GREAT LAKES FISHERY COMMISSION

Project Completion Report[1]

A Simple Protocol to Estimate Relative Abundance of Sea Lamprey from Lake Trout Assessment Data in Lake Superior

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September 1985

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RESEARCH COMPLETION REPORT

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ABSTRACT

This paper reports and tests a protocol for estimation of relative abundance of sea lamprey and lethality of lamprey attack. Using lake trout assessment data for Michigan waters of Lake Superior, we find that the probability of surviving attack is only 0.14 for lake trout 25 inches and longer. Estimated patterns of abundance of parasitic phase sea lamprey is correlated with barrier runs of spawning phase animals over the period 1958-78 for the Michigan shoreline. Finally, estimated abundance patterns in Michigan, Wisconsin, and Minnesota waters have sufficient synchrony to suggest that parasitic phase do not occur in local infestations in U.S. waters of Lake Superior.

ACKNOWLEDGEMENTS

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INTRODUCTION

Recent developments suggest that lake trout marking can be used in the direct evaluation of effectiveness and efficiency of sea lamprey control efforts in the Great Lakes. The Great Lakes Fishery Commission has established standards for recording and reporting marking statistics (King and Edsall 1979; and Eshenroder and Koonce 1984), and studies on the observability of lamprey induced mortality of lake trout (Koonce and Pycha MS) have clarified some of the uncertainties associated with interpretation of marking statistics. In this paper, we report a simple protocol to estimate lamprey induced mortality in lake trout populations and to estimate the relative abundance of parasitic phase sea lamprey. We test the protocol with assessment data for lake trout in Lake Superior.

As indicated in Eshenroder and Koonce (1984), the preferred mark statistic is marks per 100 fish. The reason is that instantaneous mortality due to sea lamprey predation is a linear function of mean marks per fish:

$$Z_L = M(1 - p)/p \qquad (1)$$

where p is the probability of surviving an attack and M is the mean marks per fish. If fishing mortality is constant or negligible, p may be estimated from the slope of a regression of total instantaneous mortality versus marks per fish:

$$Z_T = c + [(1 - p)/p]*M \qquad (2)$$

where c is natural mortality (or natural mortality plus fishing mortality if fishing mortality is constant and high relative to natural mortality).

Attack rates of sea lamprey vary with size of prey. Simulation models developed in the AEAM workshops represented this variation as a multi-prey disc equation (e.g. Koonce et al 1982; and Spangler and Jacobson 1985). Koonce and Pycha (Ms) modified this basic description of prey selectivity to represent attacks per prey size group over the time period during which a healing wound would be classified in Stages A1 to A3:

$$A_i = H*q_i*L/[1 + \sum_i(h*q_i*N_i)] \qquad (3)$$

where q_i is a selectivity coefficient, N_i is the density of the ith size group, h is the mean duration of an attack, L is the density of sea lamprey, and H is the mean healing time of a wound. Because sea lamprey spend little time searching for prey,

$$\sum_i h*q_i*N_i >> 1, \text{ and}$$

equation 3 is approximated by:

$$\sum_i A_i = H*L/(h*\sum_i N_i) \qquad (4)$$

Assuming that the mean duration of attack is constant with size, equation 4 implies that total attacks should be proportional to density of sea lamprey, but inversely proportional to density of lake trout. Furthermore, because marks per fish is directly proportional to attack rate (Eshenroder and Koonce 1984), marking rates will also express these relations.

Using equations 1 to 4, we suggest a protocol to estimate relative abundance of parasitic phase sea lamprey and the lethality of an attack. Data required for this protocol include estimates of total mortality of the largest fish in assessment catches (e.g. estimates from the descending limb of the catch curve--cf. Pycha 1980), catch per effort by size group, and marks per fish by these same size groups and by age. The protocol for estimation of lethality of attack is to fit equation 2 to the total mortality and mean weighted marks per fish by a least squares procedure, where marks per fish are weighted for representation in the assessment catch:

$$\text{Weighted } M = [\Sigma(CPE_i * M_i)]/[\Sigma CPE_i]$$

This weighting procedure avoids some of the problems in small sample sizes for marks on the largest sized lake trout (Koonce and Pycha MS).

