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# RELATION OF SEA LAMPREY SIZE AND SEX-RATIO TO SALMONID AVAILABILITY IN 3 GREAT-LAKES

**HOUSTON KA**, KELSO JRM

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**Abstract:**
Since 1980 the proportion of males appears to have increased to approximately 50% in the sea **lamprey** (Petromyzon marinus) populations of Lakes Superior and Huron following a period (1970-1980) of stability. In Lake Ontario, there has been a shift from an approximately equal sex ratio (1970-1980) to a slight preponderance (approximately 60%) of males. Multiple regression analysis indicated that prey availability (reflected by salmonid stocking or commercial catch) was significantly related to the observed changes in length, weight, and proportion of males. We also found that, while sea **lamprey** length and weight may have stabilized in Lake Superior (1960 to present), sea **lamprey** have generally become larger in both Lakes Huron and Ontario. Again, prey availability was most closely related to weight of sea **lamprey**. Sex ratio and adult weight in Great Lakes sea **lamprey** appear to be related to prey availability and therefore may not be adequate indicators of the success of sea **lamprey** control.

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GREAT LAKES FISHERY COMMISSION
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# RELATIONSHIPS OF SIZE AND PROPORTION OF MALE SEA LAMPREY TO SALMONIDS IN THREE GREAT LAKES

by

K.A. Houston and J.R.M. Kelso
Department of Fisheries and Oceans
Great Lakes Laboratory for Fisheries
and Aquatic Sciences
Canal Drive, Ship Canal P.O.
Sault Ste Marie, Ontario P6A 1P0

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Houston, K.A. and J.R.M. Kelso. Relationships of size and proportion of male sea lamprey with salmonids in three Great Lakes.

**ABSTRACT**

Since 1980, the proportion of males appears to have increased to ~50% in the sea lamprey (Petromyzon marinus) populations of Lakes Superior and Huron following a period (1970 - 1980) of stability. In Lake Ontario, there has been a shift from an approximately equal sex ratio (1970 - 1980) to a slight preponderance (~60%) of males. Multiple regression analysis indicated that prey availability (reflected by salmonid stocking or commercial catch) was significantly related to the observed changes in both length, weight and proportion of males. We also found that, while sea lamprey length and weight may have stabilized in Lake Superior (1960 to present), sea lamprey have generally become larger in both Lakes Huron and Ontario. Again, prey availability was most closely related to weight of sea lamprey. Sex ratio and adult weight in Great Lakes sea lamprey appear to be related to prey availability and therefore may not be adequate indicators of the success of sea lamprey control. However, these measures may be useful indicators of the net benefits of both fishery management and sea lamprey control.

## INTRODUCTION

Sea lamprey (Petromyzon marinus) in the Laurentian Great Lakes have adapted to their landlocked environment by becoming smaller (Vladikov 1951; Hardisty 1971; Beamish 1979; Weise and Rugen 1987) and less fecund (Applegate 1950; Vladikov 1951; Wigley 1959; Manion 1972) than their marine counterparts. With the initiation of a control program to reduce sea lamprey abundance, mean lengths and weights of sea lamprey increased and the proportion of males in the population declined as their numbers declined (Smith 1971). Heinrich et al. (1980) and Torblaa and Westman (1980) examined size and sex data to 1978 and found that growth declined after chemical control but later increased and that a shift to a preponderance of females occurred as populations declined. Smith (1971) recognized that factors other than sea lamprey abundance influenced sea lamprey size. Heinrich et al. (1980) found that in Lake Superior, sea lamprey appeared to grow faster when the control program had reduced lamprey numbers and when lake trout were more abundant.

Abundance of primary sea lamprey prey species (e.g. salmonids) has dramatically increased since the late 1970's in Lakes Ontario (Christie et al. 1987) and Superior (Krueger et al. 1986; MacCallum and Selgeby 1987) and probably also in Lake Huron (Collins 1988; data from the Great Lakes Fishery Commission (GLFC)). Because sea lamprey population characteristics are likely to respond to changes in prey density and/or fish community structure in general or to the sea lamprey control strategy in particular, (Smith 1971; Heinrich et al. 1980; Torblaa and Westman 1980; Odum 1985), we examined the 38 y of data now available for length, weight and sex composition of Great Lakes sea lamprey populations from Lakes Ontario, Huron and Superior. We first examined changes of these biological characteristics (length, weight and proportion of male sea lamprey) to the present (1987) in populations from the three Great Lakes. Second, we related any change(s) evident in weight or sex composition to general control strategy (e.g. pretreatment, barriers, chemical), an indicator of sea lamprey abundance (catches over time in a stream(s) for each lake), and prey abundance as indicated by salmonid catch and/or stocking.

## METHODS

### Data Collection

The Canadian Department of Fisheries and Oceans and the U.S. Fish and Wildlife Service have sampled spawning lamprey in streams from Lake Huron since 1951, from Lake Superior since 1953, and from Lake Ontario since 1968. Sea lamprey have not been a serious problem in Lake Erie (Pearce et al. 1980) and data were sparse. Although sea lamprey were common in Lake Michigan and an active control program has been in place since 1960 (Smith and Tibbles 1980), several interruptions in sampling occurred. In addition, Kitchell (In press) used the weight data for sea lamprey from Lake Michigan to examine their bioenergetics.

