. The 0.5 was necessary due to zero yields on some dates.

Since thirty variables were being considered, and there were only twenty-one observations for stations 1, 2, 3, 5 and 6, and twenty at station 4, only certain variables were entered into deletion regression at a time. For the first regression run, terms X1...X3, X5...X9, X14...X16, X18...X22 were entered into the program for both males and females at each of six stations. The terms X23...X27, X29, X35 and X36 were added to the statistically significant variables (5%) for the second run. A third run was used to try to improve the multiple correlation coefficient (R) using all of the quadratic and cross-product terms and a few linear terms that were consistently significant.

Variables X41...X45 were then added to the runs which explained the greatest amount of variance of the catch to determine the effect of the addition of the gonad:body weight ratio on the multiple correlation coefficient. The number of variables entered into each regression run was small enough so as not to "overload" the system (as the number of "entered variables" approaches the number of observations, the multiple correlation coefficient reflects this and moves towards unity).

After examining the best regression equations, common variables were compared between stations that appeared to be highly similar. Certain stations were alike in depth, thermal stratification, proximity to the plant, sediment composition and yield. Therefore, a two-tailed t-test to compare regression coefficients was performed for the male yellow perch between station pairs 3-5 and 2-6.

RESULTS

Males

The yields of male yellow perch for each station are shown in Table 4.

The proportions of variance that are explainable using the best predictive equations are shown in Table 5 as the squares of the multiple correlation coefficients. Station 1, the control, had the lowest R^2, followed in order by stations 4, 6, 3, 5 and 2.

The significant variables in each predictive equation and the parameters they represent are shown in Table 6. Table 6 indicates that some variables are common to all stations, whether they are quadratically or linearly related to yield. Barometric pressure was significant at five stations. Photoperiod, and air and water temperature are also common to some of the stations.

The multiple occurrence of interaction terms (X24... X29, X35, X36) indicate the complexity of parameters that affect yield of yellow perch.

Table 6 also lists the final significant variables in each predictive equation, their corresponding regression coefficients and standard errors, and the standardized

TABLE 4.--The 1973 yield of male yellow perch at each of six stations.

Date	Station 1	2	3	4	5	6
4-25	0	0	0	0	0	0
4-29	0	0	0	0	0	0
5-14	2	51	23	18	8	38
5-19	13	186	68	18	54	55
5-22	46	139	154	24	85	221
5-30	96	413	119	18	43	196
6-06	53	5	6	176	22	11
6-13	78	88	57	174	53	0
6-23	108	54	106	31	19	45
7-09	36	90	149	0	40	20
7-11	0	100	0	-	0	103
7-22	0	41	20	0	0	17
8-12	2	0	4	62	6	0
8-14	50	97	70	0	146	133
8-22	0	80	3	0	125	167
8-25	14	4	34	0	46	34
9-08	18	24	2	0	50	83
9-17	0	60	48	0	17	10
9-26	0	2	18	74	0	0
10-01	2	2	0	127	11	3
10-02	0	0	2	22	23	0
Total	518	1436	883	744	748	1136

TABLE 5.--The proportion of variance explained by the best predictive equation (R^2), for male yellow perch at each of six stations.

%					
Station					
1	2	3	4	5	6
77	99	89	87	93	88

TABLE 6.--The significant variable names, the parameters they represent, the regression coefficients and their standard errors for each variable in the predictive equations for male yellow perch at six stations.

Variable Name	Parameter	Regression Coefficient	Standardized Coefficient
Station 1			
X3	Water temperature	0.61 ± .14	3.45 ± .81
X24	Water temperature x air temperature	-0.010 ± .004	-1.64 ± .70
X25	Wind direction x air temperature	0.0015 ± .0004	3.53 ± .90
X26	Barometric pressure x air temperature	-0.018 ± .004	-3.51 ± .79
X27	Photoperiod x air temperature	0.022 ± .006	2.16 ± .56
X35	Wind direction x water temperature	-0.0017 ± .0005	-3.5 ± 1.1
Station 2			
X1	Barometric pressure	-1158 ± 142	-301 ± 37
X2	Wind direction	0.59 ± .10	59 ± 10
X3	Water temperature	3.71 ± .50	20 ± 3
X7	Light penetration	1.15 ± .20	0.94 ± .16
X14	Barometric pressure (quadratic)	19.6 ± 2.4	303 ± 37
X16	Water temperature (quadratic)	0.044 ± .008	6.5 ± 1.1
X18	Photoperiod (quadratic)	0.09 ± .01	3.1 ± .5
X22	Wind velocity (quadratic)	0.0026 ± .0008	0.27 ± .08
X23	Barometric pressure x wind direction	-0.020 ± .003	-59 ± 10
X24	Water temperature x air temperature	-0.026 ± .007	-4.4 ± 1.2
X26	Barometric pressure x air temperature	-0.06 ± .01	-11.7 ± 2.5
X27	Photoperiod x air temperature	0.14 ± .03	13.7 ± 2.7
X29	Light penetration x turbidity	0.60 ± .09	1.04 ± .15
X35	Wind direction x water temperature	-0.0004 ± .0001	-0.75 ± .25
X36	Water temperature x photoperiod	-0.31 ± .04	-25 ± 3

TABLE 6.--Continued.