The protocol for estimating relative abundance of parasitic phase sea lamprey also uses weighted marks per fish and total catch per effort, but over as wide a size range as possible (functionally lake trout 17 inches and larger in Lake Superior). Relying on the functional relationship in equation 4, this protocol requires:

1. Regression of weighted marks per fish versus 1/CPE for all sizes showing marks;
2. Use regression parameters in 1 to estimate the expected marks per fish from observed CPE for each year in the data set; and
3. Estimate relative abundance of parasitic phase sea lamprey by dividing expected marks per fish in 2 by the observed marks per fish.

APPLICATION OF PROTOCOLS TO LAKE SUPERIOR

Several assumptions were required to develop these protocols. There is substantial reason to believe, for example, that the lethality of an attack is size dependent (e.g. Farmer

1980), but the protocol based on equation 1 assumes that lethality of an attack is either constant or has a constant mean value for the sizes used in the analysis. This assumption especially poses difficulties when the abundance of large fish increases as has been the case in Lake Superior since 1958. Despite these potential difficulties, however, the protocols reveal some interesting patterns in the marking data for Lake Superior.

Applying equation 2 to marking rates for lake trout 25 inches and greater reveals a statistically significant association with total mortalities estimated from catch curves Fig. 1 (data from Pycha 1980, and more recent data). These data for Michigan waters of Lake Superior imply a natural mortality rate of 0.18 for lake trout and a probability of surviving an attack of only 0.14. Undoubtedly, low fishing mortality in Michigan waters during this period contributes to the high correlation of total mortality and marks per fish, but more importantly, the strength of this association implies the the assumptions invoked to derive the protocol are not unreasonable.

Unlike the relation between marking and total mortality, CPE data do not account for much of the variability in marking when applied to the protocol for equation 4. For Michigan waters (Fig. 2), the association between marking and CPE is not significant; accounting for less than 1% of the variability in marking rates. Wisconsin (Fig. 3, coefficient of determination 0.74) and Minnesota (Fig. 4, coefficient of determination 0.45) have better associations. Using the protocol to estimate relative abundance of parasitic phase sea lamprey, sea lamprey abundance seems to be generally declining over the period 1958 to 1984, with peaks in 1958-1969 and around 1972, Fig. 5. Comparing this pattern of abundance with the runs recorded at six electric weirs operated in Michigan waters reveals a significant correlation that accounts for about 50% of the variability in weir catches (Fig. 6).

Combining the estimated relative abundance of sea lamprey for Michigan, Wisconsin, and Minnesota also reveals an interesting pattern (Fig 7). The basic synchronization of these patterns suggest that the peak in 1972 was not isolated to Michigan waters. Although there is some indication that from 1974 to 1978 Minnesota experienced higher lamprey abundance than the other jurisdictions, the data do not suggest local infestations.

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FIGURE LEGENDS

Fig. 1. Relation between total instantaneous mortality and mean marks per fish, weighted by CPE for lake trout 25 inches in length and larger. Data are for Michigan waters of Lake Superior and are drawn from Pycha (1980) and Pycha (personal communication). Intercept of regression is 0.18, slope is 5.99, and coefficient of determination is 0.90.

Fig. 2. Correlation of weighted marks per fish and 1/CPE for lake trout 17 inches and longer in Michigan waters of Lake Superior. Coefficient of Determination is 0.0055.

Fig. 3. Correlation of weighted marks per fish and 1/CPE for lake trout 17 inches and longer in Wisconsin waters of Lake Superior. Coefficient of Determination is 0.74.

Fig. 4. Correlation of weighted marks per fish and 1/CPE for lake trout 17 inches and longer in Minnesota waters of Lake Superior. Coefficient of Determination is 0.45.

Fig. 5. Changes in estimated relative abundance of parasitic phase sea lamprey in Lake Superior waters of Michigan over the period 1958-1984.

