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WHITE SUCKER POPULATION DYNAMICS IN THE BIG TWO-HEARTED RIVER

By

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ABSTRACT

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The white suckers of the Big Two-Hearted River were studied during their spawning migration using an existing electric weir. Life history information was obtained at intervals within the spawning season. Tagged fish were returned to the river and subsequent recaptures were noted.

During 1979, the white suckers of the Big Two-Hearted River had an annual mortality rate of 40 percent and appeared to grow at approximately 6 percent per year after reaching maturity. The female white suckers grew faster after reaching maturity than the males.

Analyzing the potential yield from this white sucker population using the Dynamic Pool Model indicated that there is no optimum level of exploitation. The maximum yield identified occurs when harvest begins with four-year-old fish at an instantaneous fishing mortality of 1.1. This equates to approximately 2,800 pounds per year.

ACKNOWLEDGMENTS

This project was possible through the efforts of numerous individuals. Niles Kevern suggested this project and I took it hook, line and sinker. I thank Dr. Kevern for his patience. I thank those who helped me collect the field data, John Sefcick, James Bohan, Richard Hoppe and my wife, Bernie, they had quite an experience. I thank the personnel of Sea Lamprey Control at Marquette, Michigan, especially Leo Milkewitz. Additional thanks go to the members of my committee: Drs. William W. Taylor and Ivan Mao.

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INTRODUCTION

Background

Changes in fish community structure over the last 50 years have been dramatic for the Great Lakes. But even before that, man destroyed some fish stocks in streams tributary to the Great Lakes through logging and dam building. The later invasion of the sea lamprey (*Petromyzon marinus*) severely diminished or drove to extinction the most valued commercial fish (Hile 1946, Eschmeyer 1955). The ensuing exploitation of under-used habitats by the invading smelt (*Osmerus mordax*) and alewife (*Alosa psuedoharengus*) applied increased pressure on already struggling species such as the midwater chubs (Christie 1974). The result was a partially collapsed and totally changed commercial fishery.

There remains few high-value fish stocks in a healthy state. The survival of the commercial fishery depends, partly, on the economic development of abundant stocks of fish here-to-fore largely unused.

The biology of these under-used species is not well known, especially age 0 to age at recruitment. There has been some

estimation of yield potential for some stocks, but Lake Superior stocks have been widely ignored for numerous reasons. Lack of a large inplace commercial fishery, infertility of Lake Superior compared to the other Great Lakes and lack of accessibility are three reasons. One compelling reason for now investigating the Lake Superior fish, is the widespread contamination of fish with pesticides and industrial contaminants.

Scott (1974) reported a decrease in Michigan commercial fishery licenses from 900 in 1963 to approximately 660 in 1967. Now commercial licenses number approximately 70. In recent years efforts to develop the Great Lakes fishery by the State of Michigan have been directed toward establishment of a recreational salmonid fishery. Included in the species of choice are the chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and steelhead (*Salmo gairdneri*). The federal role, carried out by the U.S. Fish and Wildlife Service, is the attempt to develop self-sustaining populations of lake trout (*Salvelinus namaycush*) through stocking, behavioral and contaminant research, and sea lamprey control. Although Native American fishermen are taking lake trout and other salmonids in their catch, the salmonids as a whole are protected from other commercial exploitation. Efficient and equitable allocation of the Great Lakes fishery resources is a difficult problem.

Traditionally there have been two methods of allocating resources, either on a first come first served basis or on a monetary basis with the highest value taking precedence. With the commercial fishery but a shadow of its former self and the recreational fishery for Michigan waters described as a 550 million dollar industry annually (Douglas Jester, personal communication), it leaves little doubt how the highly valued salmonids are likely to be allocated. Therefore, commercial interests must work with what is available and one of the available fish is the white sucker (Catostomus commersoni). Neither the commercial harvest nor the markets have been fully developed for this species; leaving the white sucker underutilized.

White suckers in the Great Lakes spawn in streams tributary to the lakes. They are also suspected of spawning in the shallow shoal areas of the lakes (Scott and Crossman 1973). White suckers are thought to have a strong tendency to home to a spawning stream (Olson and Scidmore 1963). Spawning occurs from April to July. Green, et. al. (1966) observed the beginning of spring spawning migrations when stream temperatures reached 10° C. Barton (1980) observed that in addition to stream temperature, stream discharge was an important contributing factor in initiation and run strength for spring spawning migrations.

The fish scatter their demersal eggs along gravelly stream substrate. The usual number of eggs per female is probably 20,000 to 50,000 (Scott and Crossman 1973). Survival from egg to migrant fry may be as little as 0.3 percent (Green, et. al. 1966).

According to Scott and Crossman (1973), sexual maturity is normally attained by the third or fourth year in Ontario, Canada. Growth of males and females is similar up to age of maturity. After sexual maturity, females grow faster than males.

Mortality is thought to be low during spawning, usually less than 20 percent. Annual survival of adult white suckers is quite high. An annual survival rate of 0.87 is reported by Olson (1963) for a lake in Minnesota. Coble (1967) reported an annual survival estimate of 0.75 for South Bay, Lake Huron. The maximum age for the species reported by Scott and Crossman (1973) is 17 years which coincides with the age of the oldest fish in this study.

Purpose of This Investigation

This thesis reports the result of two years of research, having as its purpose, a description of the population dynamics of the white sucker in the Big Two-Hearted River and an estimation of the potential for exploitation of this resource. Electrical weir information collected by the U.S.

Fish and Wildlife Service revealed that two sucker species utilize the Big Two-Hearted River for spawning purposes, the white sucker and the longnose sucker (Catostomus catostomus). Weir information is available for over 20 years on the abundance of suckers running the river, however, no life history information was taken until this study.

To evaluate the potential for harvest and the impact of various harvest strategies on the recruited population, data were needed regarding (1) the age and sex composition and (2) general growth and mortality rates.

The objectives of this investigation were: (1) to determine the approximate size of the white sucker population, and (2) to estimate the potential level of harvest.

So that fishery managers and commercial fishermen might be able to estimate output from this fishery, an accurate production estimate is necessary. Even though an accurate estimate of potential harvest ensues, to greatly expand the market for suckers, impediments need to be removed, such as the poor reputation of suckers held by consumers.

Methods

Samples of white suckers caught in the electrical weir on the Big Two-Hearted River were obtained during the spring of 1978 and 1979. Data collected from the 1979 fish were used to determine the size, age, sex composition and general growth and mortality rates. Estimates of relative yield per recruit were calculated using the Dynamic Pool Model described by Beverton and Holt (1957).

All calculations assume a population of white suckers in equilibrium, that is, the population size, general growth and mortality rates are constant.

An attempt was made to estimate the recruited population of white suckers using mark and recapture. Due to the long periods between samplings, the assumption of equal probability of capture was violated and an attempt to estimate the population using traditional techniques was unsuccessful. An estimate of the approximate size of the population was calculated using the average recapture rate during the spawning season.

Electrical weir records show that white suckers comprised most of the weir catch since 1975 and their yearly spawning run strength is less variable than that of the longnose sucker. Therefore, the white suckers were chosen for study. Because of the distances involved in travel, a holding pen was provided so that a week's catch could be held for sampling. Fish were handled at stream-side and returned to the water. Each fish was sexed by external determination

(Spoor 1935), measured to the nearest 0.1 cm (total length), and weighed to the nearest 10 grams on a spring-loaded hanging scale. A pectoral fin was taken for aging purposes, and the fish was tagged with a spaghetti tag near the base of the dorsal fin. Obvious morphological anomalies were noted, e.g., broken back and fin parasites. The state of maturity was also noted. Sampling for life history data took place in the spring of 1979 between the months of May and July.

Aging was accomplished using pectoral fin rays because of information developed by Beamish and Harvey (1969) and Beamish (1973) indicating that after age 5, scales provide an inaccurate estimate of age. Green et. al. (1966) suspected inaccuracy in the scale aging method based on recaptured tagged fish that they knew were older than indicated by the scale aging method.

The first three rays of the pectoral fin were sectioned to 0.5 mm using a microtome provided by the Michigan Department of Natural Resources as described by Beamish (1973). The sections were mounted in mineral oil on microscope slides and the annuli counted with the assistance of a variable power dissecting scope. Only fin ray sections capable of being clearly read were used for aging purposes. The fin ray method of aging was verified using both scales and fin rays from young fish to ascertain whether all the annuli were being observed.

When attempting to calculate the sample size necessary to be certain that confidence intervals did not overlap for ages, data from Vondracek (1977) were used as an estimate of variance for each age and sex. Estimates of variation in length were available for ages 2 through 10 for white suckers from the Ahnapee River, Wisconsin, for females. Estimates of variation in length were available for ages 2 through 6 for males from the same location.

For female white suckers from the Ahnapee River, the desired half-width of the 95% confidence interval and subsequent ageable number of fish needed based on the Wisconsin data are shown in Table 1.