Variable Name	Parameter	Regression Coefficient	Standardized Coefficient
	Station 3		
X1	Barometric pressure	-1351 ± 182	-383 ± 52
X5	Photoperiod	-32.1 ± 4.6	-44 ± 6
X14	Barometric pressure (quadratic)	22.7 ± 3.1	384 ± 52
X18	Photoperiod (quadratic)	1.20 ± .17	45 ± 6
X19	Air temperature (quadratic)	0.035 ± .005	7.5 ± 1.1
X26	Barometric pressure x air temperature	-0.034 ± .005	-6.9 ± 1.0
X29	Light penetration x turbidity	0.13 ± .005	0.33 ± .14
X35	Wind direction x water temperature	0.0009± .0001	1.92 ± .28
X36	Water temperature x photoperiod	-0.024 ± .004	-2.1 ± .4
	Station 4		
X14	Barometric pressure (quadratic)	-0.04 ± .01	-0.59 ± .21
X16	Water temperature (quadratic)	0.025 ± .009	2.7 ± 1.0
X18	Photoperiod (quadratic)	0.04 ± .02	1.40 ± .55
X21	Turbidity (quadratic)	0.06 ± .02	0.45 ± .15
X22	Wind velocity (quadratic)	0.007 ± .002	0.47 ± .16
X24	Water temperature x air temperature	-0.04 ± .01	-5.3 ± 1.3
X26	Barometric pressure x air temperature	0.05 ± .01	8.9 ± 2.2
X27	Photoperiod x air temperature	-0.09 ± .03	-8.2 ± 2.3
X36	Water temperature x photoperiod	0.04 ± .01	2.4 ± .7

TABLE 6.--Continued.

Variable Name	Parameter	Regression Coefficient	Standardized Coefficient
	Station 5		
X1	Barometric pressure	-574 ± 120	-176 ± 37
X5	Photoperiod	-8.1 ± 2.5	-12 ± 4
X9	Wind velocity	0.71 ± .12	3.0 ± .5
X14	Barometric pressure (quadratic)	9.7 ± 2.0	177 ± 37
X18	Photoperiod (quadratic)	0.31 ± .09	12 ± 4
X22	Wind velocity (quadratic)	-0.044 ± .007	-3.4 ± .5
X24	Water temperature x air temperature	0.013 ± .002	2.2 ± .4
X25	Wind direction x air temperature	0.0013 ± .0003	2.9 ± .6
X27	Photoperiod x air temperature	-0.023 ± .004	-2.1 ± .4
X29	Light penetration x turbidity	-0.12 ± .04	-0.35 ± .12
X35	Wind direction x water temperature	-0.0014 ± .0003	-3.4 ± .7
	Station 6		
X2	Wind direction	-0.71 ± .24	-77 ± 26
X14	Barometric pressure (quadratic)	0.05 ± .02	0.75 ± .26
X21	Turbidity (quadratic)	0.97 ± .15	1.9 ± .3
X23	Barometric pressure x wind direction	0.025 ± .008	82 ± 27
X24	Water temperature x air temperature	-0.07 ± .01	-11.2 ± 1.6
X25	Wind direction x air temperature	-0.0049 ± .0008	-9.9 ± 1.7
X26	Barometric pressure x air temperature	0.054 ± .007	8.6 ± 1.1
X29	Light penetration x turbidity	-0.98 ± .15	-1.6 ± .3
X35	Wind direction x water temperature	0.0019 ± .0007	3.9 ± 1.4
X36	Water temperature x photoperiod	0.08 ± .02	6.2 ± 1.3

coefficients with their standard errors. Standardized coefficients are normalized or unitless regression coefficients found by dividing each coefficient by the standard deviation of the corresponding independent variable (Ruble et al., 1969). They can be used to determine the relative biological importance of each significant variable with respect to the other variables in the equation in proportion to their magnitude. Regression coefficients are used in the predictive equations, as they are in the units of the original observations.

The standardized coefficients for station 1 indicate that the interaction of water temperature and air temperature (X24) was least important in explaining significant proportions of variation in yield, and the interaction between wind direction and air temperature (X25) was most important. The standardized coefficients at stations 2, 3 and 5 indicate the overriding significance of parameters concerned with barometric pressure (X1, X14). The significance of many interaction terms at these stations indicates the complexity of parameters that help govern yellow perch activity.

Station 4 results include three interaction terms involving air temperature (X24, X26, X27) that are able to explain most of the variation in yield. Quadratic main effects (X14, X16, X18, X21, X22) are also significant.

Those indicate that barometric pressure, water temperature, photoperiod, turbidity, and wind velocity are related to yield in a curvilinear manner.

Wind direction and the interaction between barometric pressure and wind direction are the major contributors to the explainable variance at station 6. Interactions of those factors (and water temperature) with air temperature (X24, X25, X26) add a portion to the explainable variance.