Fig. 6. Association of estimated relative abundance of sea lamprey with runs at electric weirs (barrier dams) at 6 rivers on the Michigan shoreline of Lake Superior from 1958-1978. Coefficient of Determination is 0.50.

Fig. 7. Patterns of estimated relative abundance of sea lamprey in waters of Michigan, Wisconsin, and Minnesota for the period 1958 to 1984.

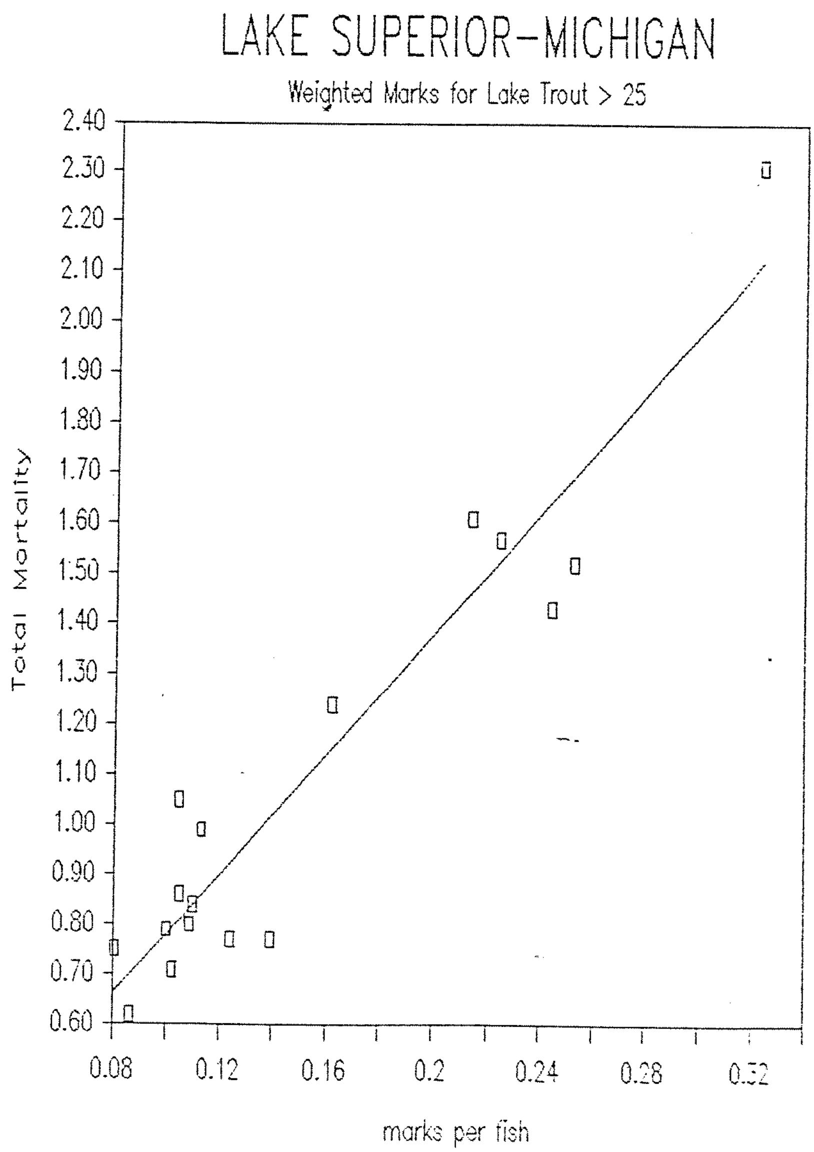

LAKE SUPERIOR-MICHIGAN
Weighted Marks for Lake Trout > 25
Total Mortality
2.40
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.08
0.12
0.16
0.2
0.24
0.28
0.32
marks per fish

