WORKSHOP TO EVALUATE SEA LAMPREY POPULATIONS "WESLP" :

Background Papers and Proceedings of the August 1985 Workshop

edited by
B. G. H. Johnson

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FOREWORD

The Workshop to Evaluate Sea Lamprey Populations (WESLP) originated among the biologists in the sea lamprey control units of the Great Lakes Fishery Commission (GLFC), who saw a need to review the methods used to evaluate sea lamprey populations, particularly as to their abilities to provide measures of the accuracy and reproducibility, over space and time, of estimates of sea lamprey abundance. Such perceptions had been intensified and focused by suggestions developed in other contexts such as the Sea Lamprey International Symposium (SLIS), the Sea Lamprey Audit Team (SLAT), the Workshop Concerning the Implementation' of Integrated Pest Management (IPM), and the Application of Decision Analysis to Sea Lamprey Control. The proposal for implementing WESLP was presented to the GLFC in 1983 by the Committee for the Review of Commonality in Sea Lamprey Control (a group of investigators appointed from the GLFC's two control units). The objectives of WESLP were to review past and present methods and practices used to assess sea lamprey populations in the larval, parasitic and spawning life stages; to investigate the needs to expand or improve current assessment strategies; and to recommend alternate ways to collect, interpret and present the data.

Following the GLFC's decision to sponsor WESLP, a formal structure was developed for the Workshop. A Steering Committee was struck for the purpose of establishing an agenda, while three sub-groups were formed -- one for each of the sea lamprey's life stages -- for the purpose of preparing background papers on the currently status of sea lamprey evaluation methods used by the control units. Other fishery investigators and managers around the Great Lakes were invited to participate in WESLP through correspondence E The final plenary session of WESLP took place In August, 1985) at Marquette, Michigan.

This publication contains the three "Life Stage" reports prepared by the sub-groups, a summary of the recommendations and workshop proceedings prepared by the Steering Committee, and lists of the workshop's organization and attendance. It is hoped that these documents will serve to describe the present methods of sea lamprey population evaluation; to record the needs expressed for the improvement of such methods; and to present the suggestions made for obtaining better measures of sea lamprey numbers.

B. G. H. Johnson
Editor

SECTION A

EVALUATION METHODS AND POPULATION STUDIES OF LARVAL PHASE SEA LAMPREY

by

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EXECUTIVE SUMMARY

This report dealing with the larval/transformer phase of the sea lamprey (Petromyzon marinus) is one of three "life stage" reports prepared for the Workshop for Evaluating Sea Lamprey Populations (WESLP) sponsored by the Great Lakes Fishery Commission (GLFC). The purpose is to develop improved methods for estimating larval sea lamprey populations in the Great Lakes and for reporting this information in a consistent format to the GLFC and its associated agencies. the goal of the workshop is to review present methods of evaluating sea lamprey populations, to identify needs for more or better information and to propose ways of satisfying these needs.

The history of the techniques used to sample larval/transformed sea lamprey is described from the sifting of stream habitat with shovels, through applications of toxicants, to the use of electrical (portable and backpack) shocking equipment.

Over the past 33 years special traps have been designed to capture downstream migrant lampreys, and various marking techniques have been developed or modified for Lamprey population studies.

Larval lamprey population studies began in earnest when the different species of lamprey could be identified. The age of Larval lamprey can be reasonably predicted by reviewing length-frequency data but definitive aging techniques for larvae older than three years or transfomning individuals have not proven reliable. Current studies are underway to develop an accurate aging technique.

The life history of the larval sea lamprey is summarized from the fecundity of adult sea lamprey, -through egg deposition and survival of embryos to duration of Larval life including growth rates, until transformation ends this stage and migration takes the parasitic sea lamprey into the 'Lakes. Larval lamprey habi tat preference and within stream movement-by larvae and transformers are described.

Both agents of the GLFC currently use similar techniques for sampling larval and transformed sea lamprey. The collecting, analysis and interpretation of larval/transformer data are standardized within agencies although somewhat different between agents. The reporting of results has conformed to the requirements expressed by the GLFC and cooperating agencies. Electronic data processing is used to facilitate retrieval and analysis of data.

As current funding and personnel available for the sea lamprey program are not adequate for extensive sea lamprey population studies, expansion by the agents to study these populations would require additional resources to carry out any commitment without jeopardizing the current management program. The Group for evaluating larval/transformer sea lamprey recommends that the GLFC provide strong direction for their agents to standardize procedures and reporting formats.

The greatest need perceived by this Group is to determine where transformed sea lamprey are produced and the numbers entering the lake system from any area, In order to achieve this goal, this Group recommends:

1. The GLFC's Canadian and United States agents must be prepared to adopt common procedures, study programs and reporting formats. In order to fully utilize the vast amounts of data available, the agents should seriously consider sharing common computer facilities and data entry or retrieval formats;

2. Efforts should be made to improve sampling equipment and techniques especially for large ammocoetes, transforming larvae and larvae in deep water habitats;

3. Better methods of estimating population size and composition require improved marking techniques for large numbers of larval lampreys. To utilize such techniques, a more efficient method must be developed to collect large numbers of larval lampreys for marking or a system must be implemented to raise the required number of ammocoetes. It may be necessary to investigate the differences in "collectibility" or "mortalities" between the native lampreys and sea lamprey because the latter are not always available in sufficient supply to conduct population estimates or mortality studies. The variabilities and requirements of estimating population sizes requires care in designing studies and in the statistical interpretation of the data;

4. It is essential to determine the natural mortality of ammocoetes from hatching through their normal larval stage to transformation and subsequent migration. The rates of transformation at given ages must be determined for reestablished populations so that the need and frequency of chemical treatments for individual streams may be assessed;

5 The need for population estimates must be reviewed in relation to the total lamprey control program. One of the most critical decisions wilt be to divide resources between management of lamprey numbers and evaluating their numbers in relation to the treatment program. Therefore we consider it important to define the resource requirements for the levels of population evaluation that we reconunend;

6. In order to refine decision analysis, it is necessary to remove subjectivity wherever possible and replace it with objective definitions, analysis and reporting.

Four proposals to evaluate Larval sea lamprey numbers have been prepared for the Workshop. The first describes the removal or depletion method for estimating sea lamprey larvae and transformers. The second describes procedures to test the efficiency of evaluating sea lamprey ammocoete populations by comparing stream rankings and expected control benefits. The third describes an estimate of transformer production from larval sea lamprey populations in streams tributary to a lake basin, Lake Superior used as an example. The fourth describes an estimate of sea lamprey production (Larval, transformer, parasitic and adult) and evaluates the interrelationships among the life phases.

INTRODUCTION

"The Great Lakes Fishery Commission (GLFC) was established in 1955 following the Convention on Great Lakes Fisheries between the governments of Canada and the United States of America. The primary charge of the GLFC was "to formulate and implement a comprehensive program for the purpose of eradicating or minimizing the sea lamprey populations in the Convention Area". Following ratification of the Convention on October 11, 1955, the United States Department of the Interior, Fish and Wildlife Service (USFWS), and the Fisheries Research Board of Canada [now the Department of Fisheries and Oceans (DFO)] were contracted by the GLFC as Agents to conduct a control program of the landlocked sea lamprey, Petromyzon marinus, in the Great Lakes area of Continental North America (Smith et al. 1974).

To successfully control sea lamprey, their distribution in nursery streams had to be mapped--a process that involved detailed surveys of all tributaries of the Great Lakes to determine the presence of larval sea lamprey (ammocoetes) and their range of habitat in each stream (Smith et al. 1974).

Although the control program has been effective in reducing the numbers of predatory sea lamprey in the Great Lakes, questions have been asked whether a minimum cost-benefit ratio for the control program can be achieved when the agents must select streams for treatment without being able to accurately measure larval lamprey population abundance or define their age structure prior to treatment scheduling. This criticism has been reinforced by recommendations generated from the 1979 Sea Lamprey International Symposium (SLIS) in Marquette, Michigan, the Report of the Audit of the GLFC's Program of Sea Lamprey Control and Research (Chamut 1980), the Committee for the Review of Commonality in Sea Lamprey Control Report (Johnson et al, 1981), the Integrated Management of Sea Lamprey Workshop in Sault Ste. Marie, Michigan, 1982, and the Application of Decision Analysis to Sea Lamprey Control (Heimbuch and Youngs 1982).

A proposal from the Committee for the Review of Commonality in Sea Lamprey Control, resulted in the GLFC sponsoring the present efforts to review the evaluation of sea lamprey populations in their three life phases--larval, parasitic and adult spawning, in a Workshop for Evaluating Sea Lamprey Populations (WESLP).

This summary deals directly with the ammocoete/transformer dynamics of the sea lamprey from the time of egg deposition until the transformed (metamorphosed) larvae leave the nursery stream.

PURPOSE AND GOALS

The purpose of the Workshop (ammocoete/transformer group) is to review present methods and practices employed in evaluating (larval) populations of sea lamprey; to recommend and/or develop methods for collecting, interpreting and reporting such information. Emphasis is placed on the need to provide quantitative rather than qualitative measures of sea lamprey abundance; and of establishing criteria for the reliability, precision and detail of the data provided. The ultimate goal is to develop better means of measuring the effectiveness of sea lamprey control, as it affects sea lamprey populations or fish stocks, in relationship to the intensity of control effort.

HISTORY OF TECHNIQUES

INTRODUCTION

The first method employed to sample larval lampreys in the stream habitat was to shovel sand from the stream- bed along the shore and collect the larvae as they attempted to escape the drying sand. A long handled dip net was employed to capture transforming sea lamprey which "more readily leave the sand when it is disturbed by the shovel, and attempt to swim away in the stream" (Gage 1893).

In preparation for lamprey control efforts, the initial stream surveys (in the State of Michigan) 1950, were conducted visually, evaluating the presence of spawning gravel, spawning nests, or presence of spawning adult sea lamprey and manually digging through larval habitat downstream of suspected spawning gravel to capture larval lampreys (Loeb and Hall 1952).

Although electrofishing had been developed for collecting biological specimens as early as 1863 (Vibert 1967), and the principles had been used for many years to collect fish for commercial and scientific purposes in Germany (Halsband and Halsband 1975), the first application of these techniques to collect larval lampreys was in 1947 when Dr. V. C. Applegate studied the sea lamprey (Applegate 1950). In 1953 the electrofisher was employed extensively to survey Michigan streams in preparation for lamprey control efforts (Stauffer and Hansen 1958). The electrofishing equipment became an important tool for collecting sea lamprey ammocoetes and after many equipment modifications (Lawrie 1955; Tibbles 1959; Tibbles 1961; Braem and Ebel 1961) a portable backpack shocker was developed 'by C. H. Harris in 1969 specifically for the sea lamprey control program. This was powered by a 12-V motorcycle battery and provided, by means of a convertor, low-frequency pulsed direct current (D.C.). The "Harris" designed backpack unit has subsequently been modified into two basic models, the Mark I and Mark II for general use in soft to moderately hard waters (Mark I) or hard to very hard waters (Mark II) (D. H. Allen, Pers. Comm.). The effectiveness of these shocker units have been limited to waters less than 1.2 m deep.

Experimental use of several chemicals to control and/or collect larval lampreys in the stream habitat had been attempted prior to 1956: copper sulphate - carbon tetrachloride emulsion; dichloro-diphenyl-trichloro-ethane (DDT) - carbon tetrachloride solution; and rotenone (4% powder) - carbon tetrachloride solution. Only toxaphene - carbon tetrachloride solution was field tested as a lampricide but its value was rejected because it was non-selective for lamprey and killed many fish (Hogg 1955). After six years of extensively testing over 6,000 chemical compounds (Moffett 1958; Applegate, et al. 1957; McKee 1968) one chemical, 3-trifluormethyl-4-nitrophenol (TFM) was found to be highly selective for larval lampreys and relatively inexpensive to manufacture (Applegate et al. 1961). TFM was patented as a method of controlling sea lamprey in Canada in 1964 (Applegate and Howell 1964) and in the United States of America in 1965 (Applegate and Howell 1965), and became the major tool for collecting large numbers of larval lampreys during stream treatments.

The need to sample deep water areas of lakes, bays or rivers led to experimental use of; orange-peel dredges (Stauffer 1959), "sandsuckers" (Stauffer 1960), anchor dredges (Thomas 1960), "poison trays" (Thomas 1961a), and electric trawls (Dodge 1964; McLain and Dahl 1968). Continuing experimental studies of .

mechanical deep water sampling methods has generated interest in utilizing a self-propelled submersible equipped with a remote controlled electrical shocking apparatus in Batchawana Bay, Lake Superior in 1985 [sponsored by the National Oceanographic and Atmospheric Administration NOAA, National Undersea Research Program (NURP), at the University of Connecticut Avery Point Campus UCAP, i.e. NOAA/NURP-UCAP].

In 1966 the 2-aminoethanol salt of 2',5-dichloro-4'-nitrosalicylanilide (Bayer 73) was formulated as a 5% active ingredient on silica sand to be used as a bottom toxicant to sample and kill sea lamprey ammocoetes (Canadian Patent No. 686,211; U.S. Patent No. 3,079,297 and No. 3,113,067). Since 1967 the 5% heavy granular Bayer 73 has been used extensively to survey for the presence of ammocoetes and to control known populations of sea lamprey ammocoetes in lake, bay or river, and deep water environments (Smith et al. 1974). Additional testing has evaluated other compounds including Antimycin A (Gilderhus et al. 1969; Gilderhus 1979), a TFM-sodium chloride solution (Nelson 1984), and clay-pelleted formulations containing TFM and Bayer 73 (Meyer 1983) with various results.

To sample transformed sea lamprey as they migrate downstream, various trap designs have been used (Applegate 1950; wolf 1950; McLain and Manion 1967), fyke net designs (Hanson 1972; L. H. Hanson and E. L. King, Pers. Comm.), mechanical weirs (Thomas 1963), electrical weirs (Hallam and Lamsa 1957) and even the catch basket of the water intake structure of the Dow Chemical Co. plant on the Pere Marquette Lake (Hodges 1972).

One major hurdle to overcome in the early years of lamprey study was the identification of larval lampreys. In 1950 a detailed description for the identification of ammocoetes with two dorsal fins permitted the separation of sea lamprey larvae from other native larval lampreys in the Great Lakes Basin (Vladykov 1950; Vladykov 1960). The process of transformation from larva to adult had been observed as early as 1666 by a Strassburg naturalist, Leonhart Boldner (Gage 1893), and a detailed description of transformation was provided by Gage (1893 and 1929), but it was not until 1970 when Manion and Stauffer described four distinct stages of transformation of the landlocked sea lamprey that morphololological changes could be attributed to specific time frames. The earliest date for identifying the commencement of transformation was found to be July 10, observed in ammocoetes held in cages in the Big Garlic River, Marquette County, Michigan (Manion and Stauffer 1970). Youson and Potter (1979) described seven distinct stages of transformation in the anadromous sea lamprey, the earliest observed commencement of transformation being mid-July in New Brunswick, Canada. They described two stages of transformation preceding the first stage described by Manion (where the eye is distinct with an obvious black pupil and the lips of the oral hood have thickened and begun to fuse to the body), and divided the Manion and Stauffer stage four into two *stages* to make a total of seven stages. Manion and Stauffer (1970) found that the onset of transformation was not observed after August 16.

Several techniques have been used to mark individual sea lamprey ammocoetes and transforming larvae for later identification. Wigley (1952) investigated the use of tattooing and subcutaneous injections of dyes (cadmium sulfide, yellow; mercuric sulfide, red; and carbon, black) mixed with water. Scott (1962) evaluated radioactive caesium as a lamprey mark and Smith and McLain (1962) conducted mark-recapture population estimates utilizing four water-insoluble dyes: cadmium sulfide; brilliant orange S.W.; chrome green; and mercuric sulfide. In an extensive evaluation of several techniques for marking transforming sea lamprey (PVC loop and disc tags, branding, perforation, microtags, and dye injection), Hanson (1972) recommended the use of tracer-glo pigments (kelly green, rose or yellow) suspended in Carbopol 960 resin and distilled water. This technique has been used by the control agents for mark-recapture studies especially when long term results are expected such as the Big Garlic River study, 1960-72 (Manion and McLain 1971; Manion and Smith 1978). Native lampreys have also been released as "marks" for population estimates of sea lamprey populations when no native ammocoetes are present in the stream system.

Numerical evaluation of mark-recapture results is normally based on a calculation where the number of individuals in the population, of which a number are known to be marked, may be estimated from a sample of which some are found to be marked (Schaefer 1951). The commonly employed Petersen estimate of population size utilizes the formula:

N = MC where; M is the number marked and released
if--

C is the number subsequently examined for marks

R is the number of marks found in the sample C

N is the total (and unknown) number in the population

N is the Petersen estimate of N

In an evaluation of the Petersen estimate and its application, Robson and Regier (1964) provided graphs (Figures 1 - 3) for predicting the number of marks to be released and the numbers of marked individuals to be examined for predictable confidence limits of population estimate. The symbol 1 - α represents the probability that the population estimate N will not differ from the true population size by more than 100p per cent, i.e., by not more than pN. In this situation p denotes the level of accuracy, and i - α the level of precision.