Predictive equations are developed from the significant regression coefficients (Table 7). The first term in the equation is a constant. This is commonly interpreted as the predicted yield when the independent variables have zero value. To the extent that zero values are not realistic, for some variables at least, the constant merely provides a mathematical base. The minimum standard error of the estimate is also shown (Table 7). The minimum standard error is found by extracting the square root of the mean square error from the analysis of variance (Ruble et al., 1969). The standard error helps determine the reliability of the predictive ability of the equations. The minimum standard error applies when yield is predicted using average values for all of the independent variables.

A two-tailed t-test was used to test for significant differences between regression coefficients of variables that were common to certain station pairs. The test-statistic,

TABLE 7.--Predictive equations and the minimum standard error of the estimate for the yield of male yellow perch.

Station	Predictive Equation	Minimum Standard Error
1	$\hat{Y} = -1.39 + .61X_3 - .010X_3X_6^{*} + .0015X_2X_6 - .018X_1X_6 + .022X_5X_6 - .0017X_2X_3$	.538
2	$\hat{Y} = 17117 - 1158X_1 + .59X_2 + 3.71X_3 + 1.15X_7 + 19.6X_1^2 + .044X_3^2 + .09X_5^2 + .0026X_9^2 - .20X_1X_2 - .026X_3X_6 - .06X_1X_6 + .14X_5X_6 + .60X_7X_8 - .0004X_2X_3 - .31X_3X_5$	.195
3	$\hat{Y} = 20313 - 1351X_1 - 32.1X_5 + 22.7X_1^2 + 1.20X_5^2 + .035X_6^2 - .034X_1X_6 + .13X_7X_8 + .0009X_2X_3 - .024X_3X_5$	.404
4	$\hat{Y} = 22.7 - .04X_1^2 + .025X_3^2 + .04X_5^2 + .06X_8^2 + .007X_9^2 - .04X_3X_6 + .05X_1X_6 - .09X_5X_6 + .04X_3X_5$	.520
5	$\hat{Y} = 8568 - 574X_1 - 8.1X_5 + .71X_9 + 9.7X_1^2 + .31X_5^2 - .044X_9^2 + .013X_3X_6 + .0013X_2X_6 - .023X_5X_6 - .12X_7X_8 - .0014X_2X_3$	.337
6	$\hat{Y} = -66.7 - .71X_2 + .05X_1^2 + .97X_8^2 + .025X_1X_2 - .07X_3X_6 - .0049X_2X_6 + .054X_1X_6 - .98X_7X_8 + .0019X_2X_3 + .08X_3X_5$	.494

$^{*}X_3X_6 = X_{24}$ for coding purposes only (see Table 3).

$t = b^A - b^B / \sqrt{V(b^A) + V(b^B)}$ (Lee, 1971), has a critical value of $t\alpha/2, \nu_e^A, \nu_e^B$, where α is the significance level and ν_e^A and ν_e^B are degrees of freedom associated with the mean square error from analyses at stations A and B. The test was utilized for station pairs 2-6 and 3-5. These station pairs seemed to be most similar by depth, yield, thermal characteristics and distance from the power plant. The results of the t-test indicate that the regression coefficients were significantly different (Table 8) Since the common variables had regression coefficients that were significantly different, neither of the station pairs were pooled to increase the number of yield observations and therefore sensitivity of measuring the regressions.

Females

The yields of female yellow perch for each station are shown in Table 9.

The squared multiple correlation coefficient for female yellow perch indicates that the variance of the catch at station 3 was most explainable, followed by stations 4, 1, 2, 5 and 6 (Table 10).

The significant variables and the parameters they represent are listed by station (Table 11). Station 1 results are similar to those of the male yellow perch at that station. Water temperature and various interaction

TABLE 8.--Results of t-tests for $H:B_A=B_B$.

Station Pairs 2-6		Station Pairs 3-5	
Variable (from Table 6)	t-Value[a]	Variable (from Table 6)	t-Value[b]
X2	0.945	X1	3.562*
X14	8.202**	X5	4.551**
X23	5.087**	X14	3.557*
X24	3.785*	X18	4.523**
X26	7.911**	X29	0.213
X29	8.993**	X35	7.647**
X35	3.231*		
X36	9.856**		

[a]15 d.f.

[b]20 d.f.

*.01 level of significance.

**.001 level of significance.

TABLE 9.--The 1973 yield of female yellow perch at each of six stations.

	Station					
Date	1	2	3	4	5	6
4-25	0	0	0	0	0	1
4-29	0	0	0	19	0	1
5-14	0	0	5	24	1	0
5-19	1	13	0	14	0	0
5-22	0	0	0	8	6	16
5-30	0	0	0	8	0	0
6-06	6	10	10	20	51	12
6-13	9	132	14	0	22	133
6-23	162	216	26	8	78	67
7-09	28	22	19	0	30	6
7-11	0	66	4	-	0	103
7-22	0	95	14	0	0	7
8-12	0	4	8	0	4	0
8-14	22	225	30	0	36	89
8-22	0	34	13	0	31	251
8-25	10	2	8	2	20	50
9-08	12	6	0	0	34	125
9-17	0	26	0	0	7	4
9-26	2	0	18	74	0	0
10-01	0	0	2	85	11	3
10-02	2	2	0	10	15	0
Total	254	853	171	272	346	868

TABLE 10.--The proportion of variance explained by the best predictive equation (R^2), for female yellow perch at each of six stations.