Therefore, to avoid uncertainties and duplication, we excluded Lakes Erie and Michigan data from our analysis. Data on length, weight and sex were available for ~25% of the 427 tributaries of the Great Lakes in which sea lamprey spawn. We used data wherever it was available (Table 1).

Because males and females were weighed and measured separately, we used Pearson correlation analysis to examine the correlation in length and weight between the sexes. There was no significant difference ($P<0.05$) between the length and weight of males and females; therefore, we pooled data from both sexes. The length, weight and sex ratio data from Lakes Superior, Huron and Ontario were analyzed separately; however, we pooled the length, weight and sex ratio data from all streams sampled in a lake since there was minimal variation among these variables (c.v.<10%) within a lake (Steel and Torrie 1960).

Salmonids (Salvelinus namaycush, S. fontinalis, Salmo trutta, Salmo salar, Oncorhynchus mykiss, O. tshawytscha, O. kisutch, and O. gorbuscha) have been stocked in each of the Great Lakes to increase abundance of lake trout or generate new fisheries (e.g. chinook, coho). Because these 8 fish species may be among the preferred prey of sea lamprey (Johnson and Anderson 1980), we summed annual stocking and commercial catch for all salmonids. Records of salmonid stocking up to 1987 for Lakes Superior, Huron and Ontario were obtained from the GLFC (M. Dakoda, GLFC, Ann Arbor, MI). Commercial catch statistics for all salmonid species were reported in Baldwin et al. (1979) and the GLFC annual reports (1978 - 1983). Commercial catch data for 1984 to present have not yet been compiled.

Data Analysis

Each time series of weight, length and percent male sea lamprey was plotted using a Distance Weighted Least Squares (DWLS) smoothing which fitted a line through the data (Wilkinson 1988). Each point on the smoothed line was estimated by a weighted quadratic multiple regression on all points which allowed the curve to flex locally to better fit the data and to provide a visual representation of the shape of each time series. Autocorrelation analysis determined how closely each value was related to previous values in the series (i.e. if there were any significant lags in the data; Wilkinson 1988). In doing so, we were able to determine if the series was random or if there were indeed significant autocorrelations and/or potential trends. As well, a linear regression was fitted to each data set to test for trends.

Catch of spawning sea lamprey from an index stream(s) was used as a relative measure of abundance in each of the 3 Great Lakes. For Lake Superior, electrical barriers were continuously operated in the Betsy, Two Hearted, Sucker, Chocolay, Iron, Silver, Brule and Amnicon Rivers until 1978. Catches from these 8 barriers were used to indicate sea lamprey abundance in Lake Superior. Catches from the Ocqueoc River were used as an indicator of sea lamprey abundance within Lake Huron, and catches from the Humber River were used for Lake Ontario.

For Lakes Superior and Huron, 3 "periods" (based on collection and/or control method) were identified: a) pre-chemical control, samples from electrical barrier and mechanical weirs only (Lake Superior pre-1958; Lake Huron pre-1958), b) initiation of chemical control and concurrent operation of electrical barriers (Lake Superior 1958-1979; Lake Huron 1958-1980), and c) chemical control only (Lake Superior 1979 to present; Lake Huron 1980 to present). These categories were established to encompass major changes in the control strategy and may reflect relative differences in lamprey abundance. In Lake Ontario, electrical barriers were never used; therefore, only 2 "periods" were identified: a) pre-chemical control (pre-1971), and b) after the initiation of control (1971 to present). An analysis of variance (ANOVA) was performed to examine the possible effect of different control strategies ("periods") on the weight and proportion of male spawning sea lamprey.

Pearson correlation analysis was used to examine the correlations between sea lamprey weight and sea lamprey abundance, salmonid stocking or salmonid catch. Pearson correlation analysis was also used to examine correlations between percent males and sea lamprey abundance, salmonid stocking or salmonid catch. We then used multiple regression to determine which of sea lamprey abundance, salmonid stocking and salmonid catch had the greatest influence on sea lamprey weight or percent males (Snedecor and Cochran 1967).

## RESULTS

### Lake Superior

The data for Lake Superior, collected from 1953 - 1987, provided 35 y of continuous measurements of length and percent males in the sea lamprey spawning run. Weights were not measured in 1953. The proportion of males in the population appeared to have changed through time in a cyclical pattern (Fig. 1), varying between 39 and 60% males. On the other hand, it appears that there was an initial decline in the length and weight of lamprey through to 1960 (from 460 to 430 mm and from 225 to 175 g), followed by cycling about some mean value (weight 172 $\pm$ 18 g; length 429 $\pm$ 12 mm). The autocorrelation analysis indicted that a significant ($P<0.05$) trend was present in length, weight and proportion of males (Table 2). Regression analysis indicated that there was no significant trend in length and weight; however, there was a significant decrease in the proportion of males in the population ($b=-0.94$; $P<0.05$).

Length and weight of sea lamprey were significantly correlated ($P<0.05$); therefore, only weight was used in further analyses of change in sea lamprey size. ANOVA indicated a significant effect of treatment "period" on the weight of lamprey ($F=7.1$, $P<0.05$) but not on the proportion of males ($F=2.8$, $P>0.05$).