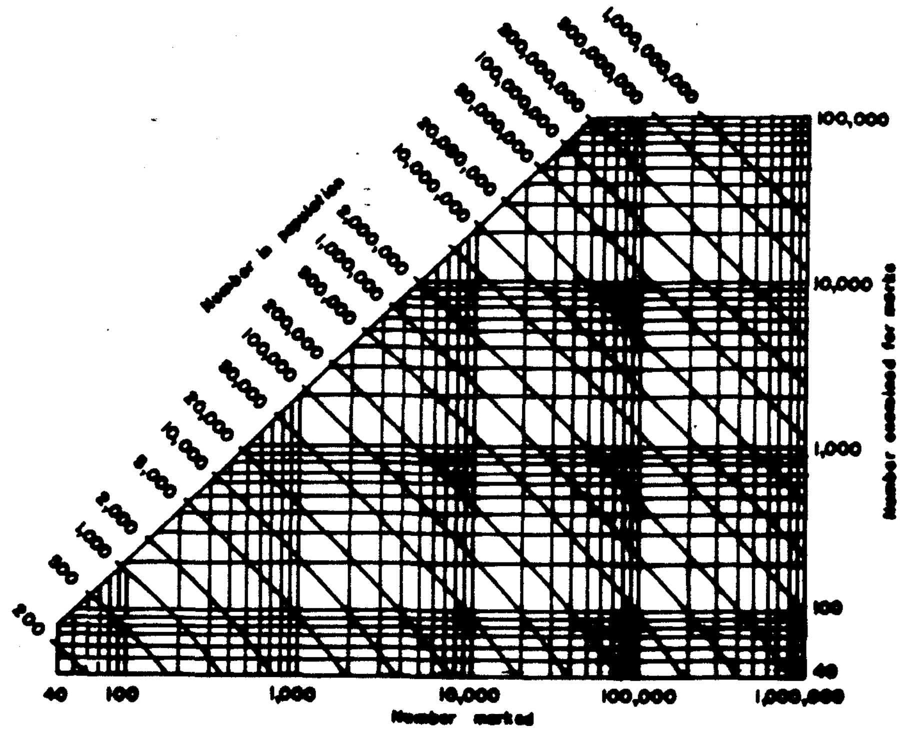


Figure A-1. Sample size when 1 - α = 0.95 and p = 0.50; recommended for preliminary studies and management surveys. Data based on normal approximation to hypergeometric distribution (Robson and Regier, 1964).

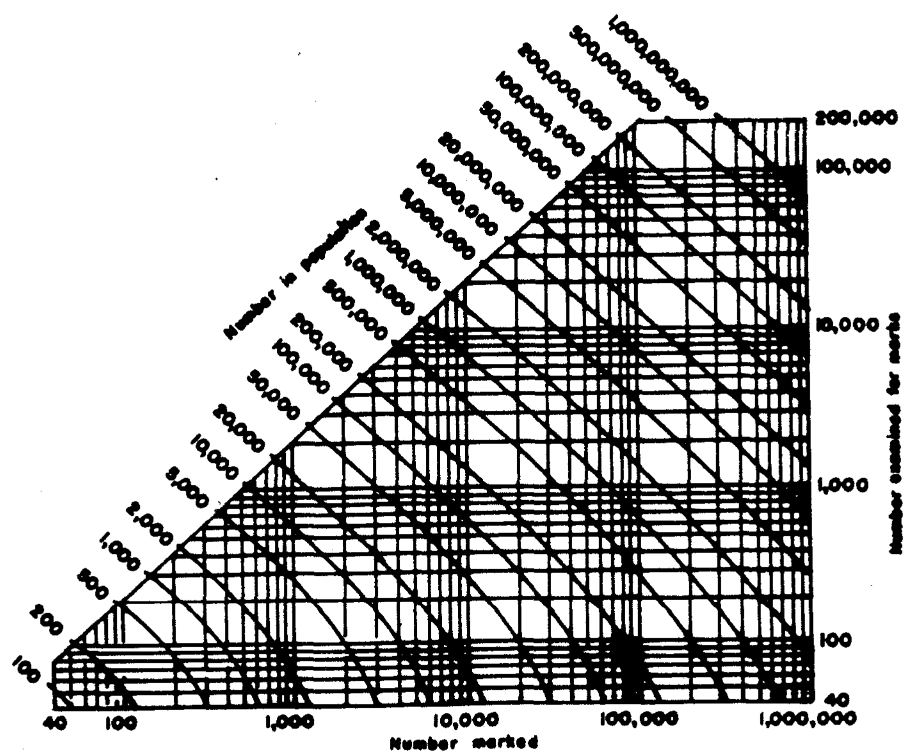


Figure A-2. Sample size when 1 - α = 0.95 and p = 0.25; recommended for management studies. Data based on normal approximation to the hypergeometric distribution (Robson and Regier, 1964).

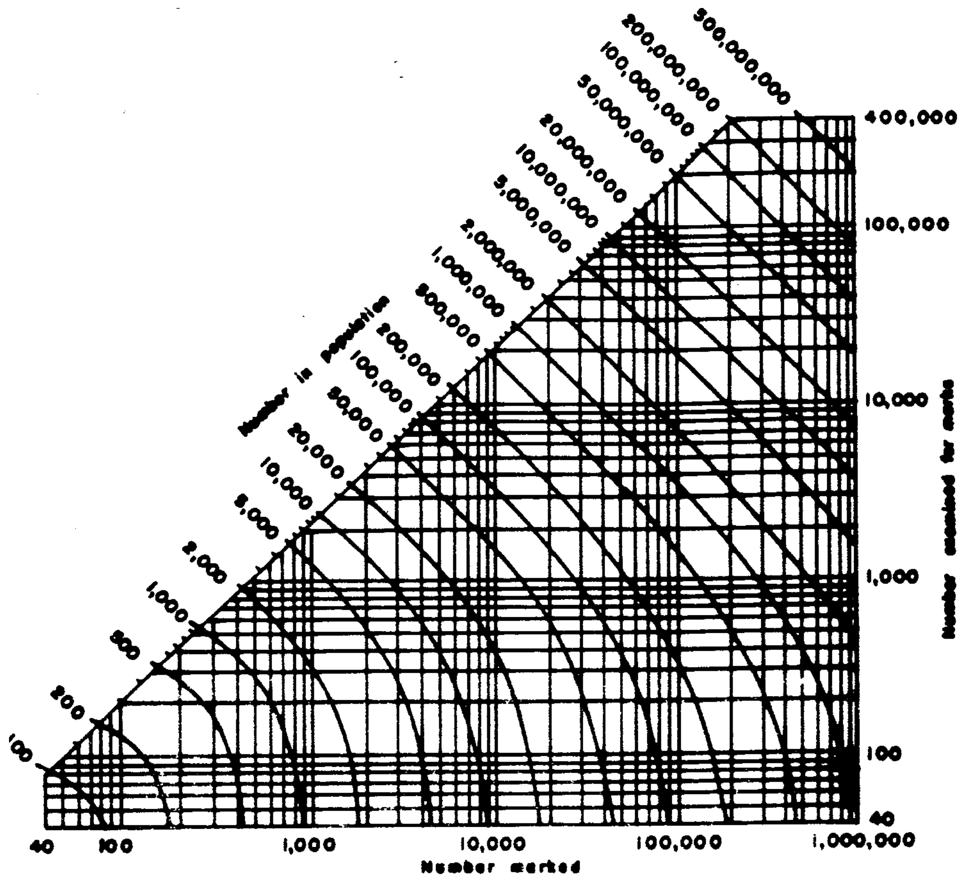


Figure A-3. Sample size when 1 - α = 0.95 and p = 0.10; recommended for research. Data based on normal approximation to the hypergeometric distribution (Robson and Regier, 1964).

CURRENT TECHNIQUES

Both agents of the GLFC currently employ similar techniques for sampling lamprey ammocoetes. The portable backpack electrofishing shocker is usually used to survey in stream waters less than one meter deep. In deep water environments granular Bayer 73 is regularly employed as a survey tool,. It is normally applied at the rate of 224 kg of product per ha in Canada and 112 kg of product per ha in the United States. Chemical treatment of streams with 3-trifluormethyl-4-nitrophenol (TFM) has provided the opportunity to make the largest collections of larval lampreys for individual streams.

Selection of sampling sites normally depends on previous sampling results, history of larval distribution obtained from treatments, and the experience of the person sampling or directing sampling. The USFWS agent makes extensive use of "index" stations in streams with long established sea lamprey histories and routinely sample these stations to provide comparable data over time. The index stations have been selected for their ease of access and collectibility, and have consistently produced significant numbers of larval lamprey representing the many year classes present in the streams. The DFO agent does not rely on established index stations but allows flexibility of sample sites dictated by the numbers and size range of larval lampreys collected. In practice, many areas of each stream have become unofficially "indexed" as perennial favourites where reliability of collections can be expected.

The larval lamprey collections are identified as sea lamprey (*Petromyzon marinus*), American brook lamprey (*Lampetra appendix*), and unspecified native lamprey of the genus *Ichthyomyzon* represented collectively by the silver lamprey *unicuspis*), the northern brook lamprey (I. *fossor*), and the chestnut lamprey (I. *castaneus*). Further separation of larval lamprey from transforming or transformed lamprey is made after July when the external characteristics of transformation are clearly visible. The DFO agent measures and records the larval lampreys in 5 mm groups while the USFWS agent measures and records the larval lampreys to the nearest millimeter. The time required for collection, the method used to collect and the area collected are also recorded along with the date of collection.

Both agents take pains to identify larval lamprey surviving chemical treatments (described as "residual" lamprey), by conducting stream surveys immediately following chemical treatment or within 1.5 years when young-of-the-year (Y.O.Y.) larvae can be easily separated by size from residual animals.

The two control agents record and summarize larval survey data on forms that are different between, but standardized within the units. The USFWS unit utilizes electronic data processing (EDP) for retrieval and statistical evaluation of data. The DFO agent has recently acquired mini-computer capability and have contracted their data processing services. There is no electronic connection between the Sea Lamprey Control offices in Marquette and Sault Ste. Marie for EDP, however word processor communication is routinely used.

Growth rates of sea lamprey ammocoetes are determined through length-frequency graphs of survey data collected from each stream system. The age groups of ammocoetes are normally- clearly defined for the first three years after treatment. Semi-annual surveys (spring and late fall) are often conducted on selected streams to verify growth rates.

Studies to define the collecting efficiencies of the portable electrofishing gear and the applications of granular Bayer 73 for larval sea lamprey have been discussed. Studies of the comparative toxicities of TFM to the various species of larval lampreys (Davis 1970; Ring and Gabel 1985) show that sea lamprey larvae are more susceptible to TFM than both the American brook lamprey and the northern brook lamprey. During stream treatments however chemical concentrations that are sufficient at the stream mouth to kill sea lamprey are usually high enough in the upstream reaches to kill all species of lamprey present. The additional length and concentration of lampricide applications are necessary to compensate for dilution, attenuation and slow mixing into eddies, pools or other current anomalies. Only near the mouth of a stream may concentrations drop to a point where there would be differential mortality among larval lampreys (Lamsa and Davis 1967).

In laboratory studies of toxicity conducted at 1.7, 7.2 and 12.8°C Applegate et al. (1961) observed little difference in the activity of TFM. The minimum lethal dose for larval sea lamprey (free swimming) was 2.0 mg per R at all three temperatures but the average time to death was 14.0, 11.8 and 10.4 h at 1.7, 7.2 and 12.8°C, respectively. Dawson et al. (1977) found that the toxicity of TFM was not significantly influenced by temperature and water hardness (40, 170 and 300 mg per R as CaC03) but that it was seven times as toxic at pH 6.5 as at 8.5. Tests of free swimming and burrowed larvae demonstrated that burrowed ammocoetes required approximately 80% more chemical to effect a 12 h LC99 mortality.

The difficulties of quantitatively sampling larval lampreys during surveys (electrofishing and granular Bayer 73) and treatments (TFM and/or Bayer 73) by actively collecting with dip (scap) nets or passively sampling with fyke nets under widely varying weather conditions is recognized but has not been satisfactorily dealt with by developing a standard unit of "ability to collect". Although weather and collecting conditions are often recorded, a uniform, objective index of "collectibility" has not been developed.

The resource requirements of the control program have limited the effort available for study of lamprey populations and have also dictated the development of convenient (and efficient) methods of stream selection for chemical treatment. The selection process most often employed by the control agents is to treat streams when, from the observed growth rates of the reestablished populations of larval sea lamprey, it is predicted that the oldest age class will reach transformation size, considered to be 120 mm (i.e., treat the potential for transformation rather than waiting for the evidence of transformation and confirming the numbers). This effective strategy which minimizes sea lamprey recruitment to the lake is modified on occasion when large numbers of residual lamprey are confirmed after treatment, or recruitment to a lentic population is to be minimized.

The additional costs required to define population parameters have been normally limited to: problem populations such as Batchawana Bay and the St. Marys River; special studies of chemical efficiency, such *as* in Big Garlic River, 1965-67 and Silver River, 1966; life history documentation, for example in Big Garlic River, 1960-72 and Ocqueoc River, 1963-73; and special cooperative programs such as the Fish Creek Study, 1982-84.

EVALUATION OF SAMPLING TECHNIQUES

The method of collecting larval lampreys during chemical treatment of streams and granular Bayer 73 application to lotic or lentic environments normally consists of manually capturing the larvae with long handled dip nets (scaps) or unmanned fyke nets which sample a 'cross section of stream flow during the period of larval activity. A comparison of these two methods of sampling larval lamprey was conducted by Morman (1982) during the treatment of Bear Creek, Manistee County, Michigan. He found that the difference in species composition collected by the two methods was relatively small (Table A-I), but that there was a major difference in numbers collected and the length distribution of the lampreys (Table A-II). It was concluded that as the fyke nets were probably less subject to discrimination by users than dip nets; they indicate the actual size composition of the lamprey population more reliably.

A comparison by the Hammond Bay Laboratory (1966) of the backpack electroshockers and granular Bayer 73 in the Ocqueoc River, Presque Isle County, Michigan was conducted in 1966. An area of 20.0 m^2 was enclosed with plastic screening and 100 dye-marked larval lamprey were randomly released in the area. A survey 20 h later with electroshockers *for* 30 minutes by two people produced 80 marked larvae plus 11 unmarked larvae. Another group of 100 differently marked larvae were released to the same area and an application of 1.5 kg granular Bayer 73, equivalent to 37.5 kg active ingredient per ha, was evenly dispersed throughout the area. During the next 4 h, 96 larvae of the first marking, 19 of the second marking and 14 unmarked larvae were collected from the area. Based only on the number of marked ammocoetes recovered by each method, the electro survey gave a recovery rate of 80% and the Bayer 73 granules 96%.

Another study by the Hammond Bay Laboratory conducted on the Silver River, Baraga County, Michigan, 1966, compared the effectiveness of granular Bayer 73 as' a survey tool with collections following TFM treatment. Prior to the treatment, an area of 45.7 m^2 was enclosed with plastic screening and 300 marked larval lamprey were randomly released 20 h before surveying. A total of 4.5 kg of granular Bayer 73, equivalent to 49.2 kg active ingredient per ha was applied to the area. All larval activity had ceased after 2 h when 261 marked and 104 unmarked larvae were collected. Four hours later, when the TFM treatment passed the surveyed area, an additional 21 marked and 39 unmarked larvae were collected. (Note: 18 or 6% of the original 300 marked lamprey were unaccounted for). Of all the larval lamprey collected from the fenced area, granular Bayer 73 accounted for 261 of 282 (93%) marked larvae and 104 of 143 (73%) unmarked larvae.

Laboratory studies by Dawson et al. (1977) on the efficacy of Bayer 73 demonstrated that the activity of Bayer *73* was slightly reduced in cold water (7°C) after 3 h of exposure, but not after 6 h or longer. Tests comparing free swimming and burrowed sea lamprey larvae demonstrated that free swimming larvae were about three times more vulnerable to the Bayer 73 than burrowed larvae. In a laboratory study of granular Bayer 73 (5% active ingredient) it was found that less than 40% of the active ingredient is released over a period of 24 h (Gilderhus and Johnson 1980).

Table A-I. Number and percentage of larval lampreys in samples collected at one site with dip nets and a fyke net during application of a lampricide to Bear Creek, August 1968 (Morman 1982).