%					
Station					
1	2	3	4	5	6
61	59	95	91	59	45

terms again indicate the complex relationships that affect fish. Station 2 appears to be influenced primarily by photoperiod and air temperature. Stations 3 and 4 have in common several significant climatic interactions (X26, X27, X29, X35). Barometric pressure is important at station 3 alone. Stations 5 and 6 are unique in that variables directly related to spawning (gonad:body weight) are significant only at these stations. Photoperiod, or an interaction involving photoperiod, is important at all stations.

The regression coefficients and standardized coefficients reveal the variability among stations and differences between males and females (Table 11). The standardized coefficients at station 1 indicate the relatively equal importance of all four significant variables. Of the explainable variance at station 2 (59%), air temperature and its interaction with photoperiod is most important. Station 3 is the only station in which barometric pressure is

TABLE 11.--The significant variable names, the parameters they represent, the regression coefficients and their standard errors for each variable in the predictive equations for female yellow perch at six stations.

Variable Name	Parameter	Regression Coefficient	Standardized Coefficient
	Station 1		
X3	Water temperature	-1.40 ± .58	-9.7 ± 4.0
X26	Barometric pressure x air temperature	0.03 ± .01	7.4 ± 3.0
X27	Photoperiod x air temperature	-0.07 ± .03	-7.8 ± 3.1
X36	Water temperature x photoperiod	0.11 ± .04	10.9 ± 4.1
	Station 2		
X6	Air temperature	-1.34 ± .49	-8.6 ± 3.2
X18	Photoperiod (quadratic)	-0.05 ± .02	-1.73 ± .73
X27	Photoperiod x air temperature	0.10 ± .03	9.6 ± 3.3
	Station 3		
X1	Barometric pressure	489 ± 99	173 ± 35
X2	Wind direction	0.010 ± .002	1.31 ± .29
X5	Photoperiod	-1.66 ± .44	-2.9 ± .8
X8	Turbidity	2.86 ± .51	4.3 ± .8
X14	Barometric pressure (quadratic)	-8.19 ± 1.67	-173 ± 35
X21	Turbidity (quadratic)	-0.47 ± .09	-4.2 ± .8
X22	Wind velocity (quadratic)	0.0019 ± .0007	0.264 ± .100
X24	Water temperature x air temperature	-0.016 ± .004	-3.5 ± .8
X26	Barometric pressure x air temperature	-0.04 ± .01	-10.0 ± 2.6
X27	Photoperiod x air temperature	0.09 ± .02	12.0 ± 2.8
X35	Wind direction x water temperature	-0.0005 ± .0001	-1.4 ± .3
X36	Water temperature x photoperiod	0.031 ± .006	3.5 ± .7

TABLE 11.--Continued.

Variable Name	Parameter	Regression Coefficient	Standardized Coefficient
	Station 4		
X5	Photoperiod	-13.0 ± 2.5	-19 ± 4
X16	Water temperature (quadratic)	0.017 ± .004	2.4 ± .6
X18	Photoperiod (quadratic)	0.54 ± .10	22 ± 4
X20	Light penetration (quadratic)	-0.05 ± .01	-0.66 ± .20
X21	Turbidity (quadratic)	-0.33 ± .07	-3.0 ± .6
X25	Wind direction x air temperature	0.0011 ± .0003	2.9 ± .8
X26	Barometric pressure x air temperature	0.03 ± .01	7.6 ± 2.3
X27	Photoperiod x air temperature	-0.09 ± .02	-9.9 ± 2.4
X29	Light penetration x turbidity	0.56 ± .13	2.7 ± .6
X35	Wind direction x water temperature	-0.0019 ± .0005	-3.8 ± 1.0
	Station 5		
X41	Gonad:body weight	-10.7 ± 4.1	-16 ± 6
X44	Gonad:body weight x photoperiod	0.70 ± .28	16 ± 6
	Station 6		
X44	Gonad:body weight x photoperiod	-0.15 ± .05	-2.1 ± .7
X45	Gonad:body weight x photoperiod x water temperature	.017 ± .007	1.8 ± .7

overriddingly important. Again, climatic interaction terms are important (X24, X26, X27, X35). Station 4 reveals non-linear association of photoperiod with female yellow perch yield (X5, X18). The presence of complex interaction terms is also an important aspect of female perch catch. Gonadal development as influenced by photoperiod and water temperature are the only significant variables at stations 5 and 6. At each station neither of the two variables are dominant in explaining the variance.

The predictive equations and minimum standard errors of the estimate are developed from the significant regression coefficients for each station (Table 12). The first term of each equation is a constant.

TABLE 12.--Predictive equations, the minimum standard error of the estimate for the yield of female yellow perch at six stations.