Fig. 1

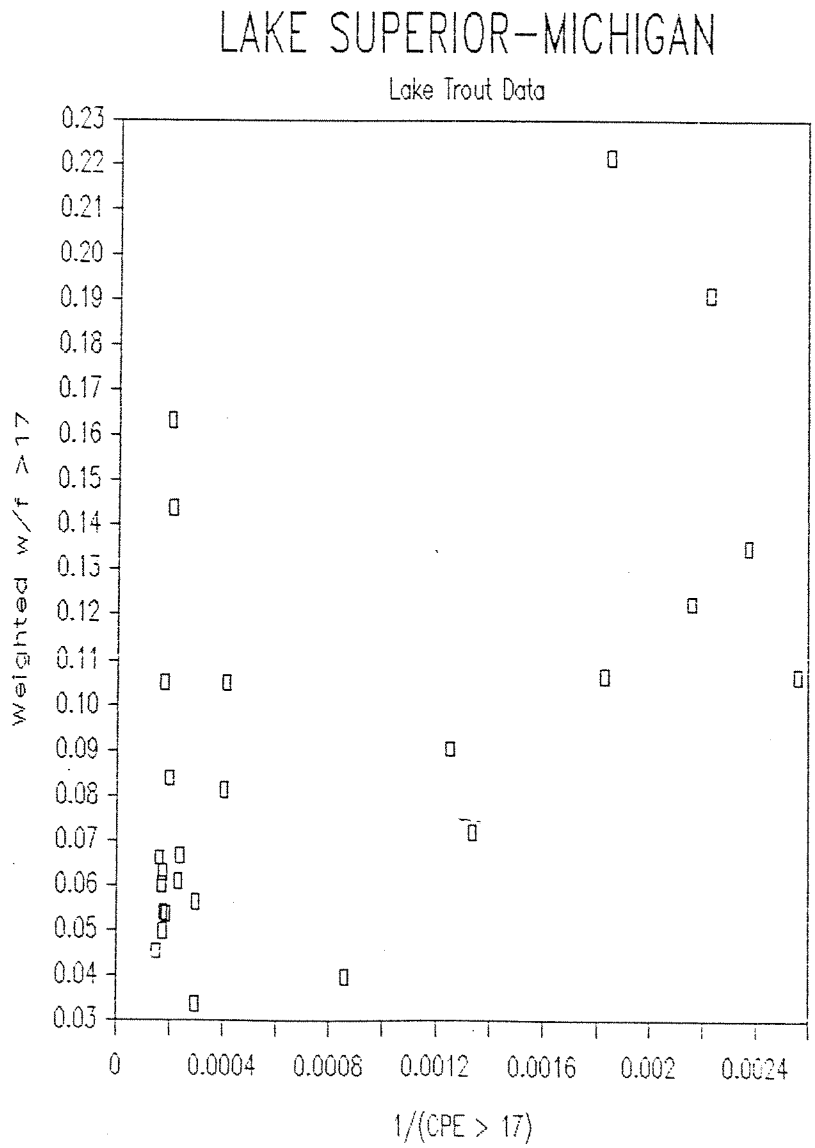

LAKE SUPERIOR-MICHIGAN
Lake Trout Data
Weighted w/f >17
1/(CPE > 17)
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0
0.0004
0.0008
0.0012
0.0016
0.002
0.0024