Species	Dip Net		Fyke Net	
	Number	Per Cent	Number	Per Cent
Ichthyomyzon sp.	10	2	35	1
Lampetra appendix	480	70	1,856	60
Petromyzon marinus.	194	28	1,187	39
TOTALS	684	100	3,078	100

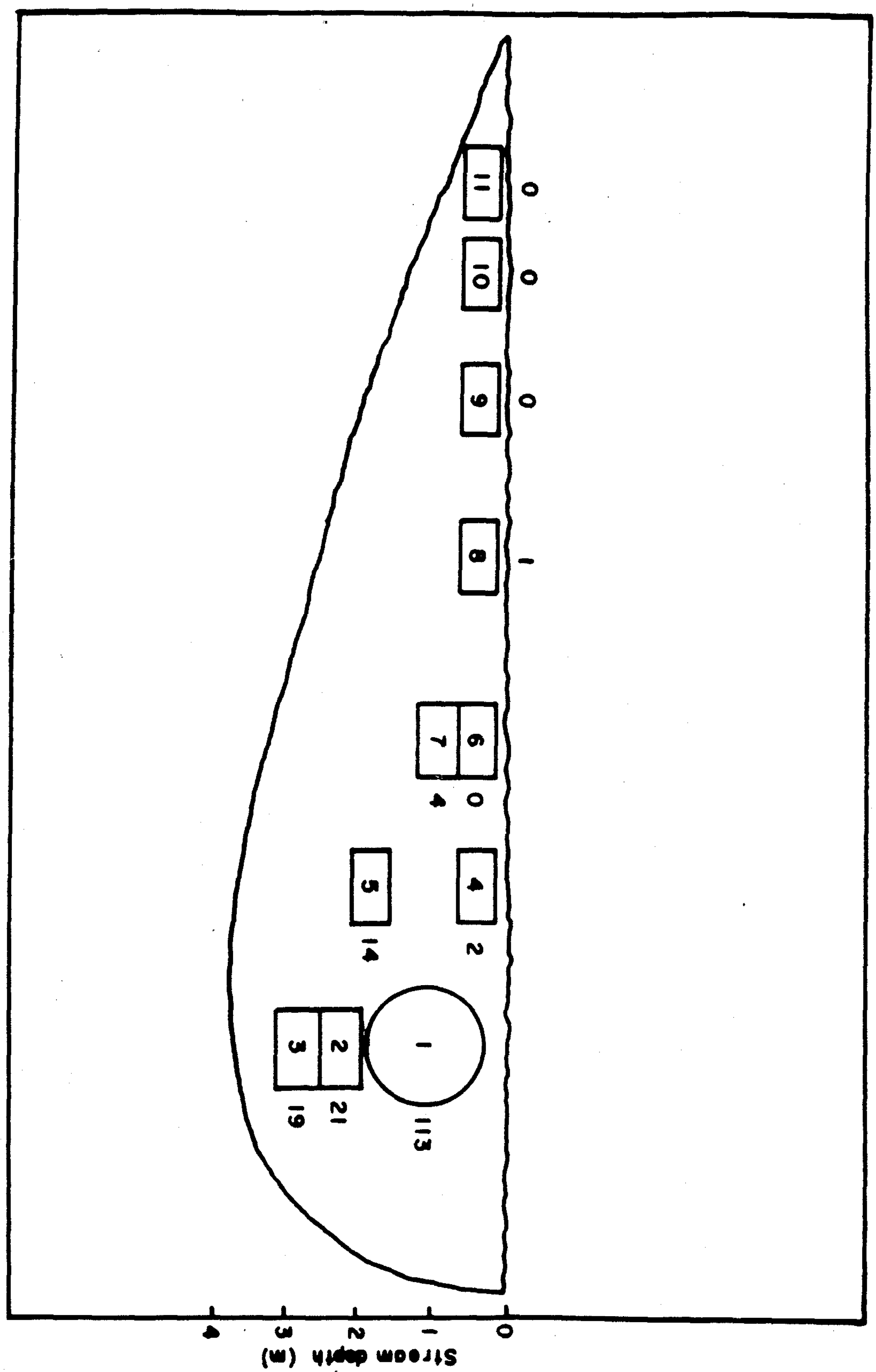
Table A-II. Number and percentage of sea lamprey larvae (metamorphosing larvae in brackets) by length group in samples collected with two dip nets and a fyke net during the lampricide treatment of Bear Creek, August 1968. (Morman 1982).

Length mm	Dip Net		Fyke Net	
	Number	Per Cent	Number	Per Cent
0-30	1	1	34	3
31-60	21	11	419	35
61-90	62	32	478	40
91-120	42	22	155	13
121-150	64(36)	33(17)	100(26)	8(2)
151-180	4 (1)	2 (0.5)	1	1
TOTALS	194(37)	100(19)	1,187(26)	100(2)

During field studies in three locations of Batchawana Bay by Shera and Higginson (1968) mean mortalities of caged larvae of 93, 97 and 80% resulted when granular Bayer 73 (5% active ingredient) was applied at rates of 5.9, 6.4 and 5.7 kg active ingredient per ha respectively, at water temperatures of 14.4 - 15.6°C.

In 1962 a netting study was conducted in the Bad River, Ashland and Bayfield Counties, Wisconsin, to evaluate the ability to capture downstream migrating sea lamprey transformers (Gabel 1984). Eleven riffle fyke nets and one hoop net were fished in the river as indicated in Figure A-4. The release of 78 marked transformers resulted in a recapture rate of 11.5% (9 animals) with -6.4% (5 animals) recaptured in the hoop net fishing between 0.5 and 2.0 m over the deepest cross section of the river channel. This net captured 113 transformers (64.9%) of the 174 taken during the test period.

Figure A-4. Bad River at net site showing positions of nets relative to width (23.8 m) and depth of stream. Net 1 was a hoop net; nets 2 to 11 were riffle nets. Number of transformed sea lampreys captured is given for each net (Gabel 1984).



A fyke net fished annually in the same location on the Ocqueoc River from 1963-73 was used to estimate fishing efficiency of the net and to estimate numbers of transforming sea lamprey migrating downstream. Between the fall of 1963 and the spring of 1968, over 10,000 marked transformed sea lamprey were released upstream of the fyke net on 32 separate occasions. Recapture of these animals varied from 1 to 12% with an average recapture rate of 5.6% (Meyer and Howell 1975; L. H. Hanson, Pers. Comm.).

The first attempt to estimate larval lamprey populations was by Hansen and Hayne (1962) on the Ogontz Bay and River, Delta County, Michigan. Comparison of the orange-peel dredge with an enclosure method (TFM was used to kill lampreys in the enclosure) revealed that the latter method was 3.10± 0.90 times as efficient at sampling ammocoete populations. The orange-peel sampler was calibrated with 6.35 mm ball bearings to determine the sampling ability in different substrates. Most of the sampling in the river was done with a circular enclosure 0.762 m in diameter. The study area of the river was divided into eight strata according to physical characteristics, each randomly sampled (one section was sampled with the orange-peel dredge because of depth) and the total population calculated from the mean number of ammocoetes per unit area, the mean width of the stream and the length of the area sampled. Ammocoetes under 25 mm were not identified and therefore were not included in the estimates even though they comprised 8% of the total collections.

In 1960, the Ogontz River was chemically treated with TFM and a mark-recapture study was conducted to estimate the population of ammocoetes in the river (Smith and McLain 1962). Efforts were made to evaluate the population according to the eight sections studied by Hansen and Hayne (1962) in the two previous years. Prior to treatment, ammocoetes were collected by electroshocking from the respective areas, identified, marked with eight individual marks and released in the same areas from which they had been collected. During treatment, riffle fyke nets and dip nets were employed to sample the ammocoete populations. A minimum of two months passed between the time of marking and treatment, A post-marking mortality study of caged animals indicated mortality of 3 out of 150 (3%) over the two month period. Only ammocoetes larger than 38 mm were marked and the recapture rate was 3.9% (range 1.8 - 14.3%) from 3,145 marked *Lampetra appendix* and 3.3% (range 0.0 - 33.3%) from 1,339 *Petromyzon marinus*. The population of the Ogontz River in 1960 by mark-recapture was estimated at 336,724 (166,154 *Lampetra appendix* and 170,570 *Petromyzon marinus*) by summing individual group data. Pooling the data for all groups yielded a value of 324,468 (174,888 *Lampetra appendix* and 149,580 *Petromyzon marinus*. The previous estimate by Hansen and Hayne (1962) had been 275,500 (138,700 *Lampetra appendix* and 136,800 *Petromyzon marinus*).

Post-marking movement of animals in the Ogontz River during the two to three month period between release and the chemical treatment was slight. In a comparable study conducted in Furnace Creek, Alger County, Michigan, a two week delay occurred between release and treatment during which severe rains and flooding caused considerable post-marking movement, including 6 (1.3%) examples of larval *Lampetra appendix* being collected upstream of their respective release sites (Smith and McLain 1962). Furnace Creek is only 762 m in length from Furnace Lake to Lake Superior, and seven of the 478 marked (1.5%) *Lampetra appendix* larvae were collected from Lake Superior after the heavy flooding. Manion (1969) found that 7% of the larval *Lampetra appendix*, marked and released six weeks prior to chemical treatment of the Big Garlic River on September 20, 1966, moved from the delta area of the river upstream as much as 3.2 km, and 1% of the larval Lampetra appendix released in the stream proper moved downstream. In 1967 the study was repeated utilizing Petromyzon marinus larvae rather than Lampetra appendix larvae. In a two week period between release and recapture, one (1%) of the larval Petromyzon marinus moved upstream from the delta area a maximum of 27.4 m and one (1%) moved from the estuarine area to the delta area.

Identification of individual age classes of larval lampreys has been limited to interpretation of length-frequency data. In scientific studies, larval lampreys were normally measured to the nearest millimeter or tenths of an inch dependent on the measurement system utilized. The U.S. Agent measures and records lengths in one millimeter increments but normally reports the results by summarizing into three millimeter groups. The Canadian Agent measures, records and reports in five millimeter groups, with a few exceptions where one millimeter data may be available. To date computerized analysis of length-frequency histograms has not been utilized to age larval lamprey, although basic groundwork is available; Ricker (1975), MacDonald and Pitcher (1979), Misra (1980), Schnute and Fournier (1980).

Accurate aging of larval lampreys may now be possible by a method (Volk, Unpubl. rep. GLFC) utilizing the calcareous otic elements (statoliths) of the ammocoetes. The technique is most reliable only for those larvae less than four years old. A current study of statolith interpretation for aging larval ***sea*** lamprey is being undertaken by Trudy Medland of the University of Guelph, supervised by Dr. F. W. H. Beamish.

S-Y OF LARVAL SEA LAMPREY POPULATION STUDIES

Population estimates for lamprey ammocoetes in the Great Lakes Basin are listed in Tables A-III, A-IV and A-V. Table A-VI summarizes data available from selected population studies.

Table A-III. Population studies of larval sea lamprey in streams of the Great Lakes Basin, 1958-1984.

	Year	Stream	County District	State/Province
1.	1958-59	Ogontz Creek	Delta County	Michigan
2.	1960	Furnace Creek	Alger County	Michigan
3.	1960	Ogontz Creek	Delta County	Michigan
4.	1960	Snyder Creek	Schoolcraft County	Michigan
5.	1960-72	Big Garlic River	Marquette County	Michigan
6.	1961	Richardson Creek	Algoma District	Ontario
7.	1961	Sucker (Gawas) Creek	Algoma District	Ontario
8.	1961	Two Tree River	Algoma District	Ontario
9.	1965	Big Garlic River	Marquette County	Michigan
10.	1965	Huron River	Baraga County	Michigan
11.	1966	Big Garlic River	Marquette County	Michigan
12.	1966	Silver River	Baraga County	Michigan
13.	1967	Big Garlic River	Marquette County	Michigan
14.	1967	Springer Creek	Menominee County	Michigan
15.	1972	Big Garlic River	Marquette County	Michigan
16.	1974	Bronte Creek	Halton County	Ontario
17.	1974	Brown Creek	Algoma District	Ontario
18.	1975	St. Marys River	Algoma District	Ontario
19.	1976	St. Marys River	Algoma District	Ontario
20.	1977	Nipigon River	Thunder Bay District	Ontario
21.	1977	St. Marys River	Algoma District	Ontario
22.	1978	Nipigon River	Thunder Bay District	Ontario
23.	1983	Big Garlic River	Marquette County	Michigan
24.	1983	Point Patterson Creek	Mackinac County	Michigan
25.	1983	St. Marys River (2)	Algoma District	Ontario
26.	1984	Fish Creek	Oneida, Oswego County	New York
27.	1984	Harmony (Chippewa) River	Algoma District	Ontario
28.	1984	St. Marys River	Algoma District	Ontario

Table A-IV. Population estimates of larval sea lamprey in lentic habitats of the Great Lakes Basin, 1966-1984.

Year	River	Lake/Bay	County/District	State/Province
1. 1966	Big Garlic River	Saux- Head Lake	Marquette County	Michigan
2. 1967	Big Garlic River	Saux Head Lake	Marquette County	Michigan
3. 1976	Gravel River	Mountain Bay	Thunder Bay District	Ontario
4. 1977	Gravel River	Mountain Bay	Thunder Bay District	Ontario
5. 1978	MacKenzie River	Mackenzie Bay	Thunder Bay District	Ontario
6. 1982	Carp River		Mackinac County	Michigan
7. 1982	10 selected stream or lentic areas		Upper Great Lakes	Michigan
8. 1983	Carp River		Mackinac County	Michigan
9. 1984	Harmony (Chippewa) R.	Batchawana Bay	Algoma District	Ontario

Table A-V. Population estimates of downstream migrating, transformed sea lamprey, 1948-1984.

	Year	Stream	County/District	State/Province
1.	1948-49	Ocqueoc River	Presque Isle County	Michigan
2	1948-49	Carp Lake River	Presque Isle County	Michigan
3.	1962	Bad River	Ashland County	Wisconsin
4.	1963-73	Ocqueoc River	Presque Isle County	Michigan
5.	1965-72	Big Garlic River	Marquette County	Michigan

Table A-VI. Summary of mark-recapture studies of larval lamprey populations in the Great Lakes Basin, 1960-84. (N.R. = not reported; N.A. = not applicable)

Date Mo-Da-Yr	Sample Site (Reference)	Area Sampled m^2	Person h Collecting	No. of Marked Animals (M) and Method	Recaptures (R) and Method	Unmarked Captures (C - R)	Mortality of Caged Animals	$N = \frac{MC}{R}$
05-14-60	Furnace Creek (Smith & McLain'62)	N.R.	N.R.	478 (1)	165 (1)	1,293	N.A.	4,224
05-22-60	Snyder Creek (Smith & McLain'62)	N.R.	N.R.	383 (1)	20 (1)	1,585	N.A.	30,736
09-01-60	Ogontz River (Smith & McLain'62)	N.R.	N.R.	3,212 (1) L.a.	124 (1)	6,425	(Marked) 2%	166,247
09-01-60	Ogontz River (Smith & McLain'62)	N.R.	N.R.	1,367 (1) P.m.	44 (1)	5,561	(Marked) 2%	170,654
04-30-61	Sucker (Gawas) Creek (Scott'62)	N.R.	10	110 (2)	2 (1)	3	N.A.	275
05-06-61	Richardson Creek (Scott'62)	N.R.	N.R.	400 (2)	63 (1)	1,266	N.A.	8,438
'05-1o-61	Two Tree River (Scott'62)	N.R.	N.R.	1,910 (2)	24 (1)	477	N.A.	39,871
09-29-65	Big Garlic River (Manion'69)	N.R.	N.R.	200 (1)	84 (1)	106	N.A.	452
09-20-66	Big Garlic River (Manion'69)	N.R.	N.R.	323 (1)	122 (1)	531	N.A.	1,503
09-20-66	Saux Head Lake (Manion'69)	6,131	*N.R.*	394 (1)	100 (2)	481	89%	3,136
07-07-67	Big Garlic River (Manion'69)	N.R.	N.R.	200 (1)	55 (1)	795	N.A.	2,862
07-07-67	Saux Head Lake (Manion'69)	6,131	N.R.	94 (1)	12 (2)	2	N.A.	120
08-10-66	Silver River (Hammond Bay Rep'66)	46	N.R.	300 (1)	261 (2)	104	73-87%	524
08-10-66	Silver River (Hammond Bay Rep'66)	46	N.R.	39 (1)	21 (1)	39	N.A.	111
- -66	Ocqueoc River (Hammond Bay Rep'66)	20	1	100 (1)	80 (3)	11	80%	143
- -66	Ocqueoc River (Hammond Bay Rep'66)	20	N.R.	120 (1)	115 (2)	14	N.A.	135

08-1o-66	Silver River (a)	12,449	6	3.0%	(3)	20 P.m.(3)			N.A.	*P.m. 670
	(Unpub. data, Marquette)					15 Ich.				
08-1o-66	Silver River (b)	3,159	13	12.1%	(3)	747 P.m.			N.A.	*P.m. 6,195
						47 Ich.(3)				
08-1o-66	Silver River (c)	975	9	15.2%	(3)	620 P.m.			N.A.	*P.m. 4,078
						22 Ich.(3)				
18-10-66	Silver River (d)	836		15.6%	(3)	819 P.m.			N.A.	*P.m. 5,265
						9 Ich.(3)				
08-1o-66	Silver River (e)	11,241	24	10.7%	(3)	1,377 P.m.			N.A.	*P.m.12,817
						4 Ich.(3)				
08-1o-66	Silver River (f)	28,659		7.8%	(3)	3,583 P.m.(3)				*P.m.45,900
08-1o-66	Silver River	N.R.	N.R.	5,000	(4)	444	(1)	6,966	N.A.	*P.m.78,500
1o-20-65	Huron River	N.R.	N.R.	3,500	(4)					
	(Unpub.Data,Marquette)									
08-13,	Huron River (m)	3,902	N.R.	N.A.			(3)	154P.m.	N.A.	10,000
17-65	(Marquette Unpub.Data)									
1o-20-65	Huron River	N.R.	N.R.	3,444	(3)	271	(1)	1,703	3.4%	29,445
	(Marquette Unpub.Data)							1,665P.m.		P.m.25,445
06-1,	Springer Creek	1,394m^2	26	1,160	(3)	247	(3)	262P.m.	N.A.	P.m. 1,226
3-67	(Unpub.Data,Marquette)							1,046L.a.		L.a. 4,916
06-3,	Springer Creek	1,394m^2	N.R.	913	(3)	299	(1)	652P.m.	N.A.	P.m. 1,995
4-67	(Unpub.Data,Marquette)							1,409L.a.		L.a. 4,307
09-06-72	Big Garlic River	N.R.	N.R.	N.R.		N.R.		N.R.	N.A.	20,000 larvae
										Trans. 1,100
05-07-74	Bronte Creek	5,574	4	42	(1)	6	(1)	203	N.A.	1,463
	(SSM Ann.Rep'74)									
05-17-74	Brown's Creek	1,104	2	395	(1)	5	(1)	362	N.A.	28,993
	(Unpub.Data,SSM)									
09-04-75	St. Marys River (g)	30,351	94	2,000	(1)	12	(2)	1,017	38%	451,316
	(SSM Ann.Rep'75)									
08-16-76	Gravel River	9,290	20	600	(1)	60	(2)	1,962	100%	20,220
	(SSM Ann.Rep'76)									
09-08-76	St. Marys River (g)	46,539	60	1,900	(1)	52	(2)	955	75%	49,059
	(SSM Ann.Rep'76)									
08-30-77	St. Marys River (g)	46,452	24	1,000	(1)	1	(2)	147P.m	29%	P.m.533,575
	(Unpub.Data,SSM)							19L.a.		
08-1o-77	Nipigon River (h)	6,968	15	400	(1)	28	(2)	1,292	48%	39,286
	(SSM Ann.Rep'77)									
08-13-77	Gravel River	9,290	15	815	(1)	7	(2)	90.	95%	11,888
	(SSM Ann.Rep'77)									

Table A-VI. (Cont'd) Summary of mark-recapture studies of larval lamprey populations in the Great Lakes Basin, 1960-84.