Station	Predictive Equation	Minimum Standard Error
1	$\hat{Y} = -.55 - 1.4X_3 + .03X_1X_6 - .07X_5X_6$ $+ .11X_3X_5$	.543
2	$\hat{Y} = 9.61 - 1.34X_6 - .05X_5^2 + .10X_5X_6$	.682
3	$\hat{Y} = -7271 + 489X_1 + .010X_2 - 1.66X_5$ $+ 2.86X_8 - 8.19X_1^2 - .47X_8^2$ $+ .0019X_9^2 - .016X_3X_6 - .04X_1X_6$ $+ .09X_5X_6 - .0005X_2X_3 + .031X_3X_5$	.248
4	$\hat{Y} = 76.2 - 13.0X_5 + .017X_3^2 + .54X_5^2$ $- .05X_7^2 - .33X_8^2 + .0011X_2X_6$ $+ .03X_1X_6 - .09X_5X_6 + .56X_7X_8$ $- .0019X_2X_3$	.358
5	$\hat{Y} = 1.52 - 10.79X_{41} + .70X_{41}X_5$	.323
6	$\hat{Y} = 1.30 - .15X_{41}X_5 + .017X_{41}X_3X_5$	.603

DISCUSSION

Males

Station One

Male yellow perch activity at this station is related to climate (Table 6). The most significant variables affecting yield are interaction terms in which interrelated parameters represent characteristics of a change in the weather pattern. The significance of five interaction terms (four of which involve air temperature) illustrates the complexity of factors which influence yellow perch activity.

A positive linear term for water temperature indicates that a direct relationship exists between yield and temperature. As bottom water temperature begins to increase, yellow perch become more active and yield increases (Pearse and Achtenberg, 1917-1918). The increase in activity makes the yellow perch more vulnerable to gill nets (Scott, 1955). All of the variables are of relatively equal importance in explaining yield variability except for the interaction term, air temperature by water temperature (X24), which is least important. Since station 1 is unaffected by the power plants' operation, it is assumed that yellow perch yield in other areas of like conditions would be explainable by similar variables.

Station Two

The two most significant variables at station 2 are barometric pressure (X1, X14, Table 6). Significance of the linear parameter (X1), indicates that as the pressure decreases, activity increases and yield climbs on the average. However, yield is related to pressure in a curvilinear manner (X14). Peterson (1972) found that spawning activity increases with a decline in barometric pressure. There may be several reasons why barometric pressure is highly significant. Generating and pumping may slightly alter water pressures, and in combination with atmospheric pressure fluctuations, barometric pressure becomes inordinately important.

As barometric pressure falls, the weather generally becomes inclement. Wind velocity may increase and cloud cover reduces available light. Transmitted light is required for formation and maintenance of schools, feeding behavior and net avoidance (Clarke, 1936, Morrow, 1948, Blaxter, 1965, Hasler and Bardach, 1949, Hergengrader and Hasler, 1968, Whitney, 1969, and Scott, 1955).

Other climatic variables support this theory. When wind velocity increases, yield increases curvilinearly (X22). Station 2 is shallow, (8 m) and contains silt from large eroded bluffs and particulate matter created by currents from the plant. Therefore, a forceful wind will create a turbid situation which reduces available light. Reduced visibility results in greater gill net yields.

Wind direction also is significant (X2). As the prevailing winds move south to west (directly onshore) and farther north, the water column and particulate matter become greatly mixed. Turbulence produced by changes in wind direction may cause fish to seek an area of less disturbance thereby resulting in a greater catch.

One variable that directly contradicts this theory is light penetration, X7. Examination of the regression coefficient reveals that clearer water produced a greater yield. However, standardized coefficients indicate the very low importance of this variable relative to others that affect yield (Table 6).

Water temperature has the same relationship to catch as at station 1. Wells, (1968) found that yellow perch move onshore with warmer water temperatures. These data support the concept of seasonal migration but also indicates the importance of photoperiod (X18). The interaction of photoperiod and water temperature (X36) reveals that "extremes" of water temperature should be viewed in relation to season, rather than absolutely.

The biological significance of certain interaction and quadratic variables may become more apparent with the addition of a time variable. The regressions were calculated on a total season basis, ignoring any time element. Utilizing time on a seasonal basis may lead to a better understanding of the significance of certain variables, particularly water temperature and photoperiod.

Station Three

Station 3 is similar to station 2 in that barometric pressure is by far the most important variable and has the same inverse relationship to catch (Table 6). Other significant climatic variables are similar to station 2 except for variables that can directly affect water currents. Because of strong currents produced by the power plant, environmental parameters that directly affect water currents have little affect at this station. Variables that might affect currents are wind direction and water temperature acting jointly. Significance of the interaction between them is probably due to winds affecting water temperatures and yellow perch responding to these changes by following preferred isotherms (Wells, 1968).

As noted earlier, yellow perch migrate offshore with cooler weather and changing photoperiod (Wells, 1968). Station 3 (14 m depth) is approximately .8 km (.5 mi) offshore. As photoperiod decreases, catch increases. The interaction of photoperiod and water temperature is again significant, as at station 2.