In the early 1950's, weights of sea lamprey declined dramatically as did the commercial catch of salmonids (Fig. 2b) and the total number of sea lamprey captured at the 8 electrical barriers (Fig. 2a). After this decline in the 1950's, lamprey weight increased (Fig. 1). This increase in weight appeared to follow the increase in salmonid stocking in this lake (Fig. 2c). Pearson correlation analysis indicated that there was a significant correlation between weight of sea lamprey and commercial catch of salmonids ($r=0.64$, $P<0.05$). The proportion of males in the sea lamprey population, however, was apparently lower at higher salmonid stocking rates ($r=-0.76$, $P<0.05$) and higher when abundance of sea lamprey was greater ($r=0.63$, $P<0.05$).

Multiple regression using sea lamprey abundance, salmonid stocking and salmonid catch indicated that sea lamprey weight was significantly ($P<0.05$) related to salmonid catch. The proportion of males was significantly related to both commercial catch of salmonids and salmonid stocking. Abundance of sea lamprey, as indicated by catches at the electrical barriers, was not related to sea lamprey weight or proportion of males.

<u>Lake Huron</u>

Although a trap was operating on the Ocqueoc River in 1948, sea lamprey were not sexed or measured until 1950 (38 y of data) or weighted until 1951 (37 y of data). Data for sea lamprey populations from other streams were not available until 1967. There was an apparent steady decline in the proportion of male sea lamprey in Lake Huron (Fig. 3) until the early 1980's.

Length and weight appeared fairly stable (413 ± 8 mm, 141 ± 8 g) through the 1950's, then began steadily increasing after 1960. Autocorrelation analysis (Table 2) indicated a significant trend in length, weight and sex ratio of sea lamprey. Linear regression indicated that there was a significant decrease in the proportion of males ($b=-0.89$, $P<0.05$) and increase in weight ($b=2.85$, $P<0.05$) and length ($b=1.93$, $P<0.05$) since the 1950's.

There was a significant difference among the three "periods" in both weight ($F=9.8$, $P<0.05$) and percent males ($F=13$, $P<0.05$). Weights of sea lamprey were initially low (131 g) while sea lamprey were apparently abundant and commercial catch of salmonids was high (Figs. 4a and 4b). After the initiation of chemical control, 1957-58, sea lamprey have slowly increased in weight. As well, catches of sea lamprey declined in the Ocqueoc R. Salmonid stocking was initiated in 1968; sea lamprey weight increased after this time as did salmonid stocking and catches (Fig. 4c).

Pearson correlation analysis indicated that sea lamprey were smaller when their abundance was greater ($r=-0.54$, $P<0.05$) and lamprey weight was greater when salmonid stocking was higher ($r=0.71$, $P<0.05$). The proportion of males was higher at higher abundance of sea lamprey ($r=0.64$, $P<0.05$). The proportion of males in the sea lamprey population also decreased when salmonid stocking increased ($r=-0.66$, $P<0.05$). Multiple regression analysis indicated that salmonid stocking was significantly related to both weight and proportion of male sea lamprey in Lake

Huron. There was, however, no significant relation between weight or proportion of males with abundance of sea lamprey.

Lake Ontario

Sampling in Lake Ontario began in 1968, providing 20 y of data (Fig. 5). Lengths and weights of sea lamprey steadily increased until the early 1980's. The proportion of males increased gradually from a somewhat equal sex ratio to a slight preponderance (~60%) of males. The autocorrelation analysis indicated a significant trend in length and weight. However, autocorrelation analysis indicated that there was no strong trend in the proportion of males in the population (Table 2). Regression analysis also indicated no significant change in percent males ($b=0.402$, $P>0.05$) over time. Both weight ($b=6.348$, $P<0.05$) and length ($b=4.554$, $P<0.05$) increased from 1968 to present.

ANOVA indicated that there were significant differences in weight ($F=11.6$, $P<0.05$) between treatment "periods" but not in the sex ratio ($F=2.3$, $P>0.05$). Sea lamprey in Lake Ontario were initially small (415 mm, 150 g). After the initiation of chemical control in 1971, weight generally increased. At the same time, the stocking rate of salmonids increased (Fig. 6c). It appears that sea lamprey abundance may be cycling but this may be an artifact of changes in trapping methodology.

Pearson correlation analysis indicated that sea lamprey weight increased when stocking of salmonids increased ($r=0.74$,

$P<0.05$). There was no significant correlation between the percent males and sea lamprey abundance, salmonid stocking or salmonid catch. Multiple regression indicated that weight of sea lamprey was significantly related to salmonid stocking only.

**DISCUSSION**

Odum (1985) suggested that biological parameters (e.g. length, weight, sex ratio) of a species will change in response to changes in population size, prey availability or external pressures (e.g. control measures, environmental change). However, caution must be exercised as a variety of factors may affect any change(s) taking place. For sea lamprey within the Great Lakes, increased abundance of salmonids, differences in selection by trapping gear, time required by populations to re-adjust (predator or prey), alterations in environmental quality (see Beeton 1969), habitat alteration or hydrologic and climatic cycles could affect changes in measured biological characteristics of the population.