Fig. 2

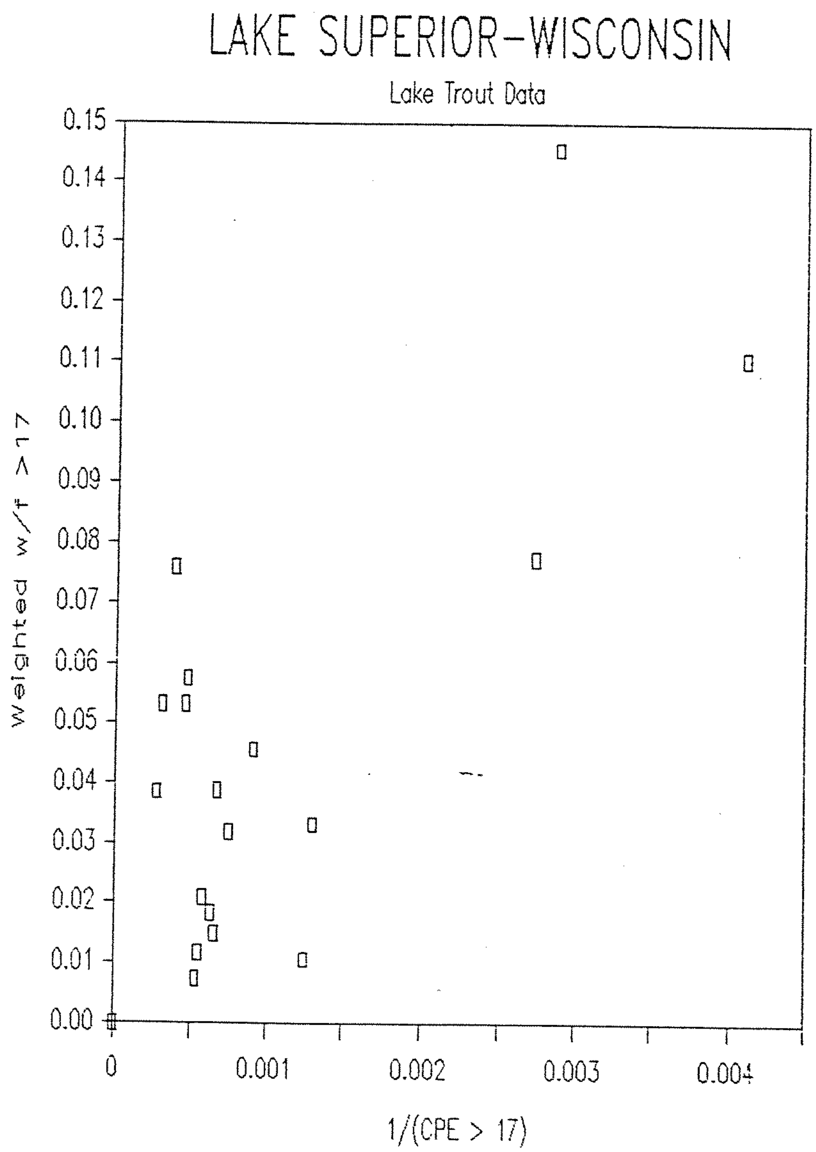
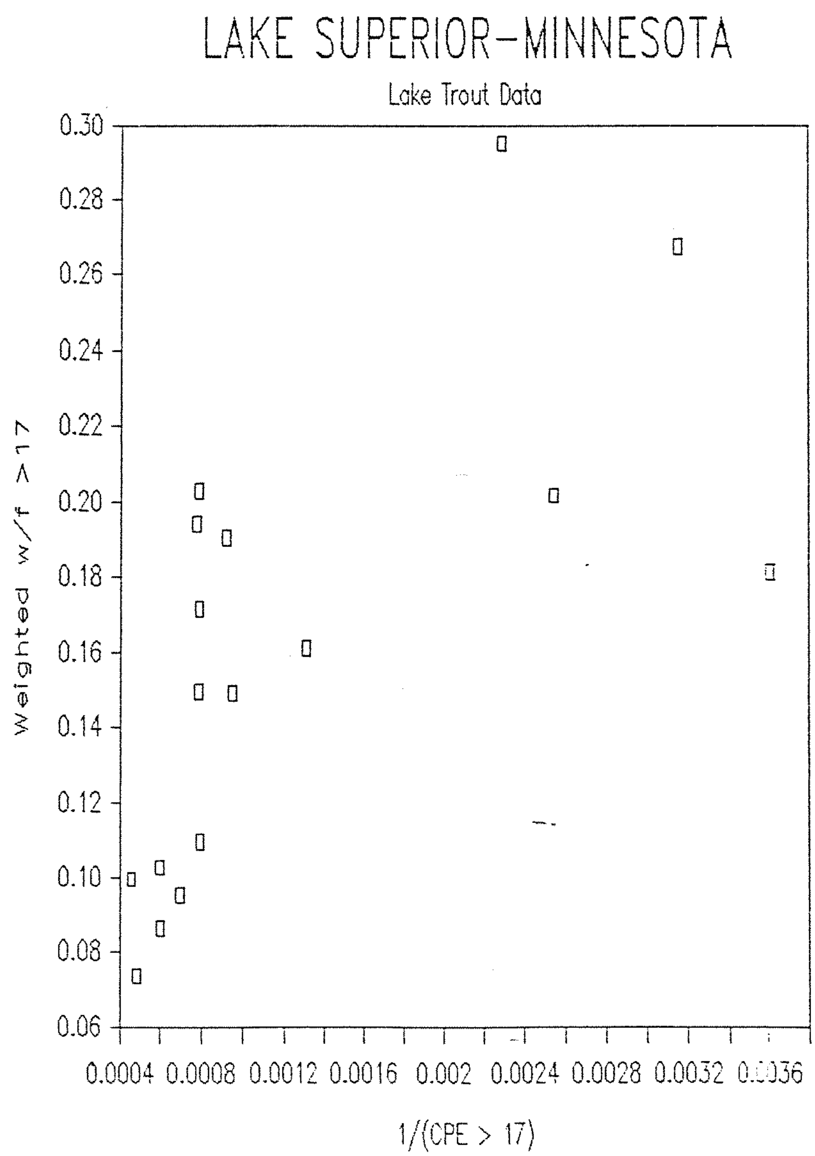