Table 1. Length (standard deviation), desired half-widths of 95% confidence interval (D) at each age for female white suckers, and estimated sample size

Age Group	Length (mm)	D (mm)	Sample Needed
II	296 (43.1)	20	41
III	375 (46.2)	20	48
IV	415 (25.7)	10	27
V	440 (22.4)	10	20
VI	433 (19.6)	10	30
VII	436 (23.0)	10	42
VIII	459 (2.7)	5	3
IX	475 (21.5)	5	167
X	462 (25.5)	10	59

For male white suckers from the Ahnapee River, the desired half-width of the 95% confidence interval and ageable number of fish for each age class needed is shown in Table 2.

Table 2. Length (standard deviation), desired half-width of 95% confidence interval (D) at each age for male white suckers, and estimated sample size

Age Group	Length (mm)	D (mm)	Sample Needed
II	291 (9.6)	25	2
III	344 (14.2)	24	3
IV	392 (21.0)	9	22
V	410 (17.1)	2	293
VI	415 (23.2)	3	469

It was decided that as many fish as possible would be collected because, (1) one is never certain that fin sections from any individual fish will be readable, (2) there is no way to know if you are within your desired half-width of the confidence interval unless aging is done concurrently with collecting, and (3) weight estimates are generally more variable than length estimates. Additionally, based on past catch records at the weir site, the number of fish needed for aging to achieve the above specified precision just about equals the annual catch.

Site Description

The Big Two-Hearted River is a large stream for the Upper Peninsula. The discharge averages 34.3 cubic meters per second from April through June. Its water is colored brown with a total alkalinity of 35 mg/l as $CaCO_3$. The bottom is sand and gravel. It drains an area of 521 square kilometers. The mouth of the river is located approximately 29 kilometers northwest of Paradise, Michigan.

The sampling point was approximately 1/2 kilometer upstream from where the stream empties into Lake Superior (Figure 1). The location of the mouth of the Big Two-Hearted River varies from year to year depending on the volume and velocity of water. At times, the stream bed scours to more than a meter below its normal elevation. The stream bottom from the weir site to the mouth consists largely of sand to cobble-sized stones.

Fishery

The river supports numerous spring spawning runs of fish in addition to its resident brown trout (Salmo trutta) and brook trout (Salvelinus fontinalis) (unpublished U.S. Fish and Wildlife Service records). The Big Two-Hearted River supports viable runs of steelhead, smelt, brown trout, white sucker, and longnose sucker.

The steelhead run gets much attention and receives a sizable amount of recreational fishing pressure. The suckers receive light fishing pressure, especially for the longnose sucker since it is easier to take by hook and line than the white sucker.

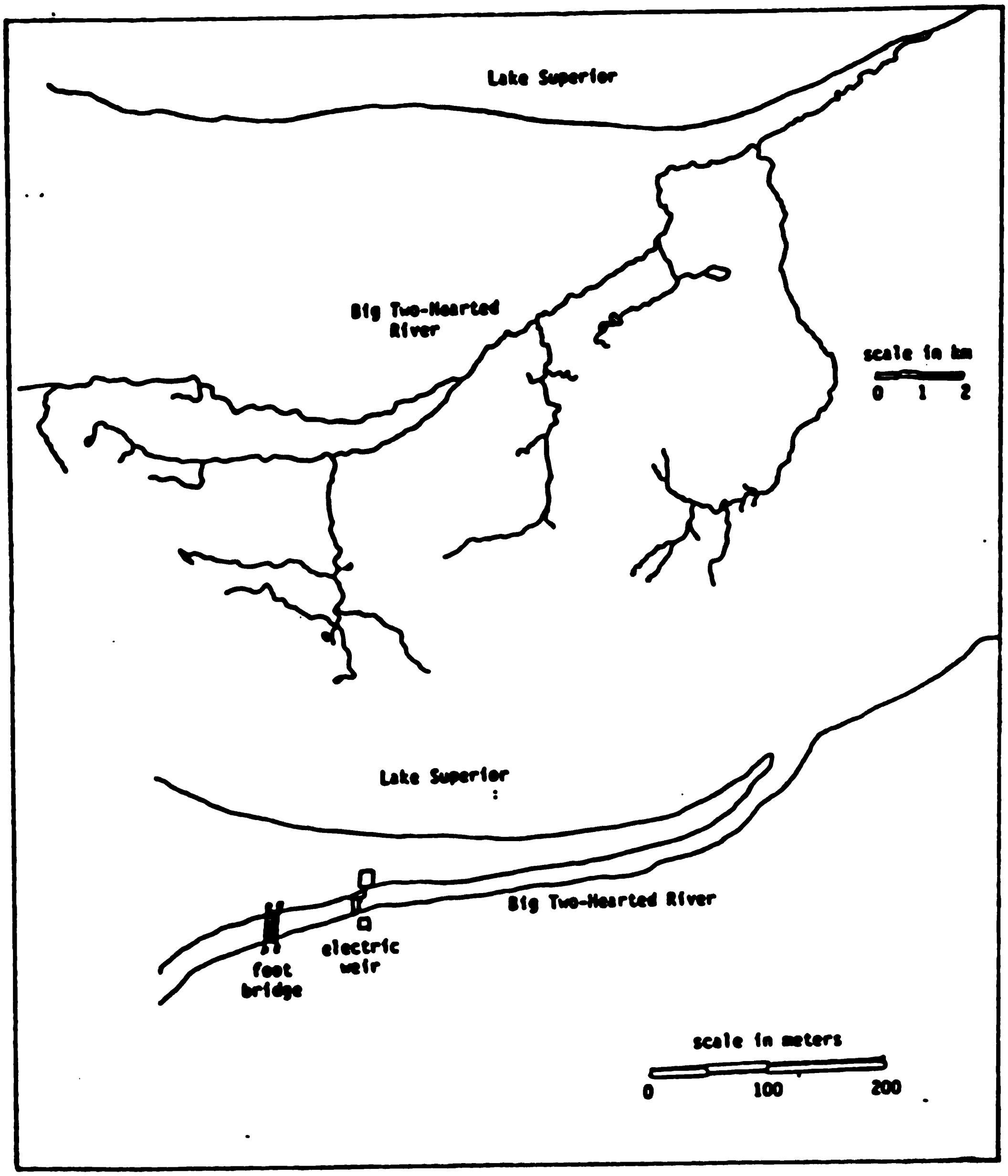

Figure 1. Big Two-Hearted River and electric weir location.

POPULATION DYNAMICS - SPRING 1979

Length Description

The spawning white suckers in the Big Two-Hearted River were sampled for life history information three times from May 12 through June 13, 1979. There were 457 fish sampled for age determination (five immature, 246 males and 206 females). Figure 2 shows the length frequency distribution of immature and mature male and female white suckers. Fish were grouped into 19 mm length groups (i.e., 200-219 mm, 220-239 mm, etc.). The figure illustrates the size distribution difference between the male and female spawners in 1979. Figures 3 and 4 illustrate the length frequency distributions for male and female by time period in the spawning season. Figure 3 shows that proportionately there is a higher occurrence of males less than 400 mm toward the end of the spawning period. There is no clear indication of any size differences among these three time periods for females (Figure 4).