Date Mo-Da-Yr	Sample Site (Reference)	Area Sampled m^2	Person h Collecting	No. of Marked Animals (M) and Method	Recaptures (R) and Method	Unmarked Captures (C - R)	Mortality of Caged Animals	N = MC / R
08-13-78	Nipigon River (h) (SSM Ann.Rep'78)	8,361	15	950 (1)	104 (2)	704	100%	7,381
08-18-78	Mackenzie River (SSM Ann.Rep'78)	12,077	25.5	490 (1)	45 (2)	209	N.A.	2,766
08-7, 8-82	Carp River (Marquette Ann.Rep'82)	14,884	N.R.	720	182 (2)	N.A.	31%	1,342
08-7, 8-82	Carp River (i) (Marquette Ann.Rep'82)	14,884	N.R.	180 (2) 180 (2) 180 (2) 180 (2)	31 (2) 36 (2) 47 (2) 68 (2)	N.A. N.A. N.A.	N.A. N.A. N.A. N.A.	N.A. N.A. N.A. N.A.
1o-07-83	Big Garlic River (Marquette Ann.Rep'83)	7,181	N.R.	1,393 (1)	580 (1)	8,747	N.A.	91,007
1o- -83	Point Patterson Creek (Marquette Ann.Rep'83)	N.R.	N.R.	298 (3)	81 (1)	415	N.A.	1,825
07-19, 20-83	St. Marys River (j) (Marquette Ann.Rep'83)	3,721	N.R.	N.R.	11% (2)	400	N.A.	3,637
07-19, 20-83	St. Marys River (k) (Marquette Ann.Rep'83)	3,721	N.R.	N.R.	35% (2)	71	N.A.	201
08-6, 7-83	Carp River (Marquette Unpub.Data)	3,721	N.R.	N.R.	34.5% (2)	N.R.	31%	N.R.
05-15-84	Seiners Creek (Marquette,Unpub.Data)	N.R.	N.R. +3 Fyke Net Sets	600 (3)	212 (1)	379 (348 P.m.) (31 L.a.)	N.A.	P.m. 985 L.a. 300
07-30-84	Harmony River (1) (SSM Unpub.Data)	13,006	68	1,050 (1)	34 (2)	5,674 (1,232 P.m.) (2 Ich.) (4,440 L.a.)	N.A.	176,276
08-30-84	Harmony River (SSM Unpub.Data)	770,832	42	2,000 (1)	70 (1)	1,060 (721 L.a.) (339 P.m.)	N.A.	32,286
08-01-84) 09-05-84)	St. Marys River (n) (SSM Unpub.Data)	58,200 (10 Individual areas)	191.5	4,653 (1)L.a. 483 (1)P.m.	541 L.a.(3) 13 P.m.(3)	2,584 L.a. 2,535 P.m. (14 Trans.)	N.A.	99,075 (318 Trans.)
06-4, 10-84	Fish Creek (SSM Unpub.Data)	1,156,174	193 +45 Fyke net sets	16,800 (1)	205 (1)	35,006	N.A.	2,885,584

Table A-VI: Notes

a) Area 1 from river mouth to weir site affected by lake seiche
b) Area 2 mainly sand and silt, some gravel
c) Area 3 half spawning habitat, half larval habitat
d) Area 4 half spawning habitat, half larval habitat
e) Area 5 gravel, bedrock and large rubble predominate
f) Silver River as a total
g) Whitefish Island area
h) Downstream of Helen Lake
i) Carp River site utilized four independent marks
j) Whitefish Island area 5.6 kg A.I. Bayer 73/ha
k) Whitefish Island *area* 11.2 kg A.I. Bayer 73/ha
l) Delta area
m) N estimate based on area shocked (3,902 m2) out of total area of habitat ($40,069\ m^2$) and an estimated shocking efficiency of 10%
n) Data currently being prepared for publication as a report

Method of Marking

1. Dye injection
2. Radioactive caesium 137
3. Species of lamprey not native to system

Method of Capture, Recapture

1. TFM application
2. Granular *Bayer* 73 application
3. Electroshocking

* Population estimated by calculating average number of animals per unit area subsampled and multiplying by total area of stream sampled.

LIFE HISTORY OF THE LARVAL SEA LAMPREY (*Petromyzon marinus*)

SPAWNING ACTIVITY AND FECUNDITY ESTIMATES

The spawning migration of adult sea lamprey is closely associated with water temperatures, with the greatest activity at mean temperatures of 10°C to 18.3°C. Water temperatures above this optimum range have an inhibiting effect upon upstream migration, while temperatures fluctuating between 4.4°C and 10°C cause infrequent, sporadic movements (Applegate 1950). Applegate found that migrants entering the streams in mid-April did not have fully developed ova and 68.4% of ova development had still to take place in the stream. In late June ova development was complete but release of the eggs into the coelom was not observed in migrants until late July.

Spawning activity commences at mean daily water temperatures of 11.4°C to 11.7°C and continues while daily fluctuations remain above 10.0°C. The peak of spawning activity occurred when mean daily temperatures rose above 14.4°C to 15.6°C. In the Ocqueoc River, 1948, the first observed nest construction was on May 22 and the last spawning activity was observed on July 28 (Applegate 1950). In the Big Garlic River, 1960, the spawning activity was observed from June 27 to July 20 (Manion and McLain 1971). Electrical barrier catches of migrating adult sea lamprey into streams tributary to Batchawana Bay, Ontario during 1956-60, regularly included adults through August and as late as September 15 (Figure A-5). A chemical treatment of Harmony River, Batchawana Bay, September 13 and 14, 1983, resulted in the collection of one spent male sea lamprey below spawning gravel in the river (Sault Ste. Marie field data).

Fecundity of the landlocked sea lamprey has been studied in detail by Applegate (1950), Wigley (1959), Manion (1972) and Morse (Pers. Comm.) and is summarized in Table A-VII. The potential fecundity, estimated by multiple regression utilizing length, weight and egg production data from these sources is presented in Table A-VIII. The data from Applegate were collected from the Ocqueoc and Carp Rivers, Lake Huron. The data from Wigley (1959) were collected from Cayuga Inlet, Cayuga Lake. The data from Manion (1972) were collected from the Chocolay River, Lake Superior. Vladykov (1951) compared the potential egg production in the anadromous sea lamprey of Quebec, with that of Great Lakes sea lamprey from the Little Thessalon River in the North Channel of Lake Huron, and Hibbards Creek in Lake Michigan. The results are shown in Table A-IX. The anadromous sea lamprey from Quebec averaged 743 mm long, 842 g in weight and produced an average of 171,589 eggs; the Lake Michigan sea lamprey averaged 359 mm long, 127 g in weight, and produced an average of 62,870 eggs; and the North Channel sea lamprey averaged 384 mm long, 136 g in weight and produced an average of 55,913 eggs. When the data are compared for sea lamprey weighing an average of 200 g (Table A-IX), the Lake Michigan lamprey produced the largest number of eggs (84,658) followed by the North Channel lamprey (75,239) and then the anadromous Quebec lamprey (69,913).

Figure A-5. Summary of electrical barrier catch, Pancake River, Lake Superior, 1956. Adult spawning run sea lamprey, Petromyzon marinus, May 24 to September 13, N = 715; downstream migrant metamorphosed sea lamprey, October 29 to November 5, N = 153.

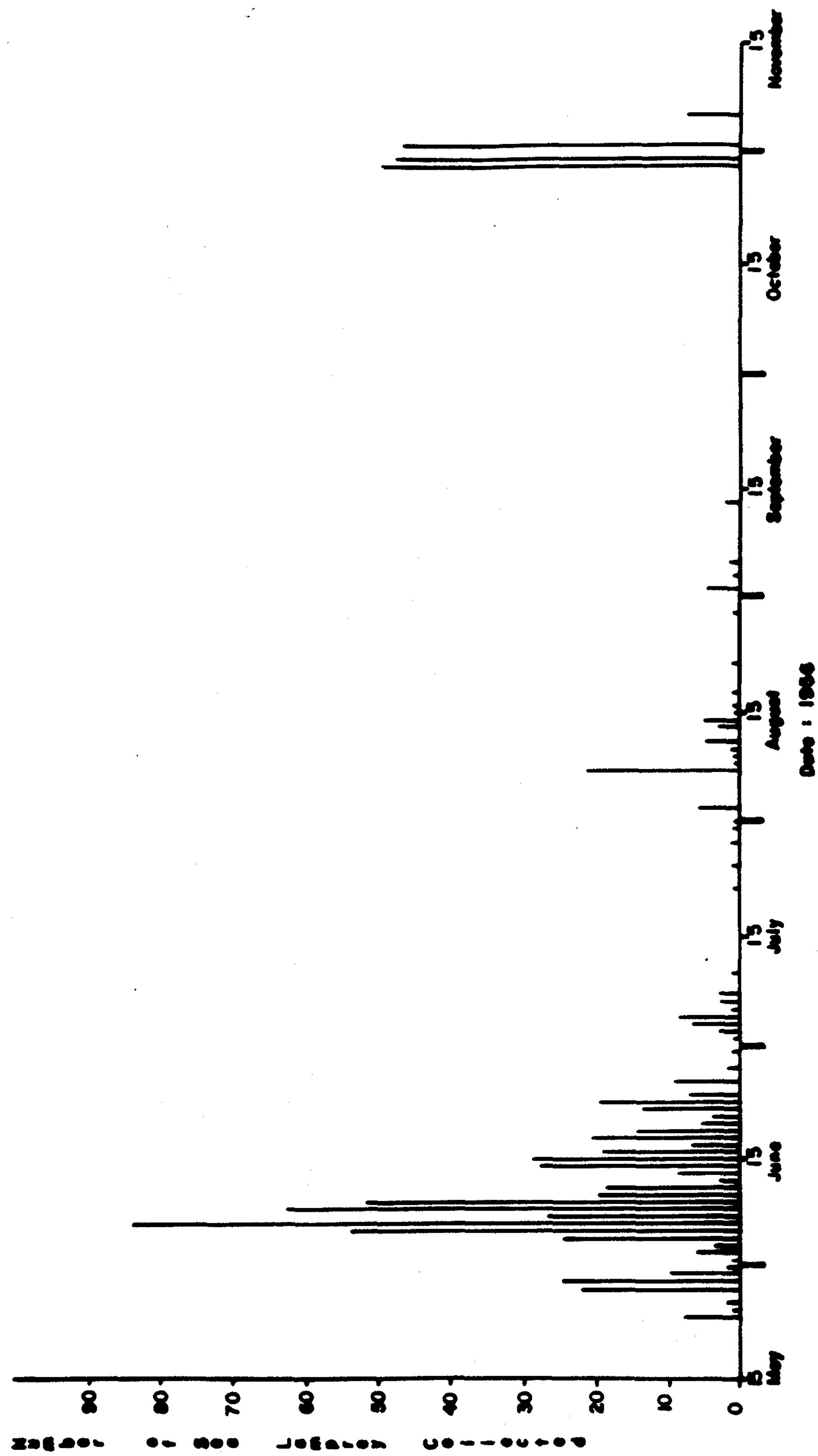


Table A-VII. Comparison of mean sea lamprey fecundity estimates made by Applegate (1950), Wigley (1959), Manion (1972), and Morse (Pers. Comm.)

Author and Year of Collection	Source of Adult Sea Lamprey	Number Examined	Mean Length (mm)	Mean Weight (g)	Average No. of Eggs
Vladykov 1948	St. Lawrence R., Quebec (anadromous)	10	743 (666-841)	842 (560-1,145)	171,589 (123,873 - 258,874)
"	Wisconsin, L. Michigan	10	359 (291-439)	127 (59-209)	62,870, (38,678 - 85,712)
"	Ontario, North Channel	10	384 (330-435)	136 (81-221)	55,913 (28,891 - 74,023)
Applegate 1947	Michigan, L. Huron	70	434 (320-536)	181 (61-328)	61,942 (21,000 - 107,138)
Wigley 1951	New York, Cayuga L.	29	396 (297-511)	145 (51-332)	45,597 (13,974 - 85,162)
Manion 1960	Michigan, L. Huron	29	406 (340-511)	158 (85-315)	68,599 (43,997 - 101,932)
Morse 1981	Lake Superior	10	430 (350-474)	205 (122-252)	70,451 (58,329 - 79,992)
"	Lake Michigan	30	452 (366-512)	264 (105-483)	81,748 (41,861 - 109,681)
"	Lake Huron	20	436 (332-516)	232 (118-368)	77,184 (49,768 - 100,161)
"	Lake Erie	20	481 (413-524)	277 (168-355)	94,344 (67,833 - 123,920)
"	Lake Ontario	30	468 (422-512)	286 (201-375)	107,429 (53,164 - 162,439)

Table. A-VIII. Comparison of potential fecundity estimates from sea lamprey adults collected from the Great Lakes Basin, 1947, 1951 and 1960.

Weight Grams	'LENGTH mm			POTENTIAL FECUNDITY		
	Applegate 1950 L. Huron	W i g l e y 1959 Cayuga Lake	Manion 1972 L. Superior	Applegate 1950 L. Huron	Wigley 1959 Cayuga Lake	Manion 1972 L. Superior
100	362	357	356	40,496	33,066	63,698
200	450	438	441	66,887	59,715	72,137
300	538	518	526	93,278	86,268	80,575
400	626	598	610	119,669	112,821	89,137
500	715	678	695	146,103	139,374	97,576

Table A-IX. Comparison of potential fecundity estimates from Great Lakes sea lamprey adults, Little Thessalon River, Ontario, and Hibbards Creek, Wisconsin, with anadromous sea lamprey adults, St. Lawrence River, Quebec, 1948.

Weight Grams	LENGTH mm			POTENTIAL FECUNDITY		
	Ontario North Channel	Wisconsin Lake Michigan	Quebec St. Lawrence River	Ontario North Channel	Wisconsin Lake Michigan	Quebec St. Lawrence River
100	354	332	536	45,350	54,718	54,220
200	437	433	564	75,239	84,658	69,913
300	519	534	592	104,306	114,598	85,607
400	601	636	620	133,373	144,619	101,300
500	684	737	647	163,261	174,559	118,068

EMBRYO MORTALITY/SURVIVAL

Laboratory study of the embryological stages in the sea lamprey by Piavis (1961) defined critical ranges of water temperature for larval development. No larvae survived to hatch below a constant temperature of 15.5°C nor above a constant temperature of 21.1°C. The optimum temperature for survival of egg to larval stage was 18.4°C where 78% survived; only 12% survived at a constant 15.5°C, and 5% survived at a constant 21.1°C to the larval stage. Since in nature temperatures are not constant, the tests by Piavis demonstrated that mortalities could follow an exposure of 15 h at 12.8°C or of only 3 h at 23.9°C. These embryo experiments were conducted in Lake Huron water which normally has a total alkalinity of 85 mg/L. The last prolarval stage (stage 17) defined by Piavis ranged in size from 7.5 - 9.0 mm and required approximately 17 days to develop from fertilization of the ova at a constant 18.4°C.