Smith's (1971) early work (Table 3) examined the sex ratio of sea lamprey in Lake Superior (1953 to 1969) and Lake Huron (1951 to 1969). He found that males predominated in the early 1950's; however, there was a gradual shift to a preponderance of females. Heinrich et al. (1980) extended this examination of sex ratio to include data from Lakes Superior and Huron to 1978 (Table 2) and confirmed this shift from males to females. Heinrich et al. (1980) suggested that the sex ratio had stabilized at 30 to 40 percent males. Torblaa and Westman (1980) found the same trends in the North Channel of Lake Huron and in Lake Superior. In recent years (after 1980), the number of males has been increasing in Lakes Superior (Fig. 1) and Huron (Fig. 3, Table 3). In both lakes there was a significant relation between proportion of males, abundance of sea lamprey and also salmonid stocking. The multiple regression, however, indicated that prey availability (as reflected by salmonid stocking in Lake Huron and commercial catch and stocking in Lake Superior) exerted the major influence.

In Lake Ontario, however, there appeared to be only a slight shift from an approximately equal sex ratio (1970 - 1980) to a preponderance of males. Salmonid stocking, commercial catches and sea lamprey abundance did not appear to be related to the proportion of males in the population (based on ANOVA, Pearson correlation analysis and multiple regression).

While the change in proportion of male sea lamprey has been pronounced in Lakes Superior and Huron, the causes of the changes are unclear. Hardisty and Potter (1971) suggested that, although significant departures from normal (equal?) sex ratios were found, the concept of labile sex determination was not valid for ammocoetes. Torblaa and Westman (1980), Heinrich et al. (1980) and Purvis (1979) implied that sex composition was density dependent and influenced by sea lamprey control programs. Our results did not dispute the influence of density reduction upon the proportion of males, but did suggest that prey availability (at least in Lakes Superior and Huron) may be related to the preponderance of males in sea lamprey populations. However, untreated populations (e.g. Niagara River in Lake Ontario) of sea lamprey may contribute disproportionate numbers of males to the lake populations described here.

The trends still apparent in sea lamprey length and weight were very different among lakes. Because there was a significant difference in weight between treatment periods (ANOVA, Table 2), the possibility exists that differences resulted from changes in capture technology. However, direction of the trend extended over more than one treatment period; therefore, we expect the differences did not result from changes in trapping (or control) technology.

The reason(s) for the trends remain speculative. Sea lamprey entered Lake Huron when food was abundant (i.e. fish stocks were high), natural predators on sea lamprey were likely non-existent, and control measures had not started (Smith 1971). By contrast, in Lake Superior, sea lamprey were subject to early pressures of control efforts; therefore, the sea lamprey population was likely held well below its carrying capacity. In addition, the food supply for sea lamprey in Lake Superior has been replenished by increased salmonid stocking and/or enhanced survival of remnant native lake trout stocks. Finally, in Lake Ontario, it appears that sea lamprey may have been an integral part of the fish community at one time; however, as a result of increasing fishing pressure, food became limited and sea lamprey populations responded accordingly.

Smith (1971) initially described a decrease in size of sea lamprey from Lakes Huron (Ocqueoc River) and Michigan; he also described a slow decrease in size in sea lamprey from Lake Superior from 1953 - 1961. Heinrich et al. (1980) found that sea lamprey size increased after the initiation of control in each lake and that the sizes had generally stabilized by 1978. We observed that, while length and weight may have stabilized in Lake Superior (Fig. 1), sea lamprey have generally become larger in both Lakes Huron (Fig. 3) and Ontario (Fig. 5).

Smith (1971) suggested that factors other than sea lamprey abundance were influencing sea lamprey size. Heinrich et al. (1980) suggested that the increase in size was a result of reduction in sea lamprey numbers due to control but indicated that stocking of salmonids may also have influenced sea lamprey size in Lake Superior. We found that, in Lakes Ontario and Huron, weight of sea lamprey was most strongly related to stocking rates of salmonids. Kitchell (In press) also found a relation between sea lamprey weight in Lake Michigan and salmonid stocking rates. In Lake Superior, however, sea lamprey weight was most closely related to commercial catch of salmonids. Sea lamprey abundance was not significantly related to weight in Lakes Superior, Huron or Ontario. These results generally indicate that prey availability, whether governed by increased stocking rates (Lakes Huron, Ontario and Michigan) or recovery of remnant lake trout stocks (Lake Superior) was extremely important in determining sea lamprey weight and sex ratio.

The management implications of these results are somewhat unclear. An apparent increase in mean size of sea lamprey may simply mean that more food is available through either increased prey abundance or decreased numbers of sea lamprey. Although numbers of sea lamprey in Lake Michigan are lower than pre-control (Kitchell In press), sea lamprey-induced mortality may have actually increased approximately six-fold for small host fish ($\leq$ 1.0 kg) over the past two decades. Further, the possible increase in fecundity resulting from increased size of sea lamprey (Wigley 1959) could further offset benefits accrued from sea lamprey management. As well, sex ratio and adult weight in Great Lakes sea lamprey appear to be related to prey availability and therefore may not be adequate indicators of the success of sea lamprey control. However, these measures may be useful indicators of the net benefits of both fishery management and sea lamprey control.