Station Four

Station 4 is similar to station 1 in that various climatic interaction terms have the most important influences (X24, X26, X27, Table 6). Other related terms are quadratic variables representing water temperature, barometric pressure and turbidity. These terms probably reflect activity pattern change. As changes occur in the weather pattern, yellow perch may try to compensate for those changes by seeking a less affected area, possibly moving to areas of greater depth. This increase in activity results in a greater yield by making perch more vulnerable to gill nets.

Water temperature and photoperiod are significantly related to yield in a non-linear manner. Since seasonal migration has been shown to be a function of water temperature and possibly photoperiod, it seems reasonable to assume that the significant quadratic terms (X16, X18, Table 6) are reflecting these migratory trends. By examining the raw data, it can be seen that the yield at station 4 decreases at the first of June and abruptly increases during the last week in September (Table 4). Again the interaction between water temperature and photoperiod is important.

Station Five

Station 5 is very similar to station 3. Barometric pressure is the single most important variable and the inverse relationship between barometric pressure and yield still exists (Table 6). As expected, climatic interaction terms are significant except for variables that directly affect water currents (X24, X25, X35). The only possible exception to this is the effect of wind velocity (X9, X22), in which their importance cannot be readily explained. Again, as at station 3, the interaction between wind direction and water temperature is important. Wind direction influences temperature change, possibly through upwelling and this temperature shift probably induces yellow perch to try to remain in a preferred temperature. This movement with the shifting isotherms results in an increase in yield.

Photoperiod is significant as at station 3 (X5, X18). As photoperiod is decreasing at an increasing rate, catch increases. As earlier, this probably reflects the seasonal migration patterns of yellow perch.

Station Six

The two most important variables at station 6 involve wind direction (X2, X23, Table 6). Also, two other interaction terms involving wind direction are significant (X25, X35). The main effect for wind direction (X2) indicates that, in general, as the prevailing wind shifts from west to south to east (decreasing degrees) the yield increases. There may be two reasons for this effect. Currents from the power plant may be attracting fish and/or affecting their activity patterns. Also, since station 6 is north of the power plant, as the prevailing wind shifts toward the south, it may complement northward currents produced by the plant. When compared to station 2, the same affect occurs. As the prevailing wind moves toward the north, it begins to complement southward currents produced by the plant and in general yield increases.

Climatic variables seem to play a role, primarily as interaction terms (Table 6). Barometric pressure is significant as a quadratic term and in two other cross-product terms. As barometric pressure rises, yield increases curvilinearly. This phenomenon is contrary to examples at stations 2 through 5, although it is relatively unimportant when compared to other significant variables at this station.

The interaction term of water temperature by photoperiod probably shows the affects of general seasonal onshore and offshore movements, although neither photoperiod nor water temperature are significant alone.

Depth at all stations is probably an important factor. The basic similarities in common variables at stations pairs 2-6 and 3-5 are offered as support. The common relationships of photoperiod and water temperature to yield at these station pairs and the importance of their interaction support seasonal movements as reported by Wells (1968).

Photoperiod may also be significant as it affects the development of sperm and the onset of spawning (Hoover, 1937, Burger, 1939, Matthews, 1939, and Kaya and Hasler, 1972). Male yellow perch store viable sperm during the late winter months until the onset of spawning (Turner, 1919). They arrive earlier and remain on the spawning beds longer than females (Scott and Crossman, 1973, and Pearse and Achtenberg, 1917-1918). The direct or inverse relationship of photoperiod to yield that occurs at these stations may help describe when spawning males are present and their migratory habits.

Females

Station One

The importance of complex interactions that influence activity can be seen at the control station. Of the four significant terms, three are interaction variables. The only significant climatic term is the interaction of barometric pressure and air temperature (X26). A logical explanation for the significance of this variable and the lack of significance of other climate-associated variables cannot be postulated at this time.

Two variables (X36, X3) are slightly more important than the other two significant terms (Table 11). The linear term for water temperature indicates an inverse relationship

with yield. As bottom water temperatures decrease, catch increases. Photoperiod also plays a role in the interaction with water temperature. This may reflect seasonal migration of female yellow perch.

Station Two

There are three highly interrelated significant variables at station 2. Air temperature and the interaction term between photoperiod and air temperature are about equally important (Table 11). The linear term for air temperature, X6, is inversely proportional to yield. Photoperiod, the least important term, is a negative quadratic that indicates an inverse non-linear relationship with yield. Photoperiod probably plays a role in on and offshore seasonal migration. It may also reflect gonad maturation and the subsequent migration onto spawning areas.

The lack of significance of many climate related terms is difficult to explain. At this station, female yellow perch appear to be unaffected by weather changes.

Station Three

As in stations 2, 3, 5 and 6 for the male yellow perch, barometric pressure is by far the most significant variable (X1, X14, Table 11). This variable is directly, but curvilinearly related to yield. As barometric pressure increases, catch increases, but at a decreasing rate.

The above weather pattern, and the complex relationships between its parameters are significant and affect catch (X24, X26, X27, X35, Table 11). The effect of wind direction, X2, is directly related to yield. Since station 3 lies south of the plant, prevailing winds changing direction to greater degrees probably acts as an additive effect with currents produced by the power plant, and yield increases. This same type of affect was found for the males at station 2 and 6, but not at station 3.