McCauley (1963) tested mortality of embryos held at 18°C, then transferred during the first 8 days of development to 12, 14, 23 and 26°C environments until they should have reached the larval stage. A maximum of 29% survived to the hatching stage when temperatures fluctuated, compared to a 54% hatch at a constant 18°C. Greatest -mortality of the embryos occurred when temperatures fluctuated during the first 4 days of embryo development.

During a chemosterilization study of sea lamprey in the Big Garlic River in 1974 (Hanson and Manion 1978), observations of embryonic development from a fertile pair of sea lamprey, June 26 - July 23, showed that from 85 - 97% of the embryos survived although the temperature range during spawning was 10.0 - 11.7°C and the mean daily water temperatures during embryonic development were below 15.6°C for 28 out of 39 days (Manion and Hanson 1980).

Manion and Hanson (1980) estimated that 86% of the eggs produced by the female sea lamprey during the spawning act were not deposited in the nest but lost to the currents. With 5% egg retention by the female lamprey (Applegate 1950), only 9% of the egg production actually reached the nest. Studies of seven individual nests suggested survival of the eggs deposited in the nest to be 85 - 94%, averaging about 90%. Hatching success, recorded by Applegate (1950) in the Ocqueoc River for three confined nests were 1.1%, 0.4% and 0.7%. Most larvae burrowed from the nest on the twentieth day, range 18 - 21 days, at an average water temperature of 21.7°C. Egg production was calculated from length-fecundity data previously collected from 70 specimens and hatching success was measured as the number of larvae swimming free of the nest area.

Manion (1968) studied 19 nests over three years; six nests in June 1963 and eight nests in July 1965 from the Little Garlic River, Marquette County, Michigan, and five nests in July 1966 from the Traverse River, Keweenaw County, Michigan. Eleven single and eight double-paired spawning nests were examined. Hatching success was estimated to be 7.8% in 1963, 5.7% in 1965 and 5.3% in 1966. Egg production was estimated from Applegate's (1950) length-fecundity data and the average length of female sea lamprey collected in electric barriers from Lake Superior for those years studied. Hatching success was measured by dismantling the nests and examining embryological development no later than 17 days post spawning.

In a study of the 1960 year class of sea lamprey larvae in the Big Garlic River, Manion and McLain (1971) observed that one group of larvae remained in the nest 34 days post spawning prior to the "burrowing stage" (Piavis 1961) compared to Applegate's (1950) observation of 21 days. Egg retention by 28 spent female sea lamprey in the 1960 Big Garlic study averaged 2.2% (range 0.3 to 6.7%) compared to Applegate's (1950) study of 40 spent females which averaged 5.0% (range 0.0 to 37.2%) retention. Egg retention by 10 normal sea lamprey in the chemosterilization study (Hanson and Manion 1978) *was* calculated to be 1.2%.

LARVAL HABITAT PREFERENCE

Gage (1893) noted that ammocoetes made their burrows in sand and mud, and that suitable locations were often found in concavities of the stream bed. Reighard and Cummins (1916), in reporting studies on habits of the Michigan brook lamprey, Ichthyomyzon fossor, observed that ammocoetes were most abundant where eddies had deposited silt in the concavities of the stream bed, where the current was slow. They considered that a mixture of silt and sand provided the most favourable habitat, but noted that ammocoetes were also present in gravelly and pure sand bottoms. **Léger** (1920) recorded that larvae of Petromyzon marinus lived in burrows in mud and fine sand. Schultz (1930) conducted a thorough study of Lampetra planeri in the State of Washington, U.S.A. His observations essentially confirmed that ammocoetes of that species had similar habits to those described for I. fossor by Reighard and Cummins (1916). He found ammocoetes to be most abundant in eddies where a rich deposit of silt mixed with a little sand had settled; ammocoetes were also common where depressions had allowed the general drift of debris and silt to settle. Very few were present in shifting sand bottoms, and they were not abundant in firm silt where plants were established. Enequist (1937) stated a belief that ammocoetes were attracted to rotting vegetation. Leach (1940), in discussing the distribution of I. fossor in streams, stated that the nature of the streams affected distribution. He believed that in rivers of fairly constant flow and consequently stable bottoms, ammocoetes were segregated by size in various deposits, but in streams of more variable flow, where deposits were more mixed and less stable, the segregation was less marked. Hardisty (1944), investigating the distribution of L. planeri in England, found that ammocoetes occurred only where the current was sluggish or where the stream meandered, and were generally distributed in streams, except in very small ones. Ammocoetes were most abundant In eddies and backwaters, below obstructions such as fallen trees or on bends in the stream. The type of mud inhabited varied, but larvae were most numerous in fine silt containing decaying organic matter. They sometimes occurred in silt-sand mixtures but seldom in coarse sand or gravel. Like Schultz (1930), Hardisty noted that ammocoetes were most numerous toward the water line.

Maskell (1929) showed that the New Zealand lamprey, Geotria australis, had similar habits to those of European lamprey. He found ammocoetes to be most numerous in mixtures of fine mud and sand, but absent in stiff clay, while only the larger specimens were present in gravel. Areas of suitable habitat for ammocoetes were found along the river banks and in small backwaters; frequently these spots were covered with either sunken or floating fallen leaves, twigs, and other debris. Like Leach (1940), Hardisty found that ammocoetes were segregated by size in different deposits, with small animals in fine silt, and longer ones where there was a deep layer of decaying debris. The largest ammocoetes were found among debris containing little or no mud. Metamorphosing individuals were sometimes found in pure sand and even gravel. Churchill (1947), stated that I. fossor ammocoetes require a fairly soft bottom in which to burrow, noting their absence in firm sand and, curiously, in extremely soft mud. Like many of the aforementioned authors, he considered the best substrate to be a mixture of sand and silt, and that a depth of water of 15 to 71 cm with aquatic vegetation was most suitable. *Ammocoetes were* found, however, in water as deep as 1.0 m.

Applegate (1950) found that the most important parameter controlling distribution of P. marinus ammocoetes was the softness of the bottom. Ammocoetes were most abundant in soft bottoms of silt, silt-sand, silt-debris, etc., which normally occurred where the current was slack, for example, in eddies, backwaters and on the inside of stream bends. Ammocoetes were found in suitable bottoms to a depth of 2.3 m of water (Figure A-6). Where springs and seepage into the bottom occurred, ammocoetes were rare. In contrast to Schultz (1930) and in common with Churchill (1947), Applegate found ammocoetes abundant where aquatic vegetation was established in small patches. Like Hardisty (1944) and Leach (1940), Applegate found some segregation by size. Young-of-the-year first occupied sites with mixtures of find sand and silt, but by the end of their first year had moved to more "mucky" bottoms. In shifting and unstable sand bottoms ammocoetes were much less abundant than in stable silted sites. As an example, a sand bottom adjacent to a silted slough had an average of 11 ammocoetes over one year old per m2, whereas in the slough 32 per m^2 was the mean population density. Areas of fine compacted sand, and gravel, were found to harbour few ammocoetes.

Baxter (1957), a British worker, made some broad generalizations concerning ammocoete habits. He observed that the "beds" occupied by ammocoetes were stable in nature and that the ammocoetes lived in them for long periods. He postulated that such beds, and thus ammocoete populations, were most likely to occur where the stream gradient was between 1.9 and 5.7 m per km. Schroll (1959) observed that L. planeri and L. danfordi were found in heavily shaded brooks and in slow river reaches, and that larvae sought out a depth of mud proportional to their age and size. Schroll stated that small ammocoetes built burrows in substrate with finer particles than did large ammocoetes, and that the bottom in which large ammocoetes built burrows was less homogeneous in regard to particle size than that in which small ammocoetes built their burrows. He stated that the water flow over ammocoete burrow locations was constant, with a surface velocity of 0.63 $m.s^{-1}$.

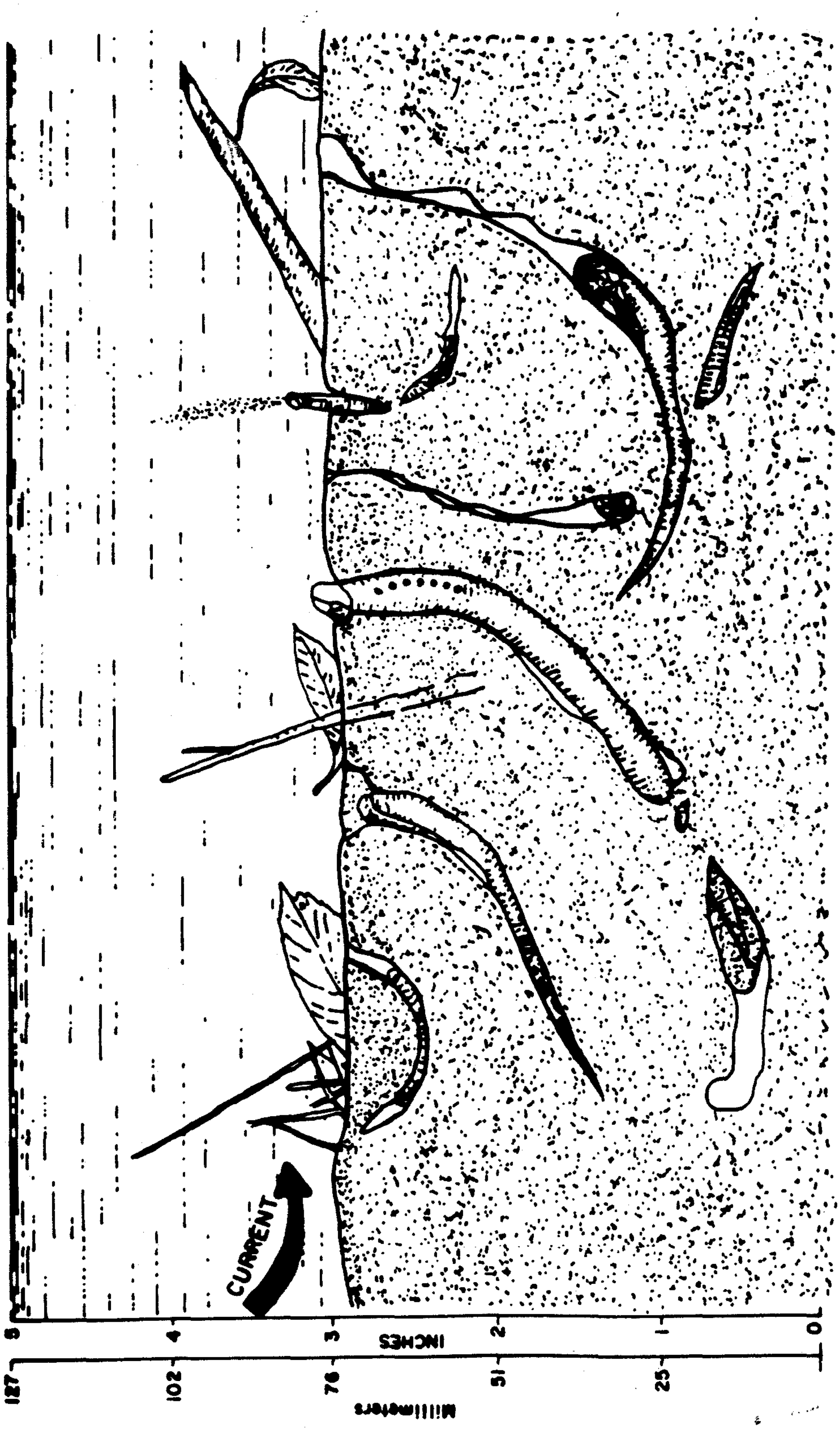
Thomas (1963) described ammocoete beds as areas of suitable habitat among less suitable bottom material found where the stream velocity exceeds that required for the laying down of silt. These beds are normally deposited by the currents in depressions of the stream bed, on the inside- of bends, behind large permanent or semi-permanent obstructions such as rocks or fallen trees, and frequently at the junction of smaller tributary streams where hydrological conditions encourage silt deposits. Where stream velocity is uniformly slow, silt is deposited throughout the entire stream bed and the larval lamprey will utilize all of the stream for burrowing (Thomas 1963).

Manion and McLain (1971) observed that larval sea lamprey preferred sand-silt habitats where 90% of the sand particles were fine (0.5 mm). They also observed that as the ammocoete increased in length over 80 mm, they preferred deeper water with sand-silt bottoms covered with detritus.

Manion and Smith (1978) observed that the deeper water habitats frequented by larval sea lamprey were characterized by reduced flows (in eddies, behind logs or rocks) and where deposits of silt and detritus had covered the bottom. Where the stream bottom was dominated by gravel and rubble, the lamprey were associated with aquatic plants (which colonized the limited sand-silt pockets available).

Thomas (1963), postulated that sea lamprey larvae required less than 0.62 $m.s^{-1}$ velocity and 2,224 g compactness (measured by penetrometer) of bottom hardness for successful burrowing activity. The corresponding values for the American brook lamprey were 0.79 $m.s^{-1}$ and 2,691 g, respectively.

Figure A-6. Composite sketch of larval lampreys as they were observed in thin-section aquaria resting or feeding in their burrows. One individual is expelling accumulated detritus from its sieve apparatus (Applegate 1950).



LARVAL DENSITIES

Applegate (1950) estimated population density for three individual ammocoete beds within a 3.2 km stretch of the Ocqueoc River where the heaviest concentration of spawning occurred. The first bed, 21.0 m^2, contained 630 ammocoetes (30 per m^2) older than Y.O.Y. plus approximately 151 Y.O.Y. per m^2, plus an estimated 104 Y.O.Y. per m^2. The third bed, 7.9 m^2 contained 31.8 larvae older than Y.O.Y. per m^2 plus an estimated 86 Y.O.Y. per m^2. The average larval density for the three ammocoete beds was 153 larvae per m^2. These estimates were conducted in the fall of the year. Re-examination of these beds the following spring revealed that most of the larvae which had hatched the previous year had disappeared, presumably having either died or migrated to suitable habitat downstream.

A population estimate conducted in 1984 in a 1.3 ha lentic area in Batchawana Bay which had been chemically treated every year since 1973 yielded a total of 175,227 ammocoetes or 13.5 per m^2. All year classes and three species of lamprey were present (137,118 Lampetra appendix, 78%; 38,047 Petromyzon marinus, 22%; and 62 Ichthyomyzon sp., 0.04%). A population estimate of the adjacent river system revealed a population of 32,286 lamprey (21,961 Lampetra appendix, and 10,325 Petromyzon marinus) in 7.7 ha with an average density of 0.04 ammocoete per m^2. The river had been treated with. chemical four times since 1973 and had been last treated in September 1983 (Sea Lamprey Control Centre, DFO; unpubl. data).

A population estimate of sea lamprey larvae in Fish Creek, New York State, in 1984 involved sub-sampling 47% of the total watershed estimated to be 245 ha in surface area. A total of 47% of the area was sub-sampled and a population estimate of 6,113,525 ammocoetes (all Petromyzon marinus) was realized. Five areas, composing 58% of the sampled area contained estimated ammocoete densities (with corresponding areas sample in parentheses) as follows: 1.57 (17.56 ha), 2.11 (37.62 ha), 3.74 (7.60 ha), 3.84 (8.83 ha), and 6.23 (5.64 ha) larvae per m^2; compared to an estimated average of 2.50 larvae per m^2 for the entire system. The population estimate from the Big Garlic River by Heinrich in 1983 resulted in a population of 91,007 sea lamprey larvae in 31,343 m^2 for an average density of 2.90 ammocoetes per m^2 (Johnson et al. 1986).

LARVAL GROWTH RATES AND DURATION OF GROWTH

The most comprehensive study of growth rates of larval and transforming sea lamprey from a single year class over time was from the Big Garlic River, Marquette County, Michigan (Manion and McLain 1971; and Manion and Smith 1978). The mean lengths and ranges of larval lamprey collected in October by electroshocking are summarized in Table A-X. Lengths of transformed ammocoetes collected in the downstream trap between September 1 and August 31 are included for comparison in Table A-X. Sex ratios of larvae and transformed sea lamprey collected in the downstream trap are summarized in Table A-XI. In the Big Garlic River transformation did not occur before age five when the average length of the ammocoetes was 107 mm (range 65 - 176) in October and the number transforming was very low, with four captured from an estimated population of approximately 950,000 ammocoetes.

Table A-X. Lengths of sea lamprey ammocoetes collected in October and transformed ammocoetes collected September 1 - August 31, from the Big Garlic River, Marquette County, Michigan 1960-1972 (Manion and Smith 1978).

Year	Total Length of Larvae (mm)		Total Length of Transformed Lamrey (mm)	
	Mean	Range	Mean	Range
1960	13	1o-19	-	-
1961	39	25-54	-	-
1962	63	37-107	-	-
1963	80	52-134	-	-
1964	92	58-159		
1965	107	65-176	162	152-172
1966	111	67-179	150	121-172
1967	113	72-165	151	127-180
1968	112	72-158	145	123-174
1969	114	76-160	143	122-173
1970	121	90-177	144	116-179
1971	128	85-170	148	118-182
1972	129	98-173	156	133-193

Table A-XI. Percentage males among ammocoete and transformed sea lamprey collected from the Big Garlic River, Marquette County, Michigan 1959--1972 (Manion and Smith 1978).