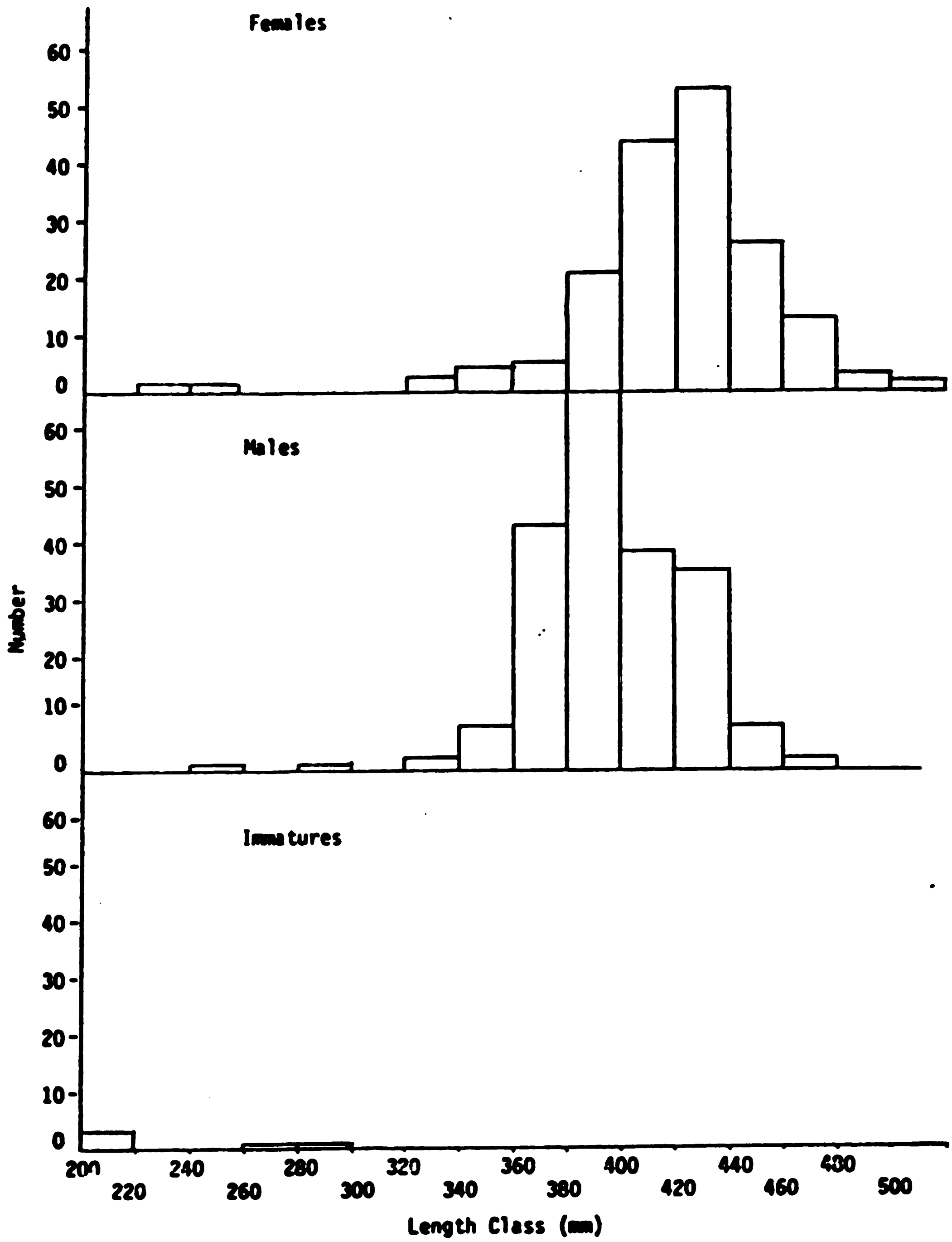

Figure 2. Length-frequency of white suckers - Spring 1979.

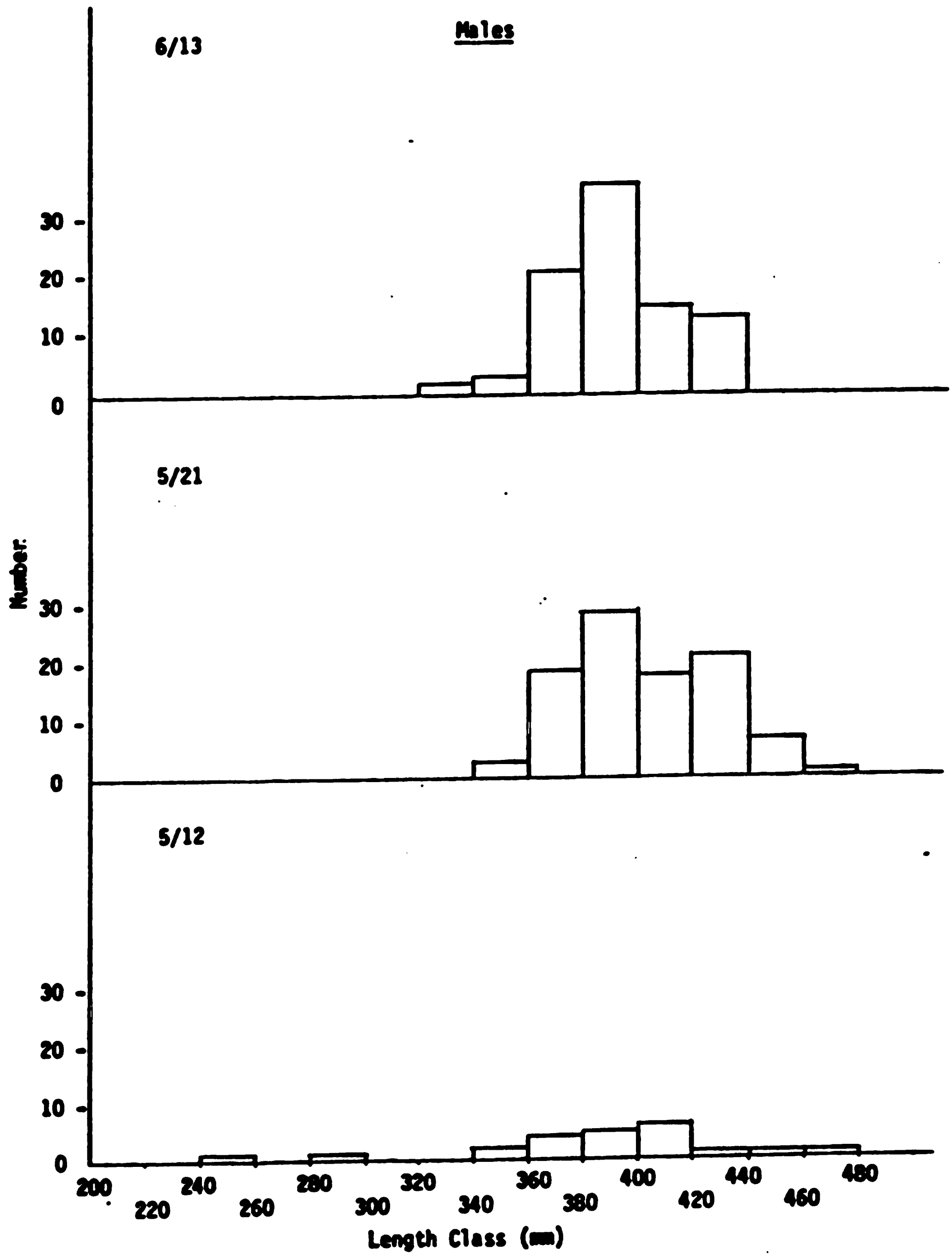

Figure 3. Distribution of males throughout spawning.

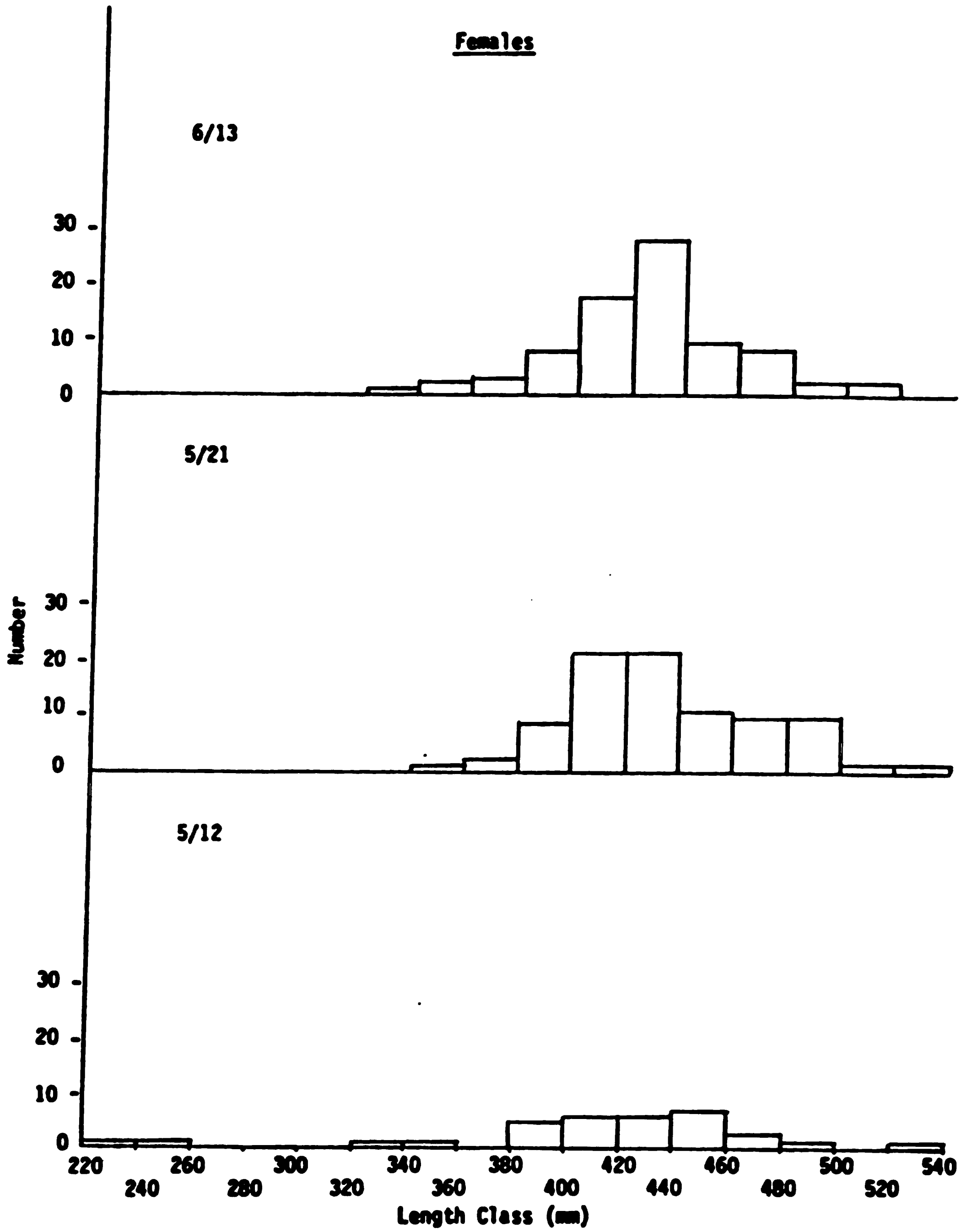

Figure 4. Distribution of females thoughout spawning.