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**Table 1:** Great Lakes tributaries sampled for spawning sea lamprey used in the analysis.

| LAKE SUPERIOR | YEARS SAMPLED |
|---|---|
| Amnicon River | 1957-79, 1987 |
| Au Train River | 1954-61, 1963-64 |
| Bad River | 1986 |
| Betsy River | 1954-61, 1963-79, 1981-87 |
| Big Garlic River | 1981-87 |
| Boot River | 1987 |
| Brule River | 1958-79, 1986-87 |
| Chocolay River | 1954-61, 1963-70, 1972-75, 1979 |
| Firesteel River | 1954-64 |
| Furnace Creek | 1963-70 |
| Huron River | 1954, 1963-65 |
| Iron River | 1954-61, 1963-72, 1976-79, 1981-86 |
| Little Carp River | 1985 |
| Little Gravel River | 1980-81 |
| Mackenzie River | 1980 |
| Middle River | 1960-62, 1967, 1984-86 |
| Miners River | 1963-64, 1966-68, 1970, 1981-85 |
| Misery River | 1960-62, 1967-69, 1986-87 |
| Pancake River | 1980-83 |
| Rock River | 1963-70, 1981-87 |
| Sable River | 1980-81, 1984 |
| Silver River | 1954-61, 1963-79, 1987 |
| Stokely Creek | 1981-85 |
| Sturgeon River | 1962-68 |
| Sucker River | 1954-61, 1963-79, 1981-85 |
| Tahquamenon River | 1981-87 |
| Two Hearted River | 1955, 1963-79 |
| White River | 1956-60 |

| LAKE ONTARIO | YEARS SAMPLED |
|---|---|
| Bowmanville Creek | 1976-87 |
| Bronte Creek | 1980 |
| Catfish Creek | 1981-85 |
| Credit River | 1980 |
| Duffin Creek | 1980-87 |
| Graham Creek | 1977-82, 85-87 |
| Grindstone Creek | 1982-87 |
| Humber River | 1968-78, 1980-87 |
| Lakeport Creek | 1986-87 |
| Little Salmon River | 1981-86 |
| Lynde Creek | 1980 |
| Salem Creek | 1981 |
| Salmon River | 1976-80 |
| Shelter Valley Creek | 1978-82, 1984-87 |
| Sterling Creek | 1982, 1986-87 |
| Sterling Valley River | 1982-87 |
| Wilmot Creek | 1976-87 |

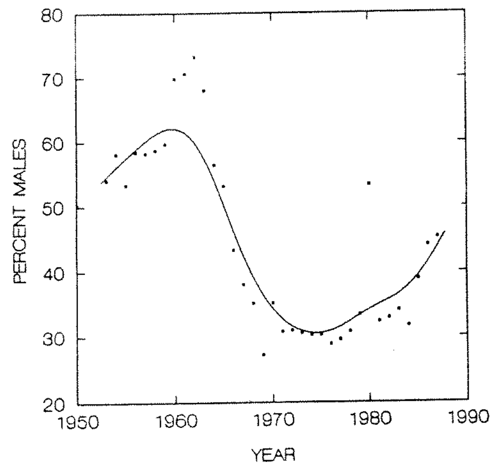
| LAKE HURON | YEARS SAMPLED |
|---|---|
| Albany Creek | 1986-87 |
| Au Sable River | 1986-87 |
| Beaver River | 1981 |
| Blue Jay Creek | 1967-77, 1980-81, 1984 |
| Cheboygan River | 1977-87 |
| East Au Gres River | 1985-87 |
| Echo River | 1980-82, 1987 |
| Kaskawong River | 1867-77, 1980-87 |
| Mindemoya River | 1984 |
| Naiscoot-Harris River | 1967-77 |
| Ocqueoc River | 1949-55, 1957, 1959-79, 1981-82, 1984-87 |
| Silver Creek | 1981 |
| Still River | 1967-77, 1987 |
| Sucker Creek | 1981 |
| Thessalon River | 1981-87 |
| Thunder Bay River | 1986 |
| Tittabawassee River | 1985 |
| Trout River | 1981-82 |

**Table 2:** Summary of results from statistical analyses of data from 3 Great Lakes. (n/s=not significant at P=0.05)

| Statistical Test/ variable | L. Superior weight | L. Superior % ♂ | L. Huron weight | L. Huron % ♂ | L. Ontario weight | L. Ontario % ♂ |
|---|---|---|---|---|---|---|
| Autocorrelation (trend?) | + | + | + | + | + | n/s |
| Linear Regression (trend?) | + | n/s | + | + | + | n/s |
| ANOVA (treatment "periods") | + | n/s | + | + | + | n/s |
| Multiple Regression | | | | | | |
| salmonid catch | + | + | n/s | n/s | n/s | n/s |
| salmonid stock | n/s | + | + | + | + | n/s |
| S/L abundance | n/s | n/s | n/s | n/s | n/s | n/s |

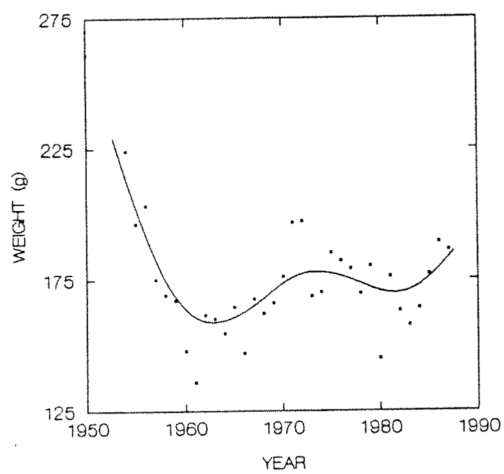
## List of Figures

A.