Year	Larvae		Transformed	
	Total Examined	Per Cent Males	Total Examined	Per Cent Males
1959*	141	19		
1966	289	21	46	54
1967	407	27	172	35
1968	904	19	313	31
1969	672	15	314	23
1970	924	18	541	21
1971	298	22	313	21
1972	357	22	298	15

1959* chemical treatment of original population of unknown age, 1966-72 data from 1960 age class of sea lamprey.

Manion and McLain (1971) determined the length-weight regression for 1,936 sea lamprey ammocoetes collected from the downstream trap in the Big Garlic River as follows:

$$\text{Log10 } w = -4.99 + 2.62 \text{ Log10 } L$$

where L = total length in millimeters, and

w = weight in grams

Growth rates of sea lamprey larvae reestablished after chemical treatment of seven streams were examined by Purvis (1979). The 1960 year class was followed until 1967 in two streams, but lampricide treatments removed this class from four other streams by 1965 and one in the spring of 1966. A comparison of mean lengths as recorded in October, 1960-65 is presented in Table A-XII. The mean growth rate, as interpreted by Purvis for the first three years of growth was 85.6 mm (range 65 - 108) for the seven streams for an average annual growth rate of 28.5 mm (range 21.7 - 36.0). During the same period of time in the Big Garlic River, the average growth rate was 80.0 mm for an average annual growth rate of 26.7 mm (Manion and Smith 1978). Mean lengths of the 1960 year class of ammocoetes were recorded for three times of the year (May, August and October) from six streams for two consecutive years, October 1961 - October 1963, Table A-XII (Purvis 1979). During these two years the mean lengths of the ammocoetes increased by 45.3 mm (range 28 - 59) for an average annual increase of 22.7 mm. The increase in length from October to May averaged 5.3 mm (range 0 - 9) in 1961-62, 7.2 mm (range 3 - 13) in 1962-63, and 6.3 mm for the two year periods, 1961-63. The length increase from May to August averaged 14.2 mm (range 10 - 19) in 1962, 9.7 mm (range 3 - 16) in 1963, and 11.9 mm for the two years (1962-63). The length increase from August to October averaged 4.5 mm (range 1 - 9) in 1962, 4.7 mm (range 1 - 13) in 1963, and 4.6 mm for the two years (1962-63).

Thomas (1963) observed that the mean length of the 1960 year class of sea lamprey in Venison Creek, Ontario, was approximately 54 mm in October 1961 (Figure A-7). By comparison in Big Garlic River the mean length was 39 mm (Table A-X) and in the six streams of Michigan (Table A-XIII) the mean length averaged 44 mm (range 37 - 49).

In a recently completed 4.5 year study of ammocoete growth rates and density relationship, Morman (In Press) caged 10 groups of one year old lamprey in five streams at two density levels. Cages were 0.9 m^2 and initial larval densities were 25 and 75 animals per cage. All ammocoetes were counted and measured each May and October until transformation was first recorded in October 1981 at age five (Table A-XIV and Figure A-9). Losses due to natural factors in two streams averaged 4% and 8% in the low density cages and 32% and 48% in the high density cages. Metamorphosis occurred at age five only in those cages of low density where five of fifty-seven animals transformed, whereas in the high density cages none of the 150 animals that survived to the end of the study transformed. Zero or negative growth, increments were observed in the 10 test cages 20% of the time (16 out of 80 time frames) overall, and 4% of the time during the summer months. At age four the larvae on the Manistee River showed an average negative growth in the summer of 1980 where the density was high, while the ammocoetes on the White River during the same summer showed negative growth in the low density cage. At age two the Rifle River ammocoetes showed no growth during the summer of 1978 (Table A-XV). A comparison of the growths of stream larvae and caged larvae is available for the first two years of growth on the five rivers (Table A-XVI).

Table A-XII. Mean lengths of sea lamprey ammocoetes of the 1960 year class recorded from seven streams in Michigan, 1960-1967 (Purvis 1979).

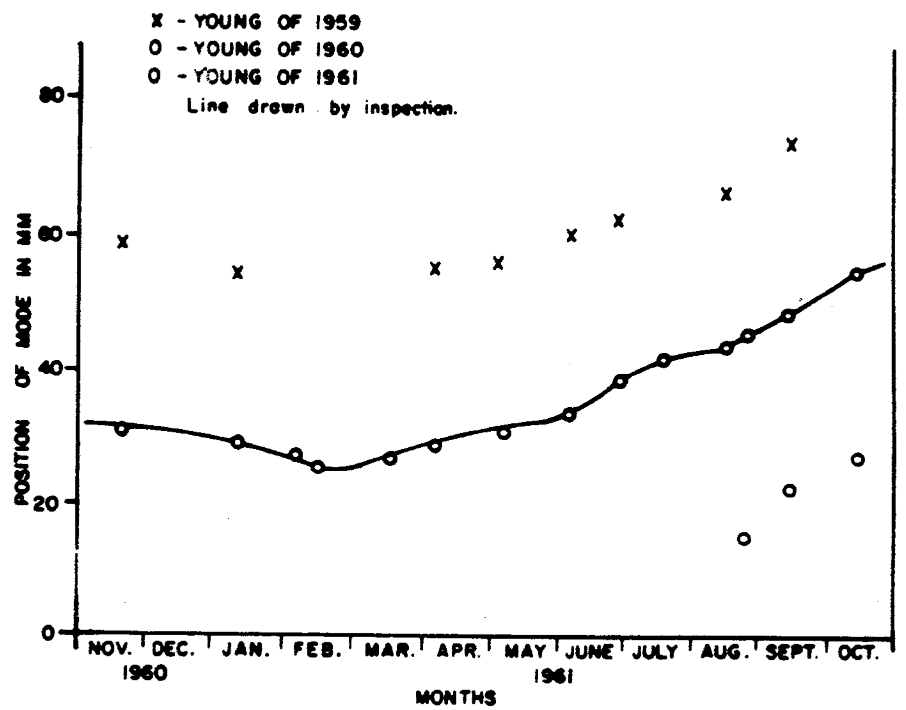
	LAKE MICHIGAN				LAKE SUPERIOR		
Age Group & Date of Collection	Marblehead Creek	Bursaw Creek	Deadhorse Creek	Hog Island Creek	Little Garlic Creek	Gratiot River	Sullivans Creek
Age Group 0 Oct. 1960	28				16	18	16
Age Group 1 Oct. 1961	49	49	38	37	45	44	
Age Group 2 Oct. 1962	75	74	62	54	71	69	56
Age Group 3 Oct. 1963	96	108	76	65	98	91	65
Age Group 4 Oct. 1964	128		92	80	121		-
Age Group 5 Oct. 1965			101				

Table A-XIII. Mean lengths of sea lamprey ammocoetes of the 1960 year class recorded from six streams in Michigan, 1961-1963 (Purvis 1979).

	LAKE MICHIGAN				LAKE SUPERIOR	
Date of Collection	Marblehead Creek	Bursaw Creek	Deadhorse Creek	Hog Island Creek	Little Garlic Creek	Gratiot River
October 1961	49	49	38	37	45	44
May 1962	57	55	42	37	54	49
August 1962	67	70	61	52	69	60
October 1962	75	74	62	54	71	69
May 1963	79	87	65	57	81	79
August 1963	95	95	68	62	95	91
October 1963	96	108	76	65	98	91

Figure A-7. Growth of Petromyzon marinus ammocoetes in Venison Creek during the year 1960-1961 (Thomas 1963).

Figure A-8. Total growth of Petromyzon marinus ammocoetes in Venison Creek (Thomas 1963).



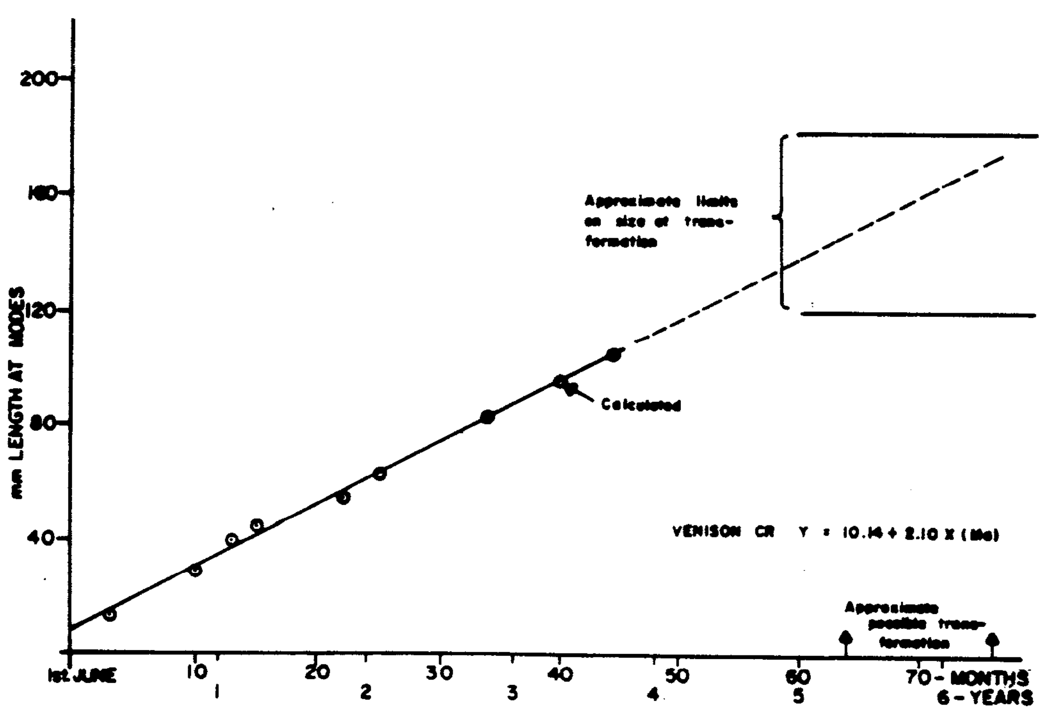


Table A-14. Mean length (mm) and range of 10 groups of the 1976 year class of sea lamprey caged in five streams in the Lower Peninsula of Michigan from May 1977 to October 1981 (Morman, In press).

Continued

		Jordan River						Manistee River					
		Group 1			Group 2			Group 1			Group 2		
		Length			Length			Length			Length		
Date	Age	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range
May 1977	I	25	25	20-33	75	29	18-48	25	41	34-48	75	42	27-58
Oct. 1977	I	24	61	52-71	71	57	44-81	24	64	43-79	65	61	39-77
May 1978	II	24	72	58-84	62	66	50-107	24	69	46-81	65	66	40-100
Oct. 1978	II	24	106	94-117	61	93	74-127	24	79	61-94	51	77	61-97
May 1979	III	24	109	97-123	50	95	78-129	0[a]/	-	-	49	76	62-85
Oct. 1979	III	24	134	123-147	43	109	92-137	-	-	-	40	96	85-112
May 1980	IV	24	134	125-146	43	105	90-138	-	-	-	39	92	E1-107
Oct. 1980	IV	24	145	132-159	40	116	103-143	-	-	-	26	91	84-102
May 1981	V	24	146	136-159	40	118	102-144	-	-	-	26	93	86-102
Oct. 1981	V	23 (1)	153 145	143-165	39	126.	114-151	-	-	-	18	102	94-109
		(transformed)											

Table A-14 (Continued from above)

White River						Sturgeon River						Rifle River					
Group 1			Group 2			Group 1			Group 2			Group 1			Group 2		
Length			Length			Length			Length			Length			Length		
N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range
25	54	42-66	75	55	44-72	25	30	23-37	75	28	19-34	25	53	39-70	75	52	36-65
25	93	80-103	72	80	67-94	25	63	52-70	69	52	31-58	24	90	79-108	75	79	65-96
25	108	100-118	72	84	74-97	25	66	55-73	63	55	45-65	24	101	89-120	52	84	70-97
25	124	110-134	64	86	71-100	19	75	67-84	62	65	58-75	5[a]/	107	97-119	52	84	69-97
25	122	104-133	64	86	68-101	10	75	66-81	62	66	59-75	5	115	103-125	41	84	74-99
25	130	110-144	57	98	82-111	5[a]/	83	72-90	46[a]/	71	63-91	5	133	115-150	5[a]/	107	102-113
24	124	105-137	56	95	79-107	5	83	72-91	42	68	62-90	10[b]/	125	106-149	-	-	-
24	123	105-134	52	96	81-111	5	105	96-115	42	89	E1-103	10	141	126-159	-	-	-
23	134	120-143	51	103	86-113	5	113	103-124	40	95	77-111	10	144	133-156	-	-	-
19 (4)	144 137	133-154 133-143	51	109	92-119	5	132	125-140	39	106	91-118	8	758	148-166	-	-	-
(transformed)																	

[a]/ Cage vandalized, loss of larvae

[b]/ Remnants of groups 1 and 2 combined in 1 cage in October 1979.

Figure A-9. Mean growth relationship between two different density populations of the 1976 year class of sea lamprey larvae caged in each of five streams in the Lower Peninsula of Michigan, May 1977 - October 1981. Initial population density was 25 in Group 1 (solid line) and 75 in Group 2 (broken line) (Morman 1987, In press).

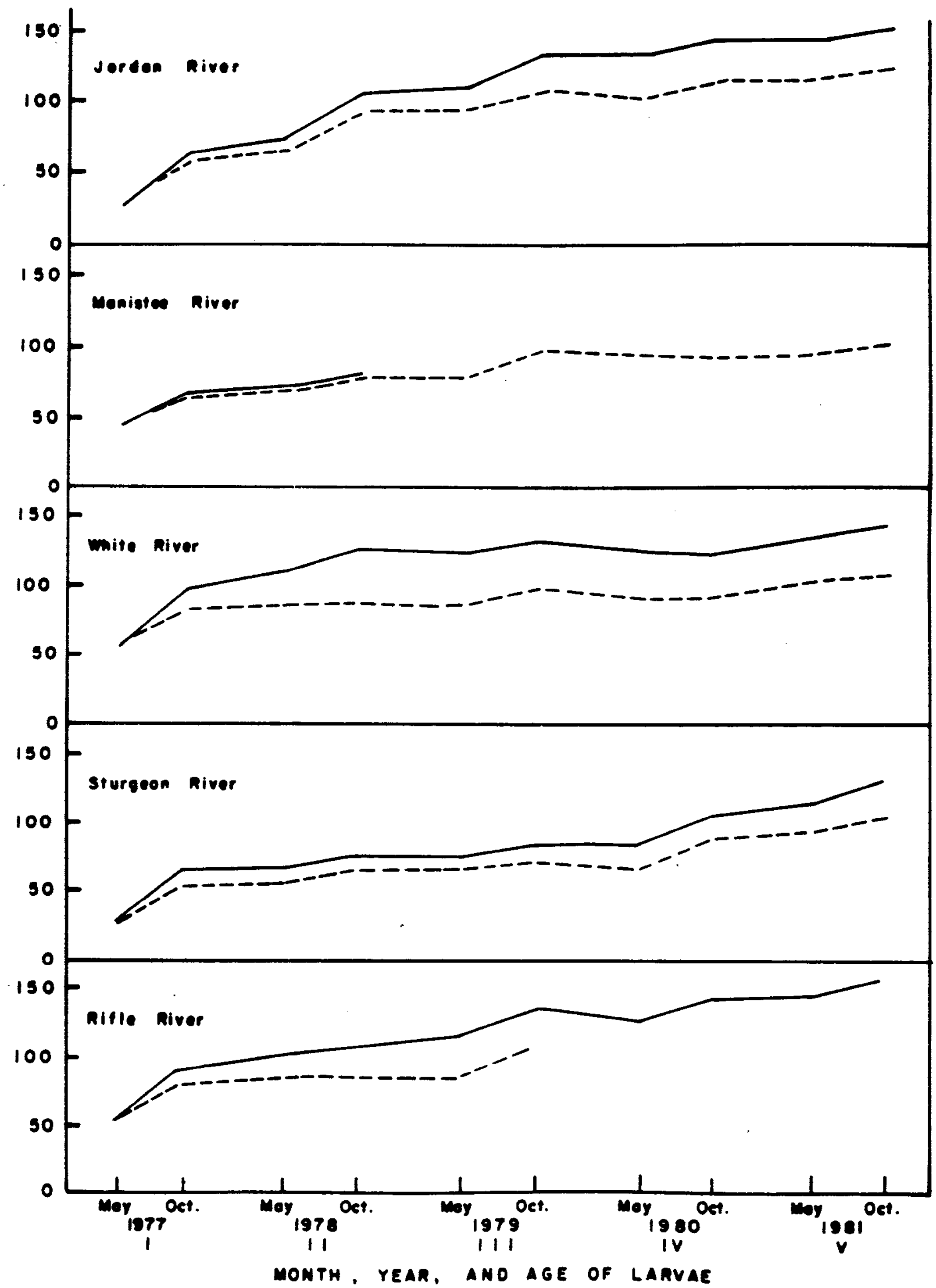


Table A-XV. Mean growth increment (mm) of low and high density groups of sea lamprey larvae held in cages in five Michigan streams, May 1977 to October 1981. Percentage of total increment in parentheses. (Morman 1987, In press).