Table 3 shows the summary statistics for the male white suckers during the spring of 1979.

Table 3. Summary statistics for males
Spring 1979

Number	Age	Avg Length (mm)	CV %	Avg Weight (gm)	CV %
2	3	374.5		600	
27	4	379.6	4.66	588.5	14.6
59	5	381.5	4.98	606.1	18.0
61	6	393.2	5.51	674.5	16.6
36	7	406.5	5.37	738.0	13.8
26	8	406.4	5.95	732.7	14.7
18	9	416.5	4.25	807.1	13.7
10	10	428.8	5.75	881.7	12.8
4	11	448.0	3.70	1026.7	10.6
2	13	437.0	3.20	840.0	11.9
1	17	452.0		1040.0	

Table 4 shows the summary statistics for the female white suckers during the spring 1979 spawning run.

Table 4. Summary statistics for females
Spring 1979

Number	Age	Avg Length (mm)	CV %	Avg Weight (gm)	CV %
12	4	369.7	17.1	635.4	45.8
50	5	406.1	5.7	800.5	14.1
48	6	414.4	6.1	815.6	18.1
41	7	429.8	5.5	893.9	19.9
15	8	459.4	5.5	1088.0	18.5
18	9	454.8	5.8	1095.6	15.4
14	10	476.1	6.2	1265.0	15.7
4	11	457.5	1.1	1150.0	8.2
1	12	515.0		1520.0	
1	13	520.0		1730.0	
1	15	472.0		1110.0	

Numerous fish captured at the weir had broken backs (presumably from impact by the electric field) and these individuals were not used in calculation of the statistics for length and weight.

Length-Weight Relationships

Growth of the white sucker population for the spring of 1979 was analyzed separately for males and females. The relationship of body weight as a function of length was investigated. The von Bertalanffy theoretical growth equation describes the growth in weight as an exponential function of length (Gulland 1969). The generalized formula is:

$$W = a\,L^{b}(\varepsilon)$$

where: W = weight,

a = a constant,

L = length,

b = growth exponent, and

ε = random error term.

The linearized form of the growth equation for use in linear regression analysis is:

$$\ln W = \ln a + b \ln L + \ln \varepsilon.$$

The spring 1979 length-weight relationship for males, ages 3 through 11, is given by:

$$\ln W = 0.000005 + 3.1 \ln L + \ln \varepsilon,$$
$$R^2 = 0.99.$$

The measure of fit (R^2) of the regression indicates that the natural logarithm of length explains 99 percent of the variability in the natural logarithm of weight for the male white suckers.

The spring 1979 length-weight relationship for females, ages 4 through 10, is given by:

$$\ln W = 0.000078 + 2.7 \ln L + \ln \varepsilon,$$
$$R^2 = 0.99.$$

The measure of goodness of fit (R^2) indicates that the natural logarithm of length again explains 99 percent of the variability in the natural logarithm of weight for female white suckers.

The spring 1979 length-weight regression for males and females taken as one population, ages 3 through 11, is given by:

$$\ln W = 0.0000063 + 3.1 \ln L + \ln \varepsilon,$$
$$R^2 = 0.99.$$

Again the natural logarithm of length accounts for 99 percent of the variability in natural logarithm of weight for the white sucker population.

The growth constant (b), for the population as a whole is very close to 3, therefore, the assumption of isometric growth (growth in weight as the cube of the length) appears justified for use in growth estimation within the Dynamic Pool Model. Analysis of covariance, however, shows that the slopes in the separate regressions for the males and females differ significantly ($p = .01$). The analysis indicated that after maturity the female white suckers grow at a faster rate than the males. The author has no site specific information on the growth rates for the two sexes prior to maturity.

Survival

There are numerous methods to calculate the survival of fish. The method used here is survival based on the assumption of a geometric distribution of numbers of fish with age (Chapman and Robson 1960).

Adult white sucker mortality based on the assumption of a geometric distribution assumes that there are few older fish relative to young fish. The basic formula of population survival is:

$$N_{(x+1)} = s \cdot N_x,$$

where: $N_{(x+1)}$ = number of fish at the next older age

N_x = number of fish of age x, and

s = the annual survival rate between age x and age (x+1)

This translates to

$$N_x = (1-a)^x N_0,$$

where: N_x = number of fish at age x,

$(1-a)^x$ = the annual survival rate at the specific age x,

N_0 = the initial number of fish at recruitment, and

a = the annual mortality rate.

The assumption is that the population is in equilibrium and the number of fish in each age group diminishes geometrically with age, implying that the annual survival rate is constant over age and time. If this assumption is correct then there is some age x_0, such that for all ages $x \geq x_0$, the probability of selection is the same and the annual survival rate is the same. The ages can be relabeled for convenience so the first fully vulnerable age $x_0 = 0$.

For the white sucker population the annual survival rate s, was based on the ages observed in the random sample of 318 individuals from the population.

The formula provided by Chapman and Robson (1960) for calculation of mortality using coded ages is:

$$\hat{s} = \frac{\Sigma x_i}{n + \Sigma x_i - 1}$$

where: n = sum of all coded age groups 0, 1, 2...

$\hat{s}$ = annual survival rate, and

Σx_i = weighted sum of the coded age groups 1, 2, 3....

The variance for survivorship is:

$$\text{Var}\ (\hat{s}) = \hat{s}\ (\hat{s} - \frac{\Sigma x_i - 1}{n + \Sigma x_i - 2})\ .$$

For the female white suckers the survival is calculated starting from age 6, which is the age at which the female fish are fully represented in the catch as indicated by the catch curve (Figure 5).

An estimate of the survivorship of the female white sucker is:

$$\hat{s} = \frac{\Sigma x_i}{n + \Sigma x_i - 1} = \frac{243}{402} = 0.6045.$$

The mortality is therefore:

$\hat{a} = 0.3955.$

An estimate of the variance of the survivorship is:

$\text{Var}\ (\hat{s}) = 0.0061$ and

the error bound $\hat{B} = 2\sqrt{\text{Var}\ \hat{s}} = 0.0494$.