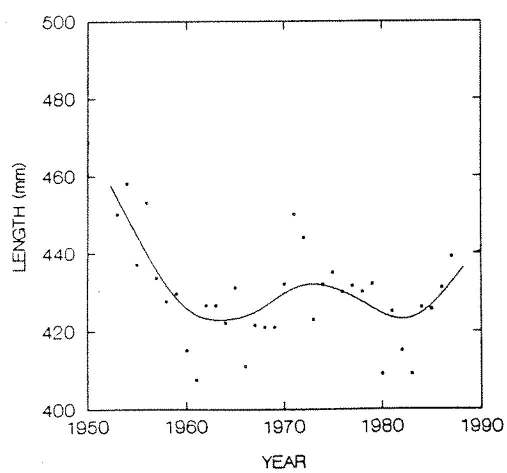
PERCENT MALES
80
70
60
50
40
30
20
1950
1960
1970
1980
1990
YEAR


B.



WEIGHT (g)
275
225
175
125
1950
1960
1970
1980
1990
YEAR

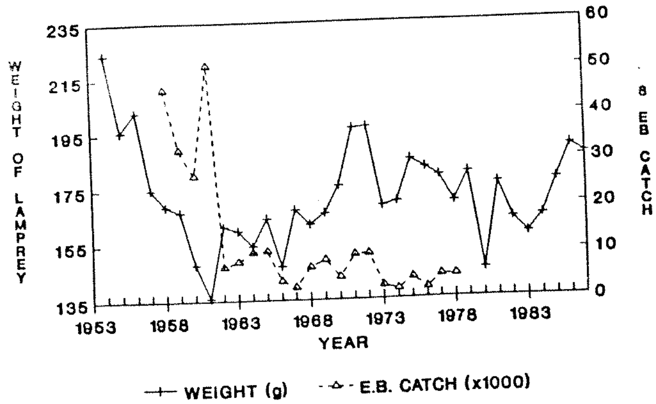

C.



LENGTH (mm)
500
480
460
440
420
400
1950
1960
1970
1980
1990
YEAR

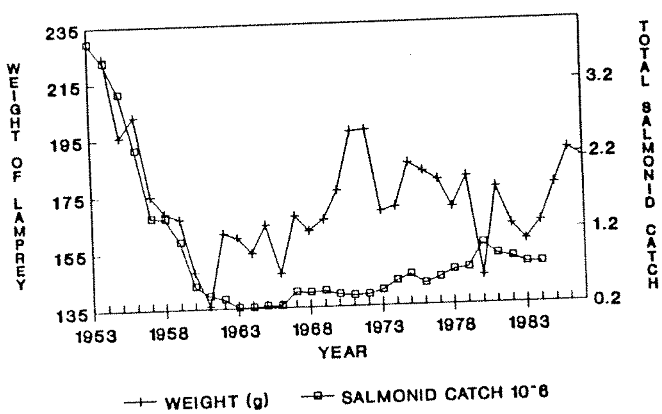
# LAKE SUPERIOR DATA

a.



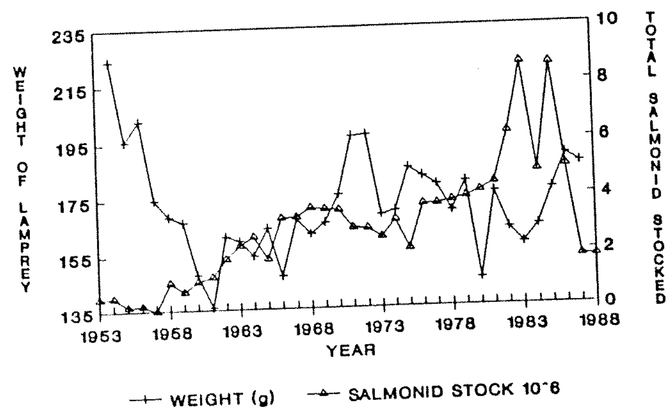

R=-0.423
P>0.05

b.



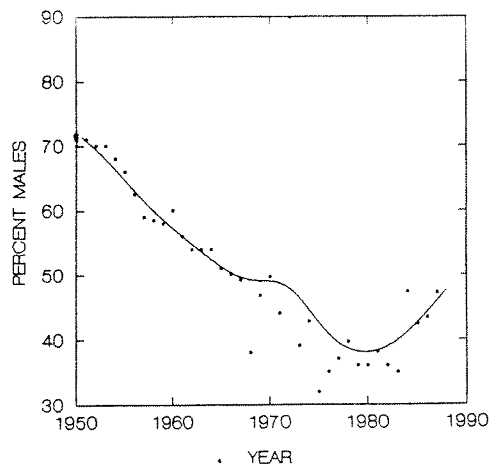

R=0.637
P<0.05

c.