		Jordan River		Manistee River		White River		Sturgeon River		Rifle River	
Season[a]/	Age	Low density	High density	Low density	High density	Low density	High density	Low density	High density	Low density	High density
Summer 1977	I	36 (28)	28 (29)	23	19 (32)	39 (43)	25 (46)	33 (32)	24 (31)	37 (35)	27
Winter	I-II	11 (8)	9 (9)	5	5 (8)	15 (17)	4 (7)	3 (3)	3 (4)	11 (11)	5
Summer 1978	II	34 (27)	27 (28)	10	11 (18)	16 (18)	2 (4)	9 (9)	10 (13)	6 (6)	0
Winter	II-III	3 (2)	2 (2)	-- b/	-1 (0)	-2 (0)	0 (0)	0 (0)	1 (1)	8 (8)	0
Summer 1979	III	25 (20)	14 (14)	--	20 (33)	8 (9)	12 (22)	8 (8)	5 (6)	18 (17)	23
Winter	III-IV	0 (0)	-4 (0)	--	-4 (0)	-6 (0)	-3 (0)	0 (0)	-3 (0)	-8 (0)	--b,c/
Summer 1980	IV	11 (9)	11 (11)	--	-1 (0)	-1 (0)	1 (2)	22 (22)	21 (27)	16 (15)	--
Winter	IV-V	1 (1)	2 (2)	--	2 (3)	11 (12)	7 (13)	8 (8)	6 (8)	3 (3)	--
Summer 1981	V	7 (5) d/	8 (8)	--	9 (15)	10 (11) d/	6 (11)	19 (19)	11 (14)	14 (13)	--
TOTALS		128	97	--	60	90	54	102	78	105	--
Total increment in summers (%)		89	90	--	98	81	85	90	91	86	--

a/ Summer is May to October; Winter is October to May for this study

b/ Cage vandalized, loss of larvae

c/ Remnant larvae combined with those in low density cage

d/ Length data from metamorphosed lamprey not included

Table A-XVI. Differences in mean length (mm) between caged groups (low and high density) and wild populations of sea lamprey larvae in five Michigan streams. Length range (mm) of larvae in parentheses (Morman 1987, In press).

Stream	Age I (October 1977)			Age II (May 1978)		
	Low density	High density	Wild group	Low density	High density	Wild group
Jordan River	(52-71) N=24	(44-E) N=71	52,58,61,64[a]/ --- ---	(5 & 4) N=24	(50-107) N=62	---b/
Manistee River	(43-79) N=24	(39-77) N=65	79,80,86,89[c]/ --- ---	(4 & 1) N=24	(406-100) N=65	80,83,88,91,92[d]/ --- ---
White River	(80-103) N=25	(67-94) N=72	(62-96) N=26	108 (100-118) N=25	(74-97) N=72	(83-109) N-14
Sturgeon River	(52-70) N=25	52 31-58) N=69	(39-69) N=86	(55-73) N=25	(45-65) N=63	53,55e/ --- ---
Rifle River	(79-108) N=24	(65-96) N=75	(64-112) N=109	101 (89-120) N=24	(70-97) N=52	(73-118) N=84

a/ Based on data collected in 1970, 1974, 1975, 1976
b/ No data available
c/ Based on data collected in 1970, 1973, 1976, 1980
d/ Based on data collected in 1971, 1972, 1974, 1977, 1978
e/ Based on data collected in 1970, 1978

LARVAL AND TRANSFORMER MIGRATION

Larval sea lamprey actively migrate downstream, with a maximum movement in April and May, normally triggered by increasing water flows and temperatures (Manion and Smith 1978). Thomas (1963) comparing downstream migration of ammocoetes to temperature and flow, calculated a multiple regression significant at the 1% level, as follows:

$$Y = 8.21\ X_1 + 1.47\ X2 - 125.4$$

where Y = Monthly catch of *P. marinus*

X_1 = Mean monthly flow in cubic feet per second (cfs)

$X2$ = Mean monthly water temperatures in °F.

In the Big Garlic River, Manion and Smith (1978) observed that ammocoete migration was often active rather than passive, normally diurnal and that larger larvae were more likely to migrate than smaller larvae.' The most rapid migration of marked ammocoetes observed was 6.4 km in seven months, but marked migrating transformers negotiated 2.6 km in four days after release.

The downstream migration of transformed sea lamprey typically begins in late October and extends through the winter and spring, ending in early April (Applegate 1950). Observations from the Ocqueoc and Carp Lake River traps by Applegate led to the conclusion that migratory activity was closely associated with rising water levels. Of the 1960 year class of sea lamprey ammocoetes in the Big Garlic River (1960-72) the earliest transformed sea lamprey migrant was observed on September 9, 1968, and the migration continued into May of the following year. The heaviest downstream movement of metamorphosed lampreys in the Big Garlic River was from September to December, averaging 95% (range 91 - 98) of the total migration. An average of 42% (range 30 - 68) of the total fall catch (September to December) of transformed lampreys migrated in one overnight period (Manion and Smith 1978). These observations are not consistent from stream to stream and the Carp Lake River, Emmet County, Michigan, had a downstream migration of sea lamprey characteristically greater during late March and early April (1948-51). Migration of transformed animals began as early as September 22, 1950 and extended as late as May 31, 1950 and 1951. During the 1949-50 migration season less than 5% of the transformers were collected during the fall (September to December) while 23% of the catch was recorded on April 4, 1950, and 15% on March 26. Coinciding with unusual flooding from April 18 to 21, large numbers of transformers migrated downstream but they could not be trapped because of the flood conditions (Applegate and Brynildson 1952).

TRANSFORMATION/METAMORPHOSIS OF LARVAL SEA LAMPREY

Thomas (1963) assumed that a minimum of five years growth was required to reach transformation size based on observed larval growth in Venison Creek (Figure A-8). Transformation size was determined from transformer lengths measured in Stony Creek (a tributary of Big Creek, like Venison Creek) where the mean size of 64 transformed sea lamprey was 152.7 mm (range 120 - 180).

On October 7, 1983 during a lampricide treatment of the Big Garlic River a population estimate of the larval sea lamprey over 120 mm was conducted (Heinrich 1983). The sea lamprey present in the stream were considered to be all progeny from sterile male studies conducted in 1974, 1976 and 1977, thereby having an estimated' age of 6.5 to 9.5 years. The stream was divided into zones and representative sections from each -zone were selected for population estimates by the mark-recapture method. The total population of sea lamprey was estimated at 91,007 (95% confidence limits 73,106 to 113,595) of which 33% (30,032) were greater than 120 mm in length. Only one transformer was collected from a total of 8,747 unmarked sea lamprey during the stream treatment.

Applegate (1950) found the mean length of 749 transformed sea lamprey from Ocqueoc River to be 136.4 mm (range 111 - 193), and that 2,482 individuals from the Carp Lake River to be 143.6 mm (range 95 - 189). The average weight of 216 transformers from Carp Lake River was 4.1 g (range 2.3 - 8.4). Transformed sea lamprey from Carp Lake River subsequently sampled from 1948 to 1959 (Applegate 1961) had a mean length of 146.4 mm (range 95 - 243) from a total of 15,110 animals. Mean weight of 1,526 transformers was 4.5 g (range 1.8 - 9.8).

Transformers from the Big Garlic River, 1965 - 72 averaged 147 mm (range 116 - 193) and 4.7 g (Manion and Smith 1978). The length-weight relationship calculated after conversion to logarithms was:

$$\text{Log10 } w = -2.99 + 2.62 \text{ Log10 } L$$

where L = total length in millimeters, and

W = weight in grams

Potter et al. (1978) calculated a "condition factor" for transforming anadromous sea lamprey as follows:

$$\text{Condition Factor} = W/L^3 \times 10^6$$

where; W = weight in grams, and

L = length in millimeters

For transforming sea lamprey larvae collected from Dennis Stream, a tributary of the St. Croix River in New Brunswick, condition factors were calculated for stages 1 to 7 (Youson and Potter 1979). The mean condition factor for larvae of metamorphosing length was 1.46, compared to values of 1.62 and 1.32 for metamorphosing stages 1 / 2 and 7, respectively. Stage 7 animals were collected during the month of November. A sample of 84 landlocked sea lamprey from Fish Creek, New York, held in the Sea Lamprey Control Centre's facilities at Sault Ste. Marie, Ontario, until transformation was complete, were measured and weighed on November 1, 1983 and a condition factor of 1.33 was calculated. The mean length was 137.2 mm (range 116 - 176) and the mean weight was 3.44 g (range 1.86 - 6.74). It has been suggested by Youson (personal communication) that calculations of a condition factor in the spring could identify those sea lamprey which would metamorphose the following fall.

SUMMARY OF RESPONSES TO QUESTIONNAIRE

A questionnaire was sent to 99 selected people concerned with fisheries and the impact of sea lamprey on them, to solicit comment on the biological and statistical information required from the lamprey control agents.

Responses to this questionnaire indicated several measures of larval populations considered to be important:

1) estimates of the numbers of transformed sea lamprey being recruited to 'the lake from;

   a) reestablished stream populations,

   b) residual stream populations,

   c) lentic populations,

   d) known but untreated larval populations,

   e) unknown populations.

2) calculation of the "condition factor" for large larvae in the spring to define potential transformers;

3) evaluation of year class strengths in individual larval populations; and

4) evaluation of numbers and/or densities in given population of larval sea lamprey.

Several suggestions were presented to define the accuracy of measures described above:

1) "index" stations should be established for all streams regularly treated with lampricide;

2) larval populations should be sampled and evaluated at age three;

3) mark-recapture techniques should be routinely used to estimate populations from the streams which are to be chemically treated and have "index" stations established on them;

4) interpretive standards are required to compare the sampling efficiencies of backpack shockers and granular Bayer 73 in terms of their abilities to evaluate population of larvae;

5) electronic data processing should be standardized and used extensively by the agents for analyzing data; and

6) all larval lamprey should be measured to the nearest mm.

Suggestions for improving sampling techniques or assessment methods included:

1) improved efficiency of backpack shocker to collect large ammocoetes under various water conditions;

2) improve deep water sampling techniques; and

3) develop reliable comparative techniques by utilizing computers and statistical models to analyze time-series data collected from surveys and chemical treatments.

Interpretation of data collected from surveys and treatments to predict the impact of sea lamprey on fish populations could be improved by:

1) predicting the annual recruitment of transformed sea lamprey from all known larval populations;

2) estimating mortality levels of larval sea lamprey;

3) defining the relationship between numbers of transformers produced and numbers of adults surviving to spawning phase; and

4) identifying stream characteristics which encourage successful colonization by sea lamprey.

Several questions were raised by people responding which related to the need for population estimates:

1) would population estimates provide more information than already available and how would this information be used?;

2) is the high cost of estimating sea lamprey numbers justifiable?;

3) is the control program conducting population estimates to evaluate what. has been killed; to eliminate lamprey recruitment to the lake, or to manage defined numbers of lamprey being recruited to the lake?;

4) in terms of personnel and budgeting, is it necessary to define larval lamprey numbers except in a few isolated cases?; and

5) are sea lamprey populations affected by current land-use practices?

GROUP RECOMMENDATIONS

After considering the information generated by the control agents and other investigators as previously summarized, and after reviewing the answers to the questionnaire, we have reached the following recommendations.

Recognizing that the control agents need improved sampling equipment and/or techniques for deep water habitats, we encourage the efforts of the laboratories at La Crosse, Wisconsin and Hammond Bay, Michigan to develop slow release antimycin, salted TFM solutions and TFM pelleted formulations; and recommend that Don Allen's study of a deep water electroshocking trap for sampling larval lamprey populations be continued. The Group also encourages the efforts of the submersible electrofishing study proposed for Batchawana Bay and hopes that this study will help define the parameters of the larval population in the bay and the potential for transformation. The continuing efforts of the control agents to improve the efficiency of the backpack electrofisher for collecting those larvae over 100 mm must be continued to provide reliable sampling from larval populations in streams. These sampling tools are necessary to precisely define larval populations, especially in the deep water habitat of lakes, estuaries or bays where density levels may be low and cold waters preclude the effective use of granular Bayer 73.

We emphasize that there is a need to standardize procedures, terms and definitions between the two agents; for example, the terms "scarce", "moderate", and "abundant" as applied to larval populations by the control units will remain ambiguous for use in evaluation until precisely defined. We recommend that "index" stations be established for streams that regularly produce sea lamprey larvae and standardized sampling techniques be based on collection effort and numbers of animals collected. Surveys of these "index" stations should be supplemented by additional studies to define larval population parameters, and by regular mark-recapture (Petersen) estimates of the larval populations.

Surveys should be scheduled for late summer or fall (especially for those streams considered to be heavy producers) one year prior to the earliest predicted transformation to evaluate age class strengths and transformation potential. Whenever possible, late summer and fall treatments of the highly productive streams should be conducted to verify the survey data and the presence of transforming sea lamprey.

An objective sampling technique is necessary to evaluate the results of granular Bayer 73 surveys and treatments in lotic or lentic waters. It is recommended that a boat be equipped with a push net similar to those described by Miller (1973) or Kriete and Loesch (1980) and that tests be conducted to evaluate larval lamprey populations based on boat speed, collecting time and mark-recapture procedures.

The statolith aging technique (Volk, Unpublished) should be studied further for confirmation of its validity. Statoliths from a single age group reared in captivity under normal stream-temperature fluctuations could be compared with those from a control held at a constant temperature and from several natural populations reestablished after chemical treatment and sampled at least biannually until transformation. An exhaustive study should also be conducted to evaluate this aging technique (utilizing statoliths) for adult sea lamprey.

It is recommended that less labour intensive methods than fyke nets or wolf traps for capturing downstream migrant sea lamprey be developed, for example modifications to the methods utilized to sample salmon smolts.

We perceive that the greatest need is to determine where transformed sea lamprey are produced and the numbers entering the lake system from each area. The deep water areas of lakes such as Helen Lake, estuarine habitats such as Byng Inlet, or bay areas such as Batchawana and Mississagi Bays have the potential for harbouring large numbers of larvae. Density patterns may be very deceptive when evaluating the total population size or the numbers of transformed sea lamprey produced annually from these sources. Concerted efforts should be directed towards accurately estimating these deep water populations and the numbers of transformed sea lamprey produced from them.

PROPOSAL NO. A-1

USE OF THE REMOVAL METHOD TO ESTIMATE POPULATIONS OF SEA LAMPREY LARVAE AND TRANSFORMERS

INTRODUCTION

Although population estimates of sea lamprey larvae have been made in the past utilizing the mark and recapture method, most were accomplished using methods other than strictly electrofishing to collect specimens. Most of the mark-recapture studies of larval lamprey populations utilizing electrofishing equipment, have been done with battery powered backpack shocker units specifically designed to collect larvae. The effectiveness of these shocker units is limited to depths of less than the wand length (1 m). Other factors which limit the effectiveness of the backpack units are excessive turbidity and/or flow characteristics at sampling stations in some streams and the low voltage output (115V DC). We describe here methods and techniques whereby sea lamprey transformers can be effectively sampled so that their populations can be estimated using the removal method.

BACKGROUND

During routine electrofishing operations conducted as part of yearling Atlantic salmon assessments on tributaries of the Connecticut River, U.S. Fish and Wildlife Service (USFWS) personnel have utilized a gasoline operated electro-fishing unit mounted in an aluminum canoe. When used with two wands (anodes) this unit is very effective in immobilizing the swift-swimming juvenile salmon typically found in riffles of moderate depths (50 to 75 cm). In slow moving current of these depths the effective radius of the shocker is from 1.2 to 2.4 m. The power output of this unit consists of two options: 250V DC, which is used in hard waters, or 500V DC which is used in waters having low conductivity. Operation of this electrofishing unit with two wands splits in half the voltage output to each anode. The cathode consists of either a copper wire mesh screen or the aluminum canoe itself.

From the commencement of involvement of the USFWS with sea lamprey assessment on Lake Champlain in 1975 to 1980, standard "Harris" type backpack shocker units were used in stream surveys. Starting in late summer of 1980, efforts were made to evaluate transformer production in the major sea lamprey stream on the Vermont side of Lake Champlain, Lewis Creek. Because of the limitations of the backpack units, the canoe-mounted electrofisher described previously was tried on *a* slow-moving riffle section having a mixed substrate of sand and fine gravel. The results were surprising. Both large ammocoetes (>100 mm) and transformers were effectively stimulated to leave their burrows and once free of the substrate, were easy targets to capture with scap nets. Because of the length of the wand (1.5 m) and anode ring (diameter 40 cm) an extensive area of stream bottom could be energized to making long sweeping motions (lateral distance of the motion generally ranged from 1 to 3 m).