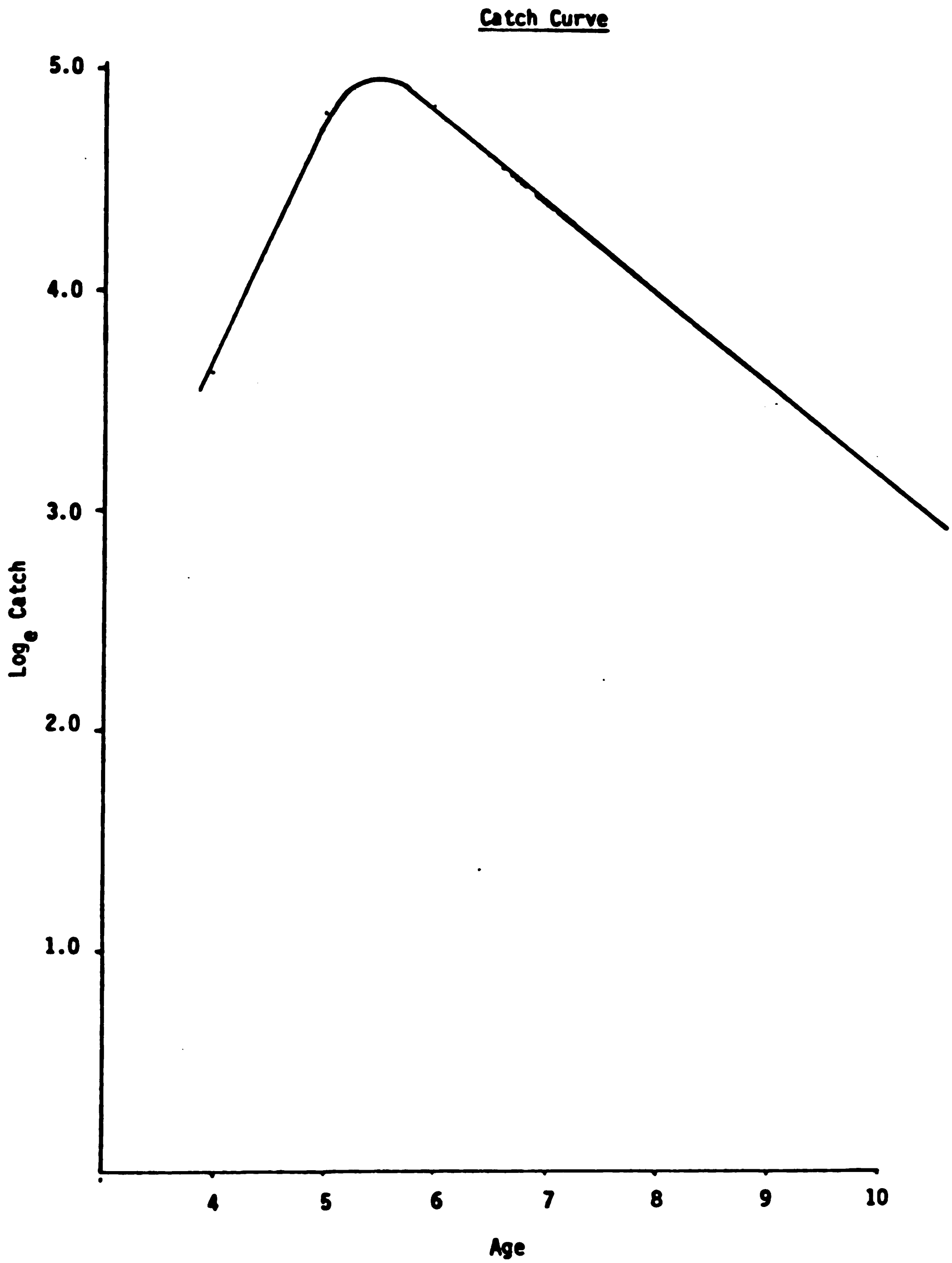

Figure 5. Catch curve for Spring 1979.

Therefore, the survivorship with an approximate 95% confidence interval is:

0.6045 ± 0.0494.

For the male white suckers the age at which the fish are fully vulnerable to the weir is also age 6.

Proceeding as before:

$$\hat{s} = \frac{\Sigma x_i}{n + \Sigma x_i - 1} = \frac{227}{384} = 0.5912,$$

$$\hat{a} = 0.4088,$$

$$\text{Var}\ (\hat{s}) = 0.000663, \text{ and}$$

the error bound $\hat{B} = 2\sqrt{\text{Var}\ (\hat{s})} = 0.0515$.

Therefore the survivorship with an approximate 95% confidence interval is:

$$0.5912 \pm 0.0515.$$

According to the above calculations the annual survivorship for the males and females is so close that they can be treated as the same.

The annual survival for further calculations will be 0.60 and the annual mortality is then 0.40. The instantaneous total mortality rate, Z, defined as the negative natural logarithm of survival, is 0.51.

Since there is essentially no sport fishery for white suckers in the Big Two-Hearted River, the instantaneous natural mortality rate M will be assumed to be equal to the instantaneous total mortality rate.

Growth - Adult White Suckers

For population analysis it is desirable to express the growth of fish in a mathematical expression. The basic requirement is an expression giving the size (in terms of weight or length) at any given age which agrees with the observed data (Gulland 1969). It also is desirable to be able to easily incorporate this expression in a model for yield. The von Bertalanffy growth equation is often used (Gulland 1969).

There are arguments for the retirement of the von Bertalanffy equation (Roff 1980), but it appears to work well when applied to the Big Two-Hearted River white sucker population. The assumption of isometric growth inherent with the use of this equation seems to be warranted.

The von Bertalanffy growth equation can be used both for determining the "rate" of growth (increase in weight or length per unit time) and the size of a fish at various ages. The instantaneous rate of growth will not be known, only lengths at certain times, however, for use in the yield model for the spawning population of white suckers in the Big Two-Hearted River that is sufficient.

The general equation used is:

$$W_{(x)} = a\, L_{(x)}{}^{b}\, \varepsilon,$$

where: $W_{(x)}$ = weight at a given age x,

a = a constant,

$L_{(x)}$ = length at a given age x,

b = growth constant, and

ε = the random error term.

Usually b is assumed to approximate 3. According to previous growth regressions this assumption appears to be valid. According to Gulland (1969) the growth in length equation derived by von Bertalanffy is of the form:

$$L_{(x)} = L_{(max)}\,(1-e^{-K(x-x_0)})\,\varepsilon$$

where: $L_{(max)}$ = maximum length attained by the species,

K = annual growth constant,

x_0 = theoretical age of fish at length 0,

x = age of fish, and

ε = the random error term.

The linearized form of the above equation for investigating the relationship of the length at age x to the length at age x + 1 can take the form:

$$L_{(x+1)} = L_{(max)} (1-e^{-K}) + e^{-K} L_{(x)} + \varepsilon$$

Regressing length at age x on length at age x + 1 results in:

$$L_{(x+1)} = 34.54 + 0.9397 L_{(x)} + \varepsilon.$$

The theoretical maximum length of the white suckers in this population can be calculated by rearranging:

$$L_{(max)} = \frac{a}{(1-b)} = 572.8 \text{ mm}.$$

Ford (1933) and later Walford (1946) independently developed an equation describing each year's growth increment as less than the previous year's. Walford noted that if length at one age was plotted against the length at the next younger age the result was a straight line and that the point of intersection of the growth line and a 45° line drawn from the origin is an estimate of $L_{(max)}$.

Figure 6 shows a Ford-Walford plot of the length at age x+1 against length at age x.

The annual growth constant (K) can be derived from the regression and is defined as:

$$- \ln e^{-K}$$

or

$$-\ln 0.9397 = 0.063.$$

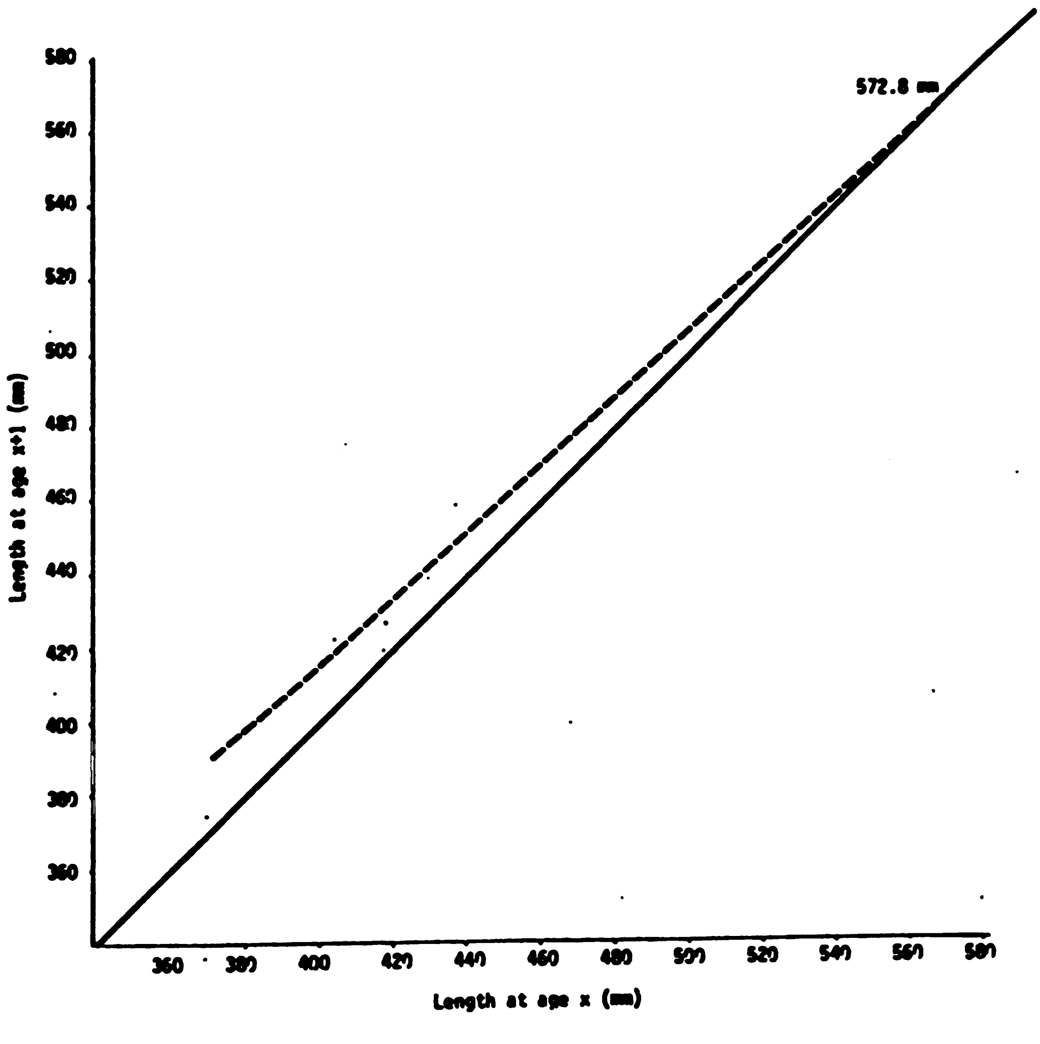

Figure 6. Ford-Walford plot for maximum length.