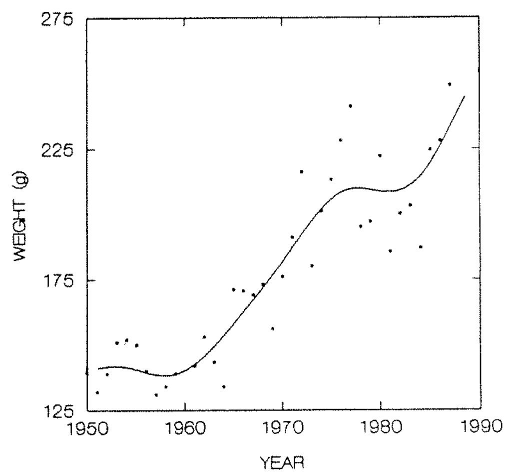



R=-0.284
P>0.05

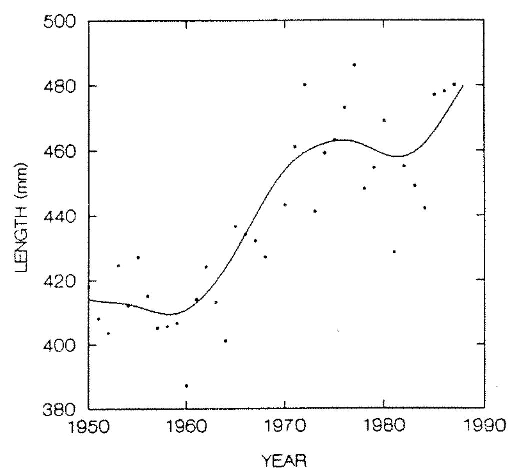
A.




B.

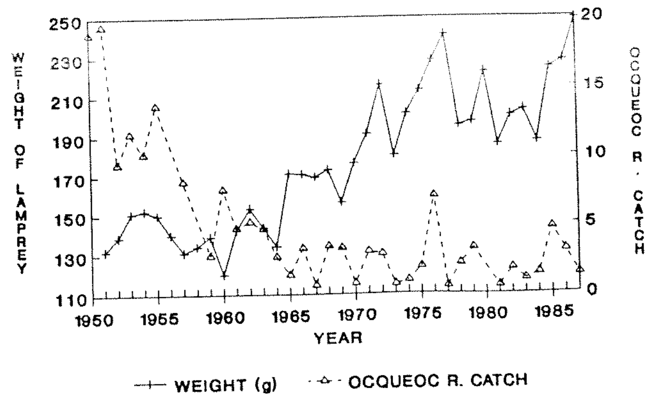



C.



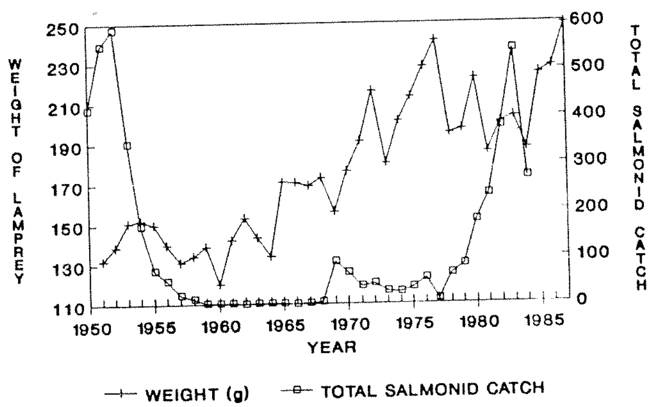
# LAKE HURON DATA

a.



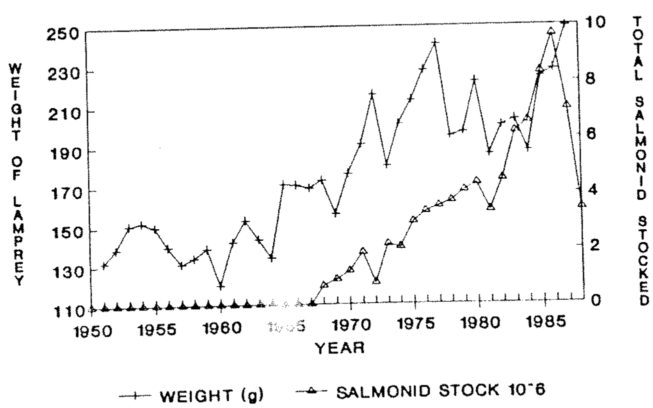

R=-0.516
P<0.05

b.



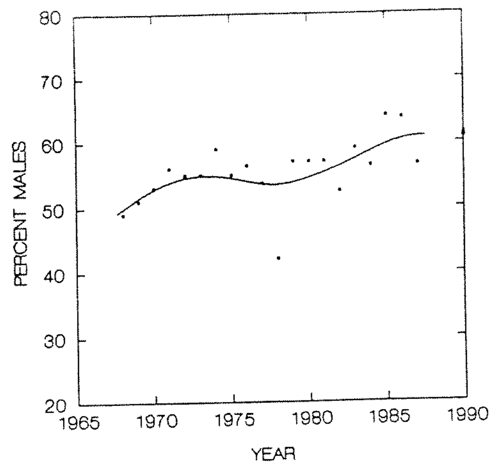

R=0.004
P>0.05

c.