LAKE SUPERIOR-WISCONSIN
Lake Trout Data
Weighted w/f >17
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
0.001
0.002
0.003
0.004
1/(CPE > 17)

Fig. 3



LAKE SUPERIOR–MINNESOTA
Lake Trout Data
Weighted w/f >17
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.0004 0.0008 0.0012 0.0016 0.002 0.0024 0.0028 0.0032 0.0036
1/(CPE > 17)

Fig. 4

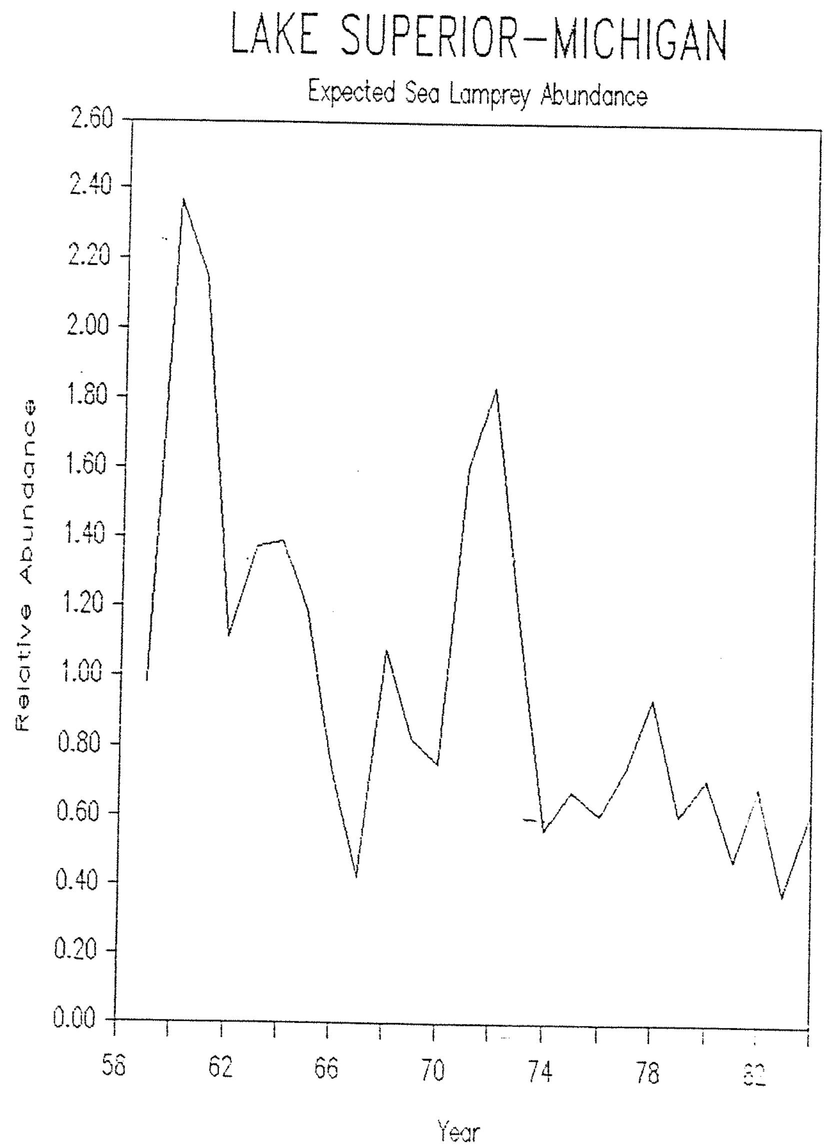

LAKE SUPERIOR–MICHIGAN
Expected Sea Lamprey Abundance
Relative Abundance
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
58
62
66
70
74
78
82
Year