Therefore K = 0.063 or the annual rate of growth of the white suckers is approximately 6 percent per year after maturity. The weight of these white suckers has been shown to vary as a power of the length (see Length-Weight Relationships).

The regression describing the data for the weight of these fish as a function of length is:

$$\ln W_{(x)} = 0.000006 + 3.1 \ln L_{(x)} + \ln \varepsilon \text{ and}$$
$$W_{(max)} = a\, L_{(max)}\, \varepsilon, \text{ therefore,}$$
$$W_{(max)} = 2218.7 \text{ grams.}$$

Figure 7 shows a Ford-Walford plot of weight at age (x + 1) against weight at age x.

One of the remaining parameters to be calculated before the von Bertalanffy growth equation can be incorporated into the Dynamic Pool Model is the theoretical age at length 0, (x_0).

$$L_{(x)} = L_{(max)} \left[1-e^{-K(x-x_0)}\right] \times \varepsilon$$

rearranging this equation gives

$$e^{-K(x-x\ )} = \frac{L_{(max)}-L_{(x)}}{L_{(max)}} \times \varepsilon$$

taking the natural logarithm yields

$$x_0 = x + \frac{1}{K} \ln \left(\frac{L_{(max)}-L_{(x)}}{L_{(max)}}\right) + \ln \varepsilon$$

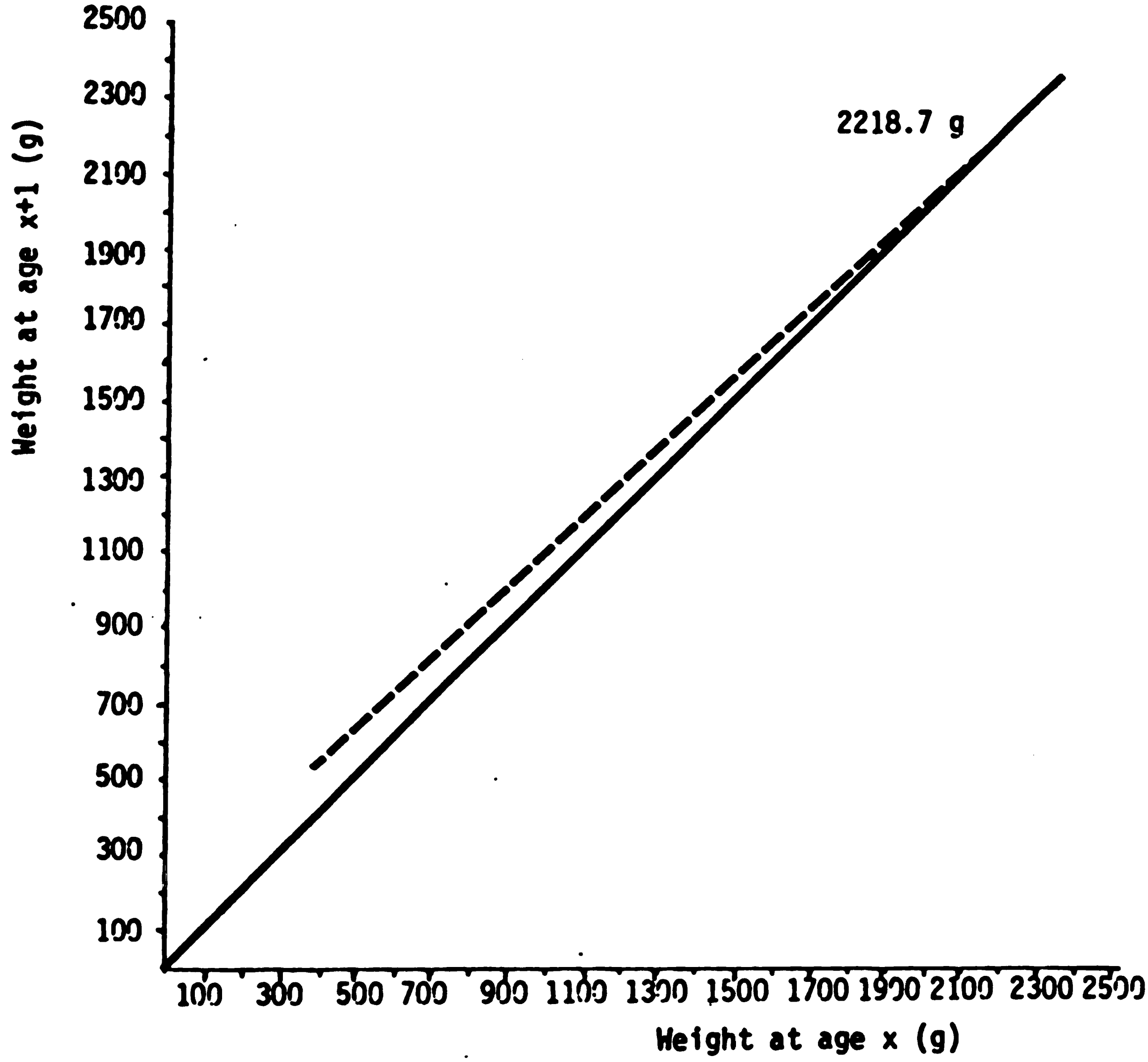

Figure 7. Ford-Walford plot for maximum weight.

which can be solved using linear regression techniques

$$x_0 = a + b \ln \left(\frac{L_{(max)} - L_{(x)}}{L_{(max)}}\right) + \ln \varepsilon \,.$$

The value for x_0 is -8.72 years. This value is simply a theoretical value and has no biological meaning but is needed to compute the growth form from time 0.

Recruitment

The age of recuitment is defined as the age at which the fish are fully vulnerable to the particular gear. In this situation, recruitment will be defined as the age when all of the fish have matured and joined the spawning population.

To determine this age a simple catch curve can be constructed. A catch curve is the natural logarithm of the number of fish caught, at a particular age, plotted against the ages of the fish in the population. This plot forms a type of parabola and the maximum height of this parabola represents the point at which all succeeding ages are fully represented in the catch. In this instance, the age of recruitment for the male and female white suckers combined is 5.5 years (Figure 5).

YIELD ESTIMATION

Model Description

The Dynamic Pool Model as it is normally used is a single stock yield model. The model incorporates data obtained on size and age composition of the fish stock. In essence the model considers the population as the sum of the individual fish.

The model can be used to analyze various fishing mortalities and ages of recruitment to a particular fishery. Assuming that recruitment is independent of stock size and that the stock is in equilibrium, the average yield from the stock during any period is proportional to the average recruitment. This leads to the conclusion that the yield from an average cohort during its life is equal to the average yield from all cohorts during any year. In addition, the yield from a cohort is proportional to the number recruited to it. Yield per recruit is, then, an expression of yield.

The Dynamic Pool Model in its simplest form is merely:

yield = fishing mortality x number of fish x weight of the fish

for any specific age group of fish. When incorporating the functions estimating the mortality, weight, and numbers over all the age groups the model can be used to estimate the yield from the entire population subject to exploitation. Two areas where the fishery can be affected are (1) the rate of fishing mortality and (2) the age at which the fish are first harvested.

Investigation of the consequences of exploitation is accomplished using the following general formula of the Beverton and Holt Dynamic Pool Model.

$$Y/R = F\, e^{-M(x_c - x_r)}\, W_{(max)} \left(\frac{1}{Z} - \frac{3\, e^{-K(x_c - x_o)}}{Z + K} + \frac{3\, e^{-2K(x_c - x_o)}}{Z + 2K} - \frac{e^{-3K(x_c - x_o)}}{Z + 3K} \right)$$

where: Y = yield in grams,

R = number of individuals recruited,

F = instantaneous fishing mortality,

M = instantaneous natural mortality,

x_c = age of the fish at catch,

x_r = age of fish at recruitment,

$W_{(max)}$ = maximum weight of fish in population,

Z = instantaneous total mortality (-ln survival),

K = von Bertalanffy growth constant, and

x_o = the theoretical age when a fish's length is 0.

Model Application

There is presently no significant fishery for white suckers on the Big Two-Hearted River, sport or commercial. Therefore, the age of fish at catch and the fishing mortality will be adjusted to inspect the reaction of yield to these variable changes.

In an effort to visually display the yield for catch at ages 3 and 6 and various fishing mortalities a plot of yield per recruit versus instantaneous fishing mortality was constructed (Figure 8). Figure 9 shows the yield per recruit for an instantaneous fishing mortality of 0.80 and the range of ages for the white suckers in the stream.

A yield contour diagram was prepared to visually display the various ages at catch and instantaneous fishing mortalities (Figure 10). There appears to be no optimum harvest rate. In other words the harder the white suckers are fished the more production can be obtained. The assumption is that as the fishing mortality increases the natural mortality will decrease allowing the population to sustain itself.