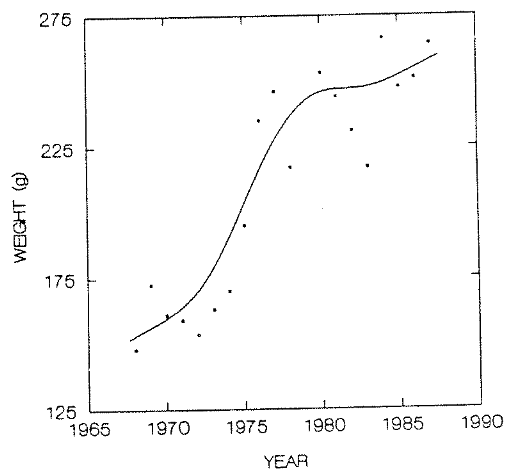



R=0.745
P<0.05

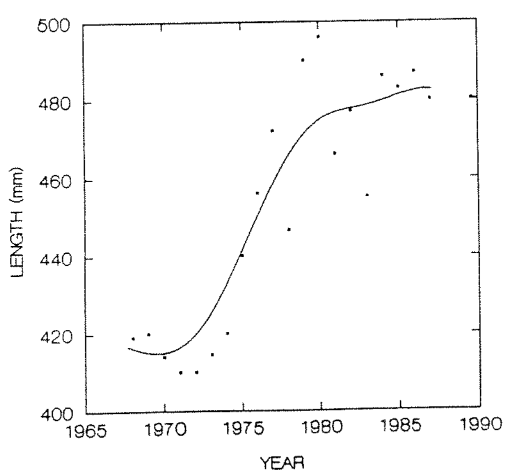
A.


80
70
60
50
40
30
20
PERCENT MALES
1965
1970
1975
1980
1985
1990
YEAR

B.

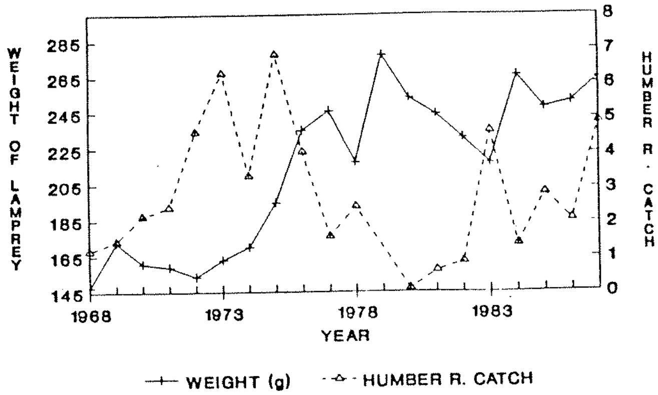

275
225
175
125
WEIGHT (g)
1965
1970
1975
1980
1985
1990
YEAR

C.


500
480
460
440
420
400
LENGTH (mm)
1965
1970
1975
1980
1985
1990
YEAR

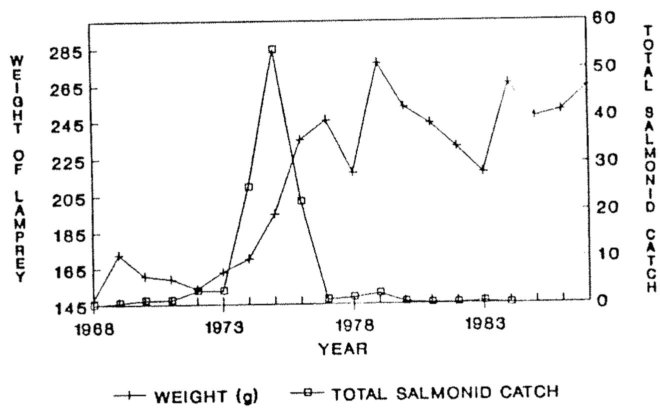
## LAKE ONTARIO DATA

a.



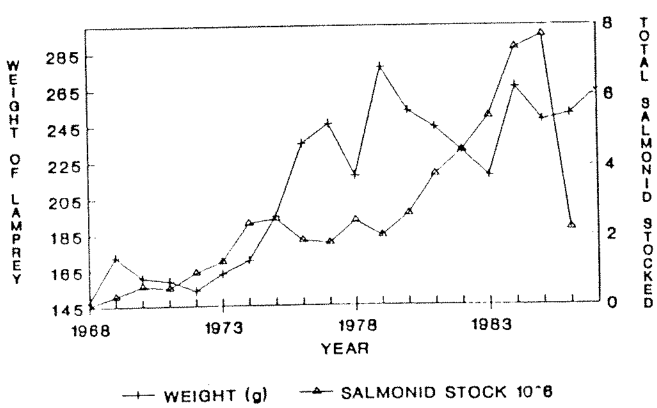

R=-0.262
P>0.05

b.




R=-0.105
P>0.05

c.




R=0.646
P<0.05

**Table 3:** Comparison of results from this study (since 1978) with those or Smith (1971) and Heinrich et al. (1980).

| **Lake** | **Variable** | **Smith (1971)**<br>**to 1969** | **Heinrich et al. (1980)**<br>**to 1978** | **This Study**<br>**to 1987** |
|---|---|---|---|---|
| Superior | % ♂ | 1950-53 equal ratio<br>1953-61 Increasing<br>1962-69 Decreasing | 1971-78 Stable | 1979-87 Increasing |
| | Size | 1950's Decreasing | 1962-72 Increasing<br>1973-78 Stable | 1979-87 Increasing |
| Huron | % ♂ | 1950-52 Increasing<br>1952-69 Decreasing | 1969-78 Stable | 1979-87 Increasing |
| | Size | 1950's Decreasing | 1951-69 Stable<br>1969-77 Increasing | 1980's Stable/ slight increase |
| Ontario | % ♂ | - | 1968-77 Stable | 1968-87 Gradual increase |
| | Size | - | 1968-73 Stable<br>1974-78 Increasing | 1978-87 Stable |