Fig. 5

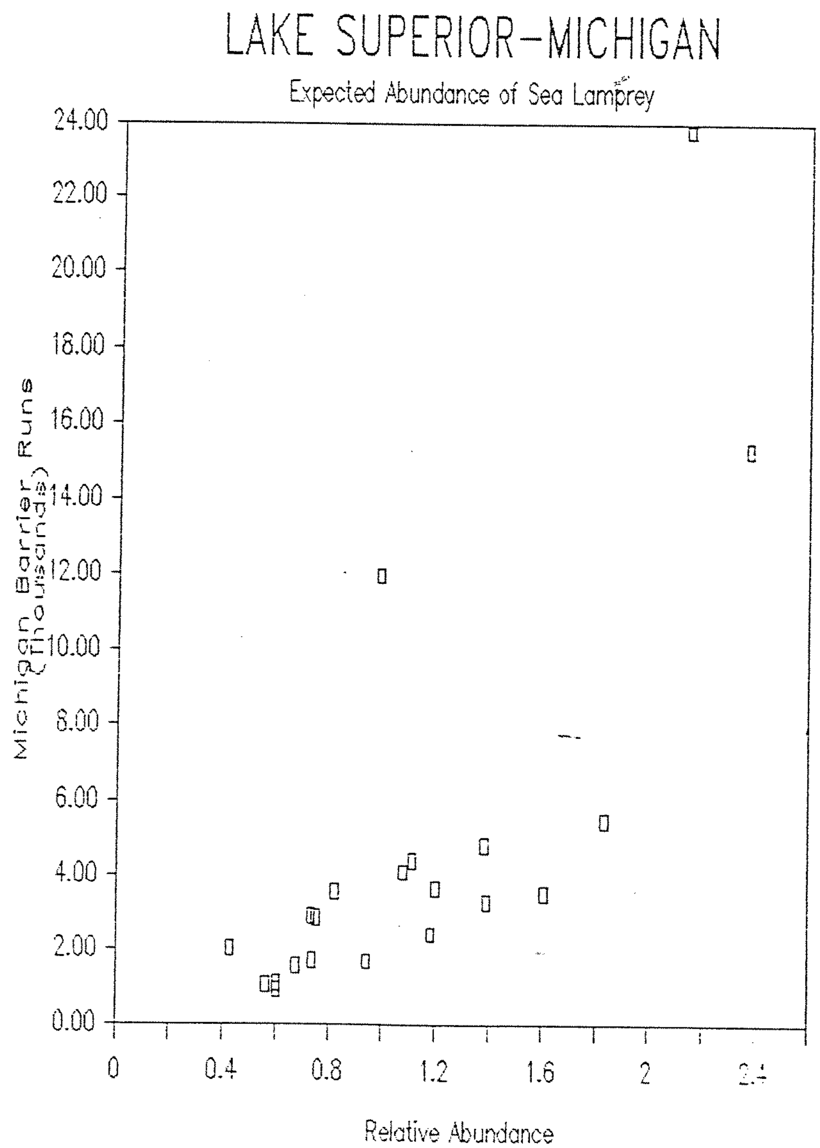
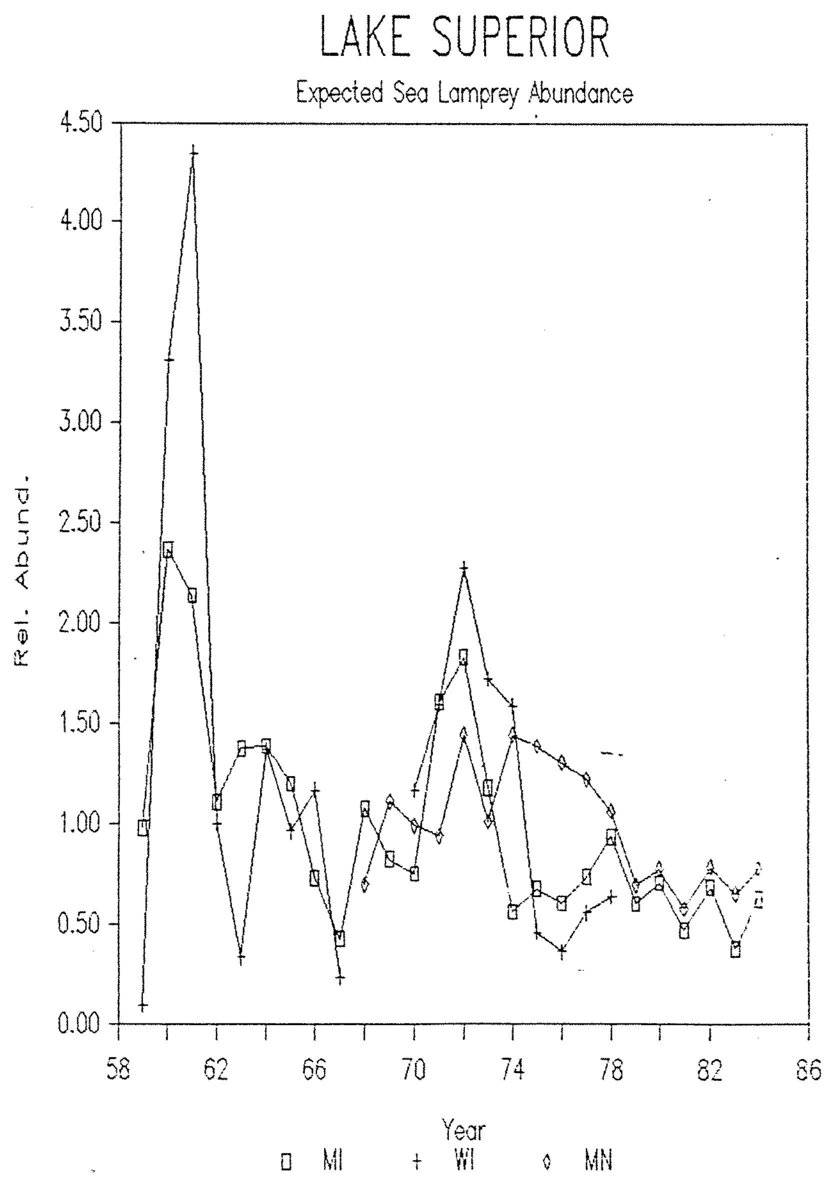

LAKE SUPERIOR–MICHIGAN
Expected Abundance of Sea Lamprey
Michigan Barrier Runs (Thousands)
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
0.4
0.8
1.2
1.6
2
2.4
Relative Abundance

Fig. 6



LAKE SUPERIOR
Expected Sea Lamprey Abundance
Rel. Abund.
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
58
62
66
70
74
78
82
86
Year
MI
WI
MN

Fig. 7