For the most part, the fish are not available in the river until they are mature so given the high fecundity of the white sucker (Kononen 1981) a relatively small number of spawners should be able to sustain the stock.

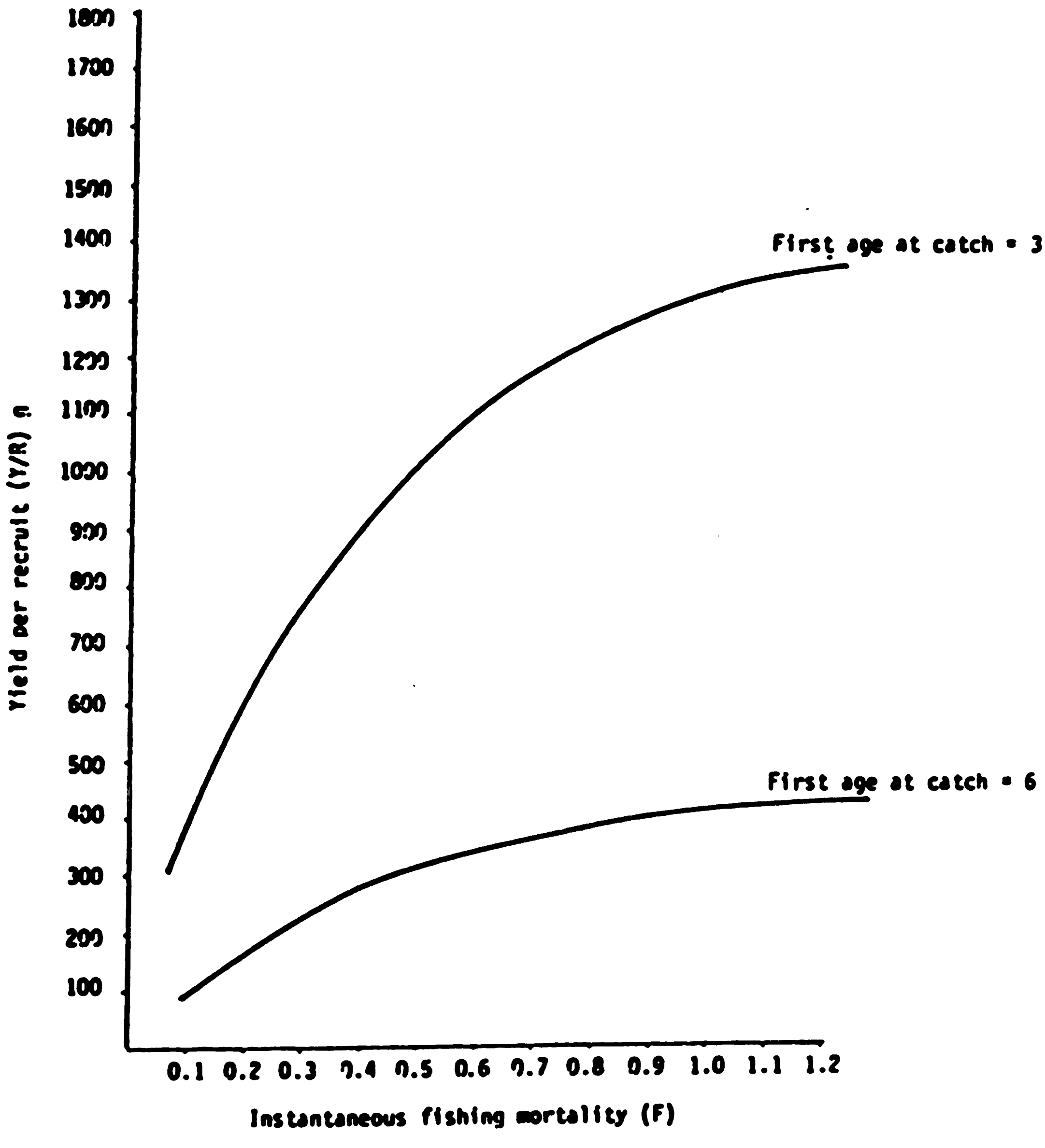

Figure 8. Yield-per-recruit at various fishing mortalities(F).

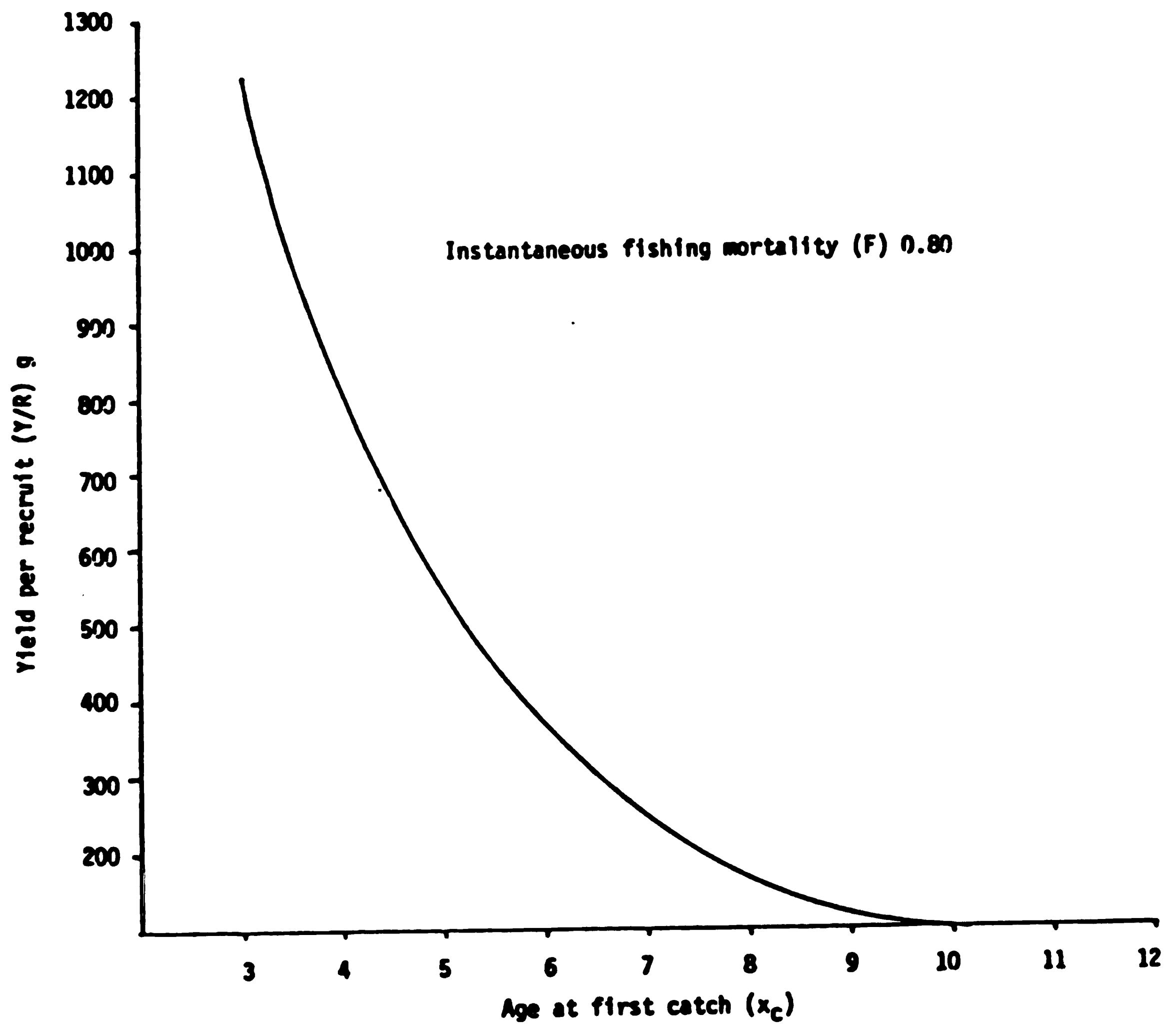

Figure 9. Yield-per-recruit for various ages at first catch.

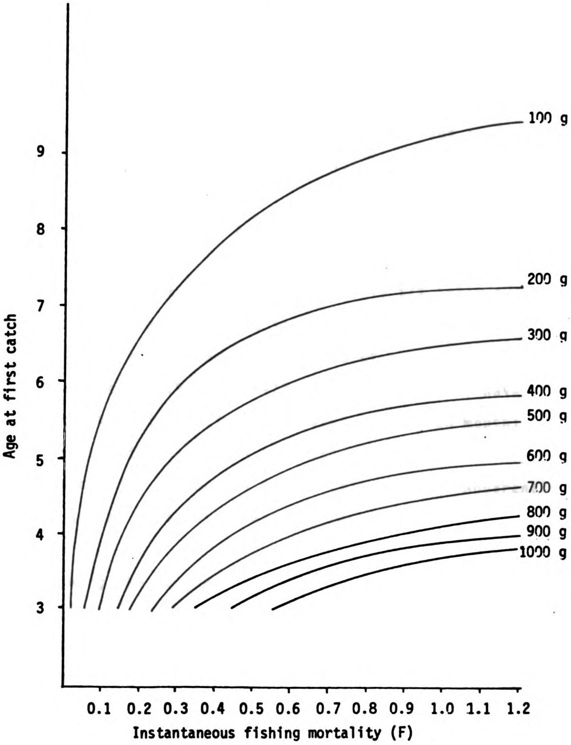

Figure 10. Yield contour diagram.