The significant turbidity variable is directly related to yield. As turbidity increases, catch increases. This may be due to a lessened ability to avoid gill nets. Since vision plays an important role in feeding, school formation and maintenance, the activity associated with these behaviors must be altered for a continuation of these behaviors.

A significant photoperiod term indicates that a decreased daylength leads to an increase in yield. When examining yields for station 3 (Table 9), the opposite appears to be true. The significance of this linear term (X5) and the interaction of photoperiod and water temperature has been attributed to seasonal migration. In this case such interpretation is difficult to make.

Station Four

The most important variables are photoperiod terms (X5, X18, Table 11). As daylength decreases, perch move offshore and yield increases at an increasing rate at this offshore station. This seasonal migration has been attributed to temperature (Wells, 1968), but photoperiod is probably important.

Water temperature is related to yield in a non-linear manner. As water temperature increases, yield increases curvilinearly.

Light penetration and turbidity (X20, X21) are both inversely non-linearly related to yield. As light penetration decreases, yields increase. This would be expected if vision were important in net avoidance at this depth. Turbidity when decreasing, results in an increase in yield (X21). Although turbidity is a curvilinearly related to yield, and more important than light penetration (X20, Table 11), a rational explanation of this affect is difficult to find.

Climatic variables reflecting weather changes are significant (X25, X26, X27, X29, and X35, Table 11). As mentioned earlier, these complex interactions probably affect female yellow perch activity patterns, possibly by causing perch to seek an area that is less affected, (a more preferred environment).

Stations Five and Six

The only significant variables at these stations are ones that influence gonadal development and spawning (Table 11). Both water temperature and photoperiod act as trigger mechanisms to produce sperm and eggs and initiate the onset of spawning (Kaya and Hasler, 1972, Matthews, 1939, Burger, 1939, Hoover, 1937, and Jones et al., 1971).

The inverse relationship of gonad:body weight (X41) at station 5 indicates that as spawning occurs, yield of female yellow perch increases.

Since these variables are the only significant terms, one may conclude that stations 5 and 6 are preferred spawning sites. Since it has been shown that males are in a ripe spawning condition longer than females and are over the spawning beds for a greater period of time (Scott and Crossman, 1973) this may also indicate that female yellow perch select an appropriate spawning site. Pearse and Achtenberg (1917-1918) also point out that many males follow one female indicating that she may be responsible for site selection.

There are obvious differences between male and female yellow perch as the regressions indicate. At the control station, 1, the catch of the males is directly related to water temperature. The females exhibit an inverse relationship. This same phenomenon is also true for barometric pressure at station 3. The yield of male perch has an inverse relationship with barometric pressure and the female yield is directly related to pressure. There are also the obvious differences at stations 5 and 6. The males reflect climatic effects and seasonal migration whereas the females are influenced by variables (gonad:body weight and its interaction with photoperiod and/or water temperature) that influence development of eggs and spawning.

Also there are basic similarities. Photoperiod and water temperature, as they affect seasonal migration, appear to affect yield similarly for both sexes, although it becomes more difficult to establish in the females. In general, weather does seem to influence activity and in turn gill net yield. Also, the prevalence of interaction terms and curvilinear relationships, at like stations indicates the complexity of interrelationships that govern yellow perch movements.

SUMMARY

This investigation was undertaken to determine which of several factors affected the yield of yellow perch near the Ludington Pumped-Storage Power Plant. Yellow perch were chosen due to their local abundance and popularity for sport fishing.

The yield, or dependent variable, was analyzed by a step-wise deletion multiple regression routine. The independent parameters were climatic variables such as wind direction and velocity, barometric pressure and air temperature. Water condition factors included bottom water temperature, light penetration and turbidity. The gonad:body weight ratio and photoperiod were also incorporated into the regressions as these variables would reflect changes in gonadal development and influence spawning. Quadratic polynomial terms were used to express curvilinear relations between yield and the independent factors. Also, two-factor interactions were considered.

The results indicate that the independent variables examined could explain 77 to 99 percent of the variation in yield of male yellow perch. Standardized regression coefficients at station 1 show that yield of male perch was affected

by changes in the weather pattern and water temperature. Barometric pressure was the main parameter that affected yields at station 2, 3 and 5. The catch at station 4, like station 1, was primarily influenced by complex climatic interaction terms. Wind direction and its various interaction terms were the main influencing factors at station 6.

Barometric pressure may be highly significant for several reasons. Pumping and generating may slightly alter pressures by causing a head to be formed to move large amounts of water. Pumping, which generally coincides with the two major activity periods of yellow perch (pre-sundown and sunrise), may cause a general water pressure decrease. This may complement and magnify the effects of a decrease in barometric pressure. Also, barometric pressure may be reflecting changes in weather conditions.

Photoperiod and water temperature influence seasonal inshore and offshore migration of male yellow perch.

Similarities were noted between station pairs 2-6 and 3-5 in that the sampled areas may be biologically alike in that thermal stratification, yield, distance from the power plant (current affects) and depth was similar, but their regression coefficients were statistically different.