Ancillary Observations

Numerous fish were afflicted with parasites between the rays in the paired fins. No attempt was made to identify the type of worm between the fin rays. Kononen (1981) made a similar observation for suckers in Saginaw Bay.

Lamprey parasitism was not apparent in the fish handled.

The electric weir was located approximately 1/2 kilometer upstream from the mouth of the stream. The stream bottom in this section of the stream is comprised of cobble, gravel and sand. From the mid 1950s to 1979, the white suckers have been limited to this section for spawning (weir to mouth). Despite the confinement, this population has not had a noticeable decline in numbers during this period. Apparently the white sucker is a very adaptable species.

When examining the tagging data it became apparent that these white suckers have quite an extended spawning period. Numerous fish that were first captured in late April were recaptured throughout the spawning season even into July.

Because of the distance to the river, daily tagging and releasing was not possible. Therefore, a population estimate could not be made using any of the commonly used methods. However, as I examined the recapture of tagged fish for the various periods of study it became apparent that the time within the spawning season that a fish was first captured and tagged strongly influenced the number of times an individual was captured. A plot of the average recapture rate as a function of the date of first capture within the spawning season should indicate how large the spawning population is relative to the total weir capture. Examination of Figure 11 shows that the average recapture rate over the season is 1.4 recaptures per individual. Therefore, if the total number of fish captured in the 1979 field season is divided by 1.4 a rough estimate of the spawning population can be had. The index number at the weir was 2,384 so the probable adult population is approximately 1,600.

SUMMARY AND CONCLUSIONS

Summary

The objective of this investigation was to determine the approximate size of the white sucker population and to estimate the potential level of exploitation in this river. The population dynamics (e.g., age and growth information) are only considered representative of the stock spawning in the Big Two-Hearted River. There is evidence, however, from tag returns that some of the adult suckers caught in the Big Two-Hearted River will ascend other nearby rivers, presumably to spawn.

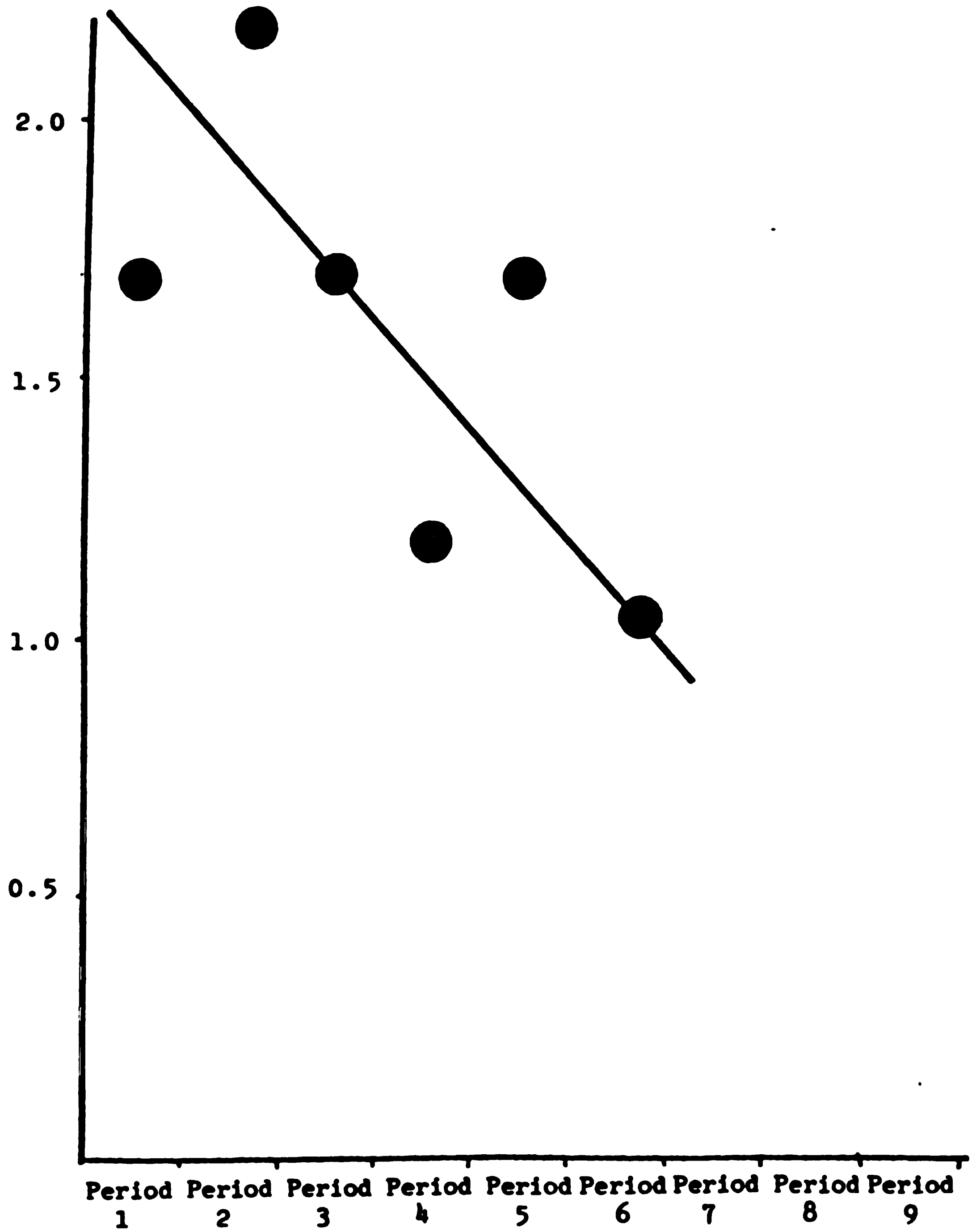

Figure 11. Average recaptures over the spawning period.

The method of capture used in this study (electric weir) is assumed to capture all the white suckers attempting to pass the point of the weir in the stream. It is further assumed that those fish captured represent the true spawning population of the river. The first assumption is subject to equivocation as it is the opinion of some workers operating these electric weirs that the suckers "stack-up" downstream of the barrier. This investigator observed that some of the fish entering the stream and first captured in April were recaptured numerous times spanning the duration of the spawning season indicating a strong urge by these fish to ascend the stream to spawn, thus supporting the assumption that all the fish would attempt to pass the point of the weir and be captured. The fact that immature white suckers (less than 225 mm in length) as well as large numbers of other small fish (i.e., smelt) were captured tends to support the assumption of total susceptability to the gear, thus a representative catch.

The length-weight relationship developed for the males and females show that the females grow faster than the males after they reach maturity. No data were available prior to maturity for these fish. The growth constant (b) within the function describing the relationship of length to weight for the whole population is very close to 3 indicating that the assumption of isometric growth is justified.

These white suckers appear to have a mortality rate similar to populations studied elsewhere. Operating under the assumption of an equilibrium population and constant survival, the annual survival rate is 0.60. The survival rate reported by Kononen (1981) for Saginaw Bay white suckers ranged from 0.59 to 0.72 and that reported by Coble (1967) for South Bay, Lake Huron, ranged from 0.70 to 0.75.

The age at which all fish are mature and recruited to the spawning population appears to be age 6. Males start maturing at age 3 and females at age 4. Use of a catch curve (natural log of catch vs. natural log of age) demonstrated that the maximum height of this parabola, representing the point at which all succeeding ages are fully represented in the catch, is age 5.5.

Conclusions

Calculation of yield per recruit as a function of fishing mortality showed that there is no optimum rate of exploitation (e.g., the higher the fishing mortality the greater the yield). In an effort to visually display the result of various ages at first capture and fishing mortalities, a yield contour diagram was prepared (Figure 10). According to the model, the greatest yield is 800 grams per recruit while fishing four-year old fish with an instantaneous fishing mortality of 1.1. This information combined with the estimate of the adult population ascending the Big Two-Hearted River indicates the yield from this stream would be approximately 2,800 pounds per year. This estimate is for whole fish, in-the-round.

If the exploitation of this stock is undertaken, it is recommended that similar calculations be completed as part of an ongoing monitoring program because of probable changes in age at maturity and rate of growth adjustments induced by exploitation.

Future studies should focus on obtaining an adequate population estimate for the spawning run and investigating the life history of the immature fish.

APPENDIX

General References

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General References

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