Stations 1 and 4 were similar in that cross-product terms involving weather patterns were the primary influencing factors. The significant regression coefficients at station 4 also included a number of non-linear terms. The importance of these curvilinear terms may be due to depth.

The variation in yield of female yellow perch as explained by the independent variables had a range of 45 to 95 percent. The yields of stations 1 and 2 are primarily determined by complex climatic terms. Barometric pressure exerts the greatest influence at station 3 and photoperiod is the dominant factor at station 4. The catch at stations 5 and 6 is due to variables that directly relate to spawning and gonadal development. The significant variables that affect spawning at stations 5 and 6 indicate that these areas may be the only spawning stations in this sampling design and that female yellow perch may actually choose the spawning site.

The multiple correlation coefficient was more variable from station to station for female perch. Different variables were significant from station to station for the female yellow perch, making those results more difficult to interpret than results for male perch.

LITERATURE CITED

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Alley, W. P. 1968. Ecology of the burrowing Amphipod Pontoporeia affinis in Lake Michigan. Spec. Rep. #36 Great Lakes Res. Div. Inst. Sci. and Tech. 77-86.

Blaxter, J. H. S. 1965. Effect of change of light intensity on fish. Int. Comm. N. W. Atl. Fish. Spec. Publ. No. 6:647-661.

Burger, J. W. 1939. Some experiments on the relation of the external environment to the spermatogenetic cycle of Fundulus heteroclitus (L). Biol. Bull. 77:96-103.

Burrows, R. E. 1958. Light as a factor in accelerating the spawning of blueback salmon. Prog. Fish. Cult. 20(2):57.

Clarke, G. L. 1936. On the depth at which fish can see. Ecol. 17:452-456.

Elliott, J. M. 1971. Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biol. Assoc. Sci. Publ. No. 25. 144 pp.

Hasler, A. D., and J. E. Bardach. 1949. Daily migrations of perch in Lake Mendota, Wisconsin. J. Wildl. Manage. 13(1):40-51.

Hasler, A. D., and J. R. Villemonte. 1953. Observations of the daily movement of fishes. Sci. 118(3064): 321-322.

Hergenrader, G. L., and A. D. Hasler. 1968. Influence of changing seasons on schooling behavior of yellow perch. J. Fish. Res. Bd. Can. 25(4):711-716.

Hoover, E. E. 1937. Experimental modification of the sexual cycle in trout by control of light. Sci. 86:425-426.

Jones, B. R., K. E. Hokanson, and J. H. McCormick. 1971. Winter temperature requirements of yellow perch. EPA. Nat. Water Qual. Lab.

Kaya, C. M., and A. D. Hasler. 1972. Photoperiod and temperature effects on the gonads of green sunfish Lepomis cyanellus (Rafinesque), during the quiescent, winter phase of its annual sexual cycle. Trans. Am. Fish. Soc. 101(2):270-275.

Lee, P. J. 1971. Multivariate analysis for the fisheries biology. Tech. Rep. Fish. Bd. Can. No. 244. 182 pp.

Lewis, S. L. 1969. Physical factors influencing fish populations in pools of a trout stream. Trans. Am. Fish. Soc. 98(1):14-19.

Liston, C. L., and P. I. Tack. 1973. A study of the effects of installing and operating a large pumped storage project on the shores of Lake Michigan near Ludington, Michigan. 113 pp.

Matthews, S. A. 1939. The effects of light and temperature on the male sexual cycle in Fundulus. Biol. Bull. 77:92-95.

Morrow, J. E. 1948. Schooling behavior in fishes. Quart. Rev. Biol. 23(1):27-38.

Moyle, J. B., and R. Lound. 1960. Confidence limits associated with means and medians of series of net catches. Trans. Am. Fish. Soc. 89(1):53-58.

Olson, G. R. 1974. Personnal Communication.

Pearse, A. S., and H. Achtenberg. 1917-1918. Habits of yellow perch in Wisconsin lakes. Bull. Bur. Fish. 36:293-366.

Peterson, D. A. 1972. Barometric pressure and its effect on spawning activities of rainbow trout. Prog. Fish. Cult. 34(2):110-112.

Ruble, W. L., D. Kiel, and M. E. Rafter. 1969. Calculation of least squares (regression) problems on the LS routine. Mich. St. Univ. Agric. Exp. Station. 60 pp.

Scott, D. C. 1955. Activity patterns of perch, Perca flavescens, in Rondeau Bay of Lake Erie. Ecol. 36(2):320-327.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Bd. Can. No. 184.

Searle, S. R. 1971. Linear models. 532 pp.

Turner, C. L. 1919. The seasonal cycle in the spermary of the perch. J. Morph. 32:681-711.

Walburg, C. H. 1972. Some factors associated with fluctuation in year-class strength of sauger, Lewis and Clark Lake South Dakota. Trans. Am. Fish. Soc. 101(2):311-316.

Wells, L. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. Fish. Bull. U.S. Fish. and Wildl. Serv. 67(1):1-16.

Whitney, R. R. 1969. Schooling of fishes relative to available light. Trans. Am. Fish. Soc. 98(3): 497-504.