Efficiency Comparison with Backpack Unit

Generally the canoe-mounted electrofisher was determined to be from 3 to 5 times more effective (in terms of the number of large ammocoetes ortransformers collected) than the backpack shocker in conditions where the battery powered units were operable. In most cases where heavy concentrations of large ammocoetes and pre-transformers were found (primarily in mid-stream) the backpack shocker units had limitations, in that the area energized was too small to prevent the escapement of larvae-swimming at distances greater than 0.61 m from the anode. To make a valid population inventory of lamprey larvae in a relatively large sampling area, capture efficiency must be maximized. In typical transformer habitat the large shocker unit was generally able to energize an area extending from 2 to 3 m from the anode (depending on the conductivity of the waters shocked). Probably ammocoetes and transformers directly under the anode were immobilized by the current, however this factor was compensated for by swift movements of the anode in a generally rectangular pattern (1 to 3 m laterally and 1 m longitudinally). These broadly rectangular movements of the anode appeared to stimulate the larvae to leave their burrows and once free of the substrate the lampreys were momentarily immobilized by the current where they could be quickly netted.

Where streams were excessively turbid, the capture of ammocoetes was not efficient, however the capture of transformers was quite effective. Observations on the behaviour of ammocoetes which have been shocked generally have shown that in areas having some noticeable current, most of the animals typically drift along the bottom with a lateral "rolling" motion. The behaviour of transformers exposed to the electrical field of the shocker unit was quite different. In almost all cases the transformers quickly swam to the surface and with rapid snakelike swimming motion headed away from the anode. In situations where the transformers reached the stream banks , generally they attempted to seek cover in grass or woody debris commonly found in those locations. Few transformers were observed attempting to re-burrow into the stream substrate. Even in situations where the transformers were able to slip past the shocker crew, many were captured after being observed swimming along the surface at distances of 5 to 10 m downstream of the operation. After the sampling area had been electrofished, a sweep of the anode along either stream bank normally. resulted in the capture of several transformers hiding in the shallows.

The Problem of Sampling in Pools

The sampling of deep pools poses a serious problem to investigators attempting a total stream population inventory. The application of granular Bayer 73 would be a way to make collections in pool areas, however the variability of the application and collection efficiency could cause serious errors in making a population estimate. For example some larvae may receive an insufficient dose of the chemical to cause them to leave their burrows, 'while others may die before they can swim to the surface.

An approach that has been used with success in deep pool situations is to attach a float to the positive wand of the canoe mounted electrofishing unit and remotely drag the anode slowly through the pool, with people equipped with scap nets stationed around the perimeter (Figure A-10). Because sea lamprey transformers tend to surface, they are easy to spot and capture. This technique used repeatedly in pool areas has resulted in the collection of large numbers of transformers from deep pools in several Lake Champlain tributaries.

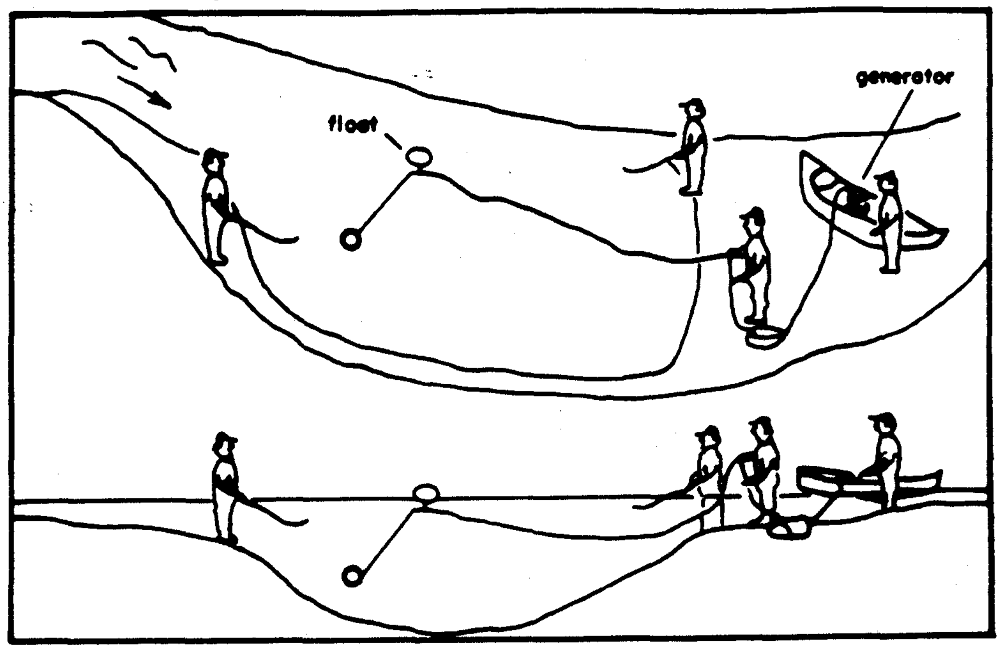


Figure A-10. Methodology for effectively sampling sea lamprey transformers in deep pool habitat.

OBJECTIVES

1) Examine the usefulness of making population estimates of sea lamprey larvae using the removal method versus the Petersen mark and recapture estimate.

2) Outline the statistical approach and the methodology to be used in estimating the total population of sea lamprey, transformers in a tributary, using Lewis Creek of Lake Champlain as an example.

3) Determine if the method and materials used in estimating the population of sea lamprey transformers in a tributary of Lake Champlain can be used with acceptable accuracy in tributaries to the Great Lakes.

PROCEDURES

1) Compare the efficiency and effectiveness of the removal method with the standard mark and recapture techniques for estimating populations of larval sea lamprey.

2) Divide the sea lamprey inhabited portion of Lewis Creek 15.2 km into three study zones based upon changes in the character of the gradient as measured along the longitudinal stream profile as follows:

   Zone I — High gradient upper section below barrier

   Zone II — High to moderate gradient middle section

   Zone III — Low gradient lower section down to lake level

3) Conduct a habitat survey on each section of Lewis Creek accessible to sea lamprey spawning adults categorizing the stream sections into seven water types which form the basis for evaluating spawning habitat, larval habitat, transformer habitat, and non-usable habitat (i.e., rock ledges, etc.) and estimating the total area of the habitat types in each section.

4) During the period August 1 to September 15, utilizing electrofishing equipment, estimate the transformer population in each section by the removal method which generally requires a minimum of three passes throughout the study areas for the development of a regression curve from which an estimate can be made.

   Generally it has been found that, in areas with high population levels, one hour should be spent shocking during the initial period as well as subsequent periods in order to obtain a regression line. In areas having a moderate to low density of transformers the shocking interval can be reduced to one-half hour.

   In making population estimates of transformers it is best to wait until the first of August by which time the early manifestations of metamorphosis (enlargement of the eye, etc.) are present in virtually all larvae which will transform in that year.

Background on Removal Versus Mark and Recapture Methods of Population Estimation

Because of the costs in time and effort required in making assessments of lamprey larval populations using dye marks in standard mark and recapture estimates, other proven methods of estimating population size, including those involving the removal of a proportion of a population of fish on a catch per unit effort basis, were tried. The most successful method involved collecting lampreys in a series of sampling efforts of equal duration until the catch per unit effort (which is considered to be proportional to the population of lampreys present) was noticeably reduced.

The removal method relies on the fact that the decline in the catch per unit effort as the population is reduced bears a direct relationship to the extent of the reduction. Use of this method requires that a significant proportion of the lamprey population must be removed during each sampling effort as the precision of the estimate varies with the slope of the regression of catch per unit effort on the accumulated catch or effort.

METHODS

In mid-September 1983, an electroshocking survey to inventory sea lamprey transformers was conducted on a riffle area of the lower portion of Lewis Creek (tributary of Lake Champlain). The purpose of the survey was to:

1) collect transformers to develop catch per unit effort (CPE) data as an index of population densities, and

2) using mark and recapture techniques, attempt to make an estimate of the sea lamprey transformer population in the section, and

3) attempt to make an estimate of the transformer population using the depletion method, and compare the results with the Petersen mark and recapture estimate.

Two methods of computing the results were compared to determine the method most adaptable and efficient for our particular applications: the Leslie Method (Leslie and Davis 1939) and the DeLury Method (LeLury 1947). The Leslie Method involves plotting, over a period of successive sampling efforts, the CPE against the cumulative catch. In the DeLury Method the logarithm of CPE is plotted against cumulative effort. From the straight line fitted to the data in both methods the initial population of lampreys can be estimated.

The initial application of the removal method on sea lamprey transformers was made in a slow-moving riffle section in the lower portion of Lewis Creek during late September 1983. Since the accuracy of the removal method of estimating larval lamprey populations was unknown, a concurrent experiment whereby a group of 56 sea lamprey transformers were collected, dyemarked and released back into the study area a week prior to the removal survey, was conducted. On September 30 a survey was made to recapture as many transformers dyemarked the previous week as possible. The unit of sampling effort (shocking time) was a one-half hour period which was to be repeated until the catch dropped off significantly.

RESULTS

(a) Field Collections

After the first sampling period in which 41 sea lamprey transformers were captured, the catch rate dropped off dramatically during each of the successive shocking periods as follows: 24, 15, and 8. During the last sampling period no transformers were seen or captured (Table A-XVII).

A total of 88 sea lamprey transformers were collected during the five sampling periods including 40 of the original 56 which had been dyemarked during the initial survey on this stream section. Using the Chapman modification of the Petersen mark and recapture method, the population of transformers in the study section was estimated to be 124± 28.

Table A-XVII. Results of sea lamprey transformer electrofishing recapture survey conducted on a riffle section in the lower portion of Lewis Creek in September 1983.

Shocking Period		NUMBER OF SEA LAMPREY TRANSFORMERS Dye Marked	Unmarked	Total No. marked and unmarked
	1st half hour	21	20	41
	2nd half hour	12	12	24
	3rd half hour	4	11	15
	4th half hour	3	5	8
	5th half hour	0	0	0
Totals	2.5 hours	40	48	88

(b) Mathematical Treatment

Using the Leslie Method (format and computations shown in Table A-XVIII) the original population was estimated at 100 transformers, whereas the DeLury Method estimated the population at 107 (Table A-XIX). Although the computed estimates derived from the removal method were low when compared to the Petersen estimate they were within the fiducial limits of that estimate.

Concerning the Leslie Method, Table A-XVIII shows the catch taken during one-half hour unit, and cumulative catch taken to the start of the interval plus half of that taken during the interval. By replacing K_t values by X and Ct values by Y, and using symbols of Snedecor (1946) for formulae for the squares, products and regression statistics, the regression analysis uses CPE as the dependent variable (Y) and accumulated catch as the independent variable.

Regarding the DeLury Method, Table A-XIX shows shocking effort in one-half hour units f_t, cumulative effort to the halfway point of each successive time interval E_t, CPE each time interval (Ct/ft), and the natural logarithm of the latter $LOG_e(C_t/f_t)$. This latter expression is regressed against Et to obtain the regression equation.

A comparison between the mark and recapture method and the removal method reveals several important points. With marking experiments a considerable measure of time is spent handling the animals including anesthetizing, marking, and sorting dead or injured specimens. Reintroducing them to suitable embedding habitat so they remain in the study section is also important and takes time. Later a recapture survey with many of the time consuming activities as the marking run (except dyemarking) must be made.

DISCUSSION

With the removal method, back to back capture techniques must be repeated on the population in a single day until a definitive drop in the catch rate is recorded. Except for anesthetization (for tallying purposes) of the specimens, there need not be additional handling time costs. Specimens collected during each unit of effort can be kept separate and then preserved and labeled to undergo further analysis under laboratory conditions. The survey crew is free to proceed immediately to the next sampling location. Under most conditions two, and in some cases three, sites could be surveyed per 8-h work day.

Table A-XVIII. Catches and fishing effort for the September 1983 sea lamprey transformer electroshocking survey using the Leslie Method of population estimation which relates fishing success to catch. 1/

SHOCKING RUN	C_t Y	$C_t/2$	K_t X	XY	$(X)^2$	$(Y)^2$
			CATCH AND EFFORT FIGURES			
1	41	20.5	20.5	840.5	420.25	1.681
2	24	12	53	1,272	2,809	576
3	15	7.5	72.5	1,087.5	5,256.25	275
4	8	4	84	672	7,056	64
Σ	88	230	3,872.0	15,541.5	2,596	
Σ^2	7,744	52,900				

Symbol explanations are as follows:

- NO Original population size
- C_t Catch taken during time interval $_t$
- Kt Cumulative catch to the start of interval $_t$ plus half of that taken during the interval
- X As used in formulae below, same as Kt
- Y As used in formulae below, same at C_t

$\Sigma xy = (\Sigma XY) - (\Sigma X)(\Sigma Y)/n = -1,188.0$

$\Sigma y^2 = \Sigma(Y^2) - (\Sigma Y)^2/n = 660$

$\Sigma x^2 = \Sigma(X^2) - (\Sigma X)^2/n = 2,316.5$

Slope $= b = \Sigma xy/\Sigma x^2 = -0.51284$

Y intercept $= a = (\Sigma Y - b\,\Sigma X)/n = 51.488$

The REGRESSION EQUATION in the original symbols, becomes; $C_t = 51.488 - 0.51284\ K_t$

THE ESTIMATE OF THE POPULATION IS $N_o = a/b = 100.4$ (i.e. 100)

1/ From Ricker, W. E. 1975, pages 151-153

Table A-XIX. Catches and fishing effort for the September 1983 sea lamprey transformer electroshocking survey using the DeLury Method of population estimation which relates fishing success to effort. 1/

SHOCKING RUN	C_t	f_t	E_t	C_t/f_t	LOGe(Ct/ft)
			CATCH AND EFFORT FIGURES		
1	41	1	0.5	41	3.7136
2	24	1	1.5	24	3.1781
3	15	1	2.5	15	2.7081
4	8	1	3.5	a	2.0794
TOTALS	88	4			

Symbol explanations are as follows:

- N_o Original population size
- C_t Catch taken during time interval t
- f_t Fishing effort during time interval t
- E_t Cumulative catch up to the start of interval t, plus half of that during the interval
- C_t/f_t As used in formulae below, same as K_t

*NOTE LOGe(Ct/ft) is regressed against E_t to obtain the regression equation

THE REGRESSION EQUATION IS $LOG_e(C_t/f_t) = 4.0615 - 0.54395E_t$

THE ESTIMATION OF THE POPULATION IS

$$_{NO} = \text{ANTILOG, } 4.0615 / 0.54395 = 58.063 / 0.54395 = 106.7 = 107$$

1/ From Ricker, W. E. 1975, pages 151-155

SAMPLING SCHEDULE, MANPOWER REQUIREMENTS AND COSTS

SCHEDULE	TIME	ACTIVITY
July	3 days	Stream Habitat Survey
Mid-july	1 day	Pre-Estimate Surveys
Late July - mid-September	5 days	Population Estimates

MANPOWER	MAN DAYS	COST U.S. DOLLARS
1 biologist	19	2,200.
2 technical personnel	40	3,000.
TOTAL	49	5,200.

EQUIPMENT	
13 ft. Aluminum canoe	450.
Portable gasoline powered generator	1,000.
Miscellaneous equipment Water proof switches, gloves electrical cord, nets, pails, jars	250.
Lodging 7 days x $50/day	350.
Vehicular costs-fuel and oil	125.
TOTAL	2,275.
ALL COSTS	$7,375.

Approaches Used to Implement Sea Lamprey Transformer Population Estimates on a Stream Wide Basis

Habitat characteristics based upon gradient and substrate types in Lewis Creek

Generally most Lake Champlain streams, including Lewis Creek, have a longitudinal profile consisting of three different gradient types. The upper reaches typically are characterized by steep gradients and large substrate particle sizes. The lower reaches are areas of deposition having a low gradient, with small substrate particle sizes. The middle areas are typically zones of transition between the other two types characteristically having a moderate gradient and a substrate consisting of particles of intermediate size. In the Lake Champlain drainage basin the upstream distributional limits of larval populations in most sea lamprey producing streams is limited to the "fall line", a physiographic feature which marks the location of waterfalls in all rivers of moderate size and larger.

Although densities of sea lamprey transformers tend to be higher in the lower reaches of tributaries, they have also been found in suitable habitat a short distance below natural barriers and in suitable habitat elsewhere in the stream. In low gradient sand bottom streams characterized by meandering stretches of long pools alternating with shallow riffles, densities of transformers have been highly correlated with the swiftest flowing waters. In streams having long stretches of a low gradient nature with a few riffle breaks, the distribution of large ammocoetes and transformers follows a different pattern. In those streams a large percentage of the population resides in mid-channel sediment deposits or behind obstructions and in the sediment deposits along the inside meander bends. In some streams having beaver impoundments the main concentrations of transformers (as well as large ammocoetes) have been found to be associated with the outlet areas of the dams.

The results of electrofishing surveys for larval sea lampreys in various Lake Champlain tributaries had led to the development of a scheme of classification of water types to allow for the expansion of the results of habitat specific population estimates to a streamwide estimate.

Using the following scheme of habitat suitability, a density index can be assigned to each of the seven water types listed below:

Cascade: High gradient section characterized by water falls or whitewater stretches with a substrate of ledge or large boulders. <u>Lamprey habitat value: none</u>

Riffle: High gradient section characterized by turbulence with some whitewater, depths under 3 m with a substrate ranging in particle size from small gravel up to boulder size. <u>Lamprey habitat value: prime spawning habitat</u>

Run: Medium gradient section characterized by turbulent flow, depths over 3 m and substrate particle size ranging from sand up to mixed gravel/boulder combination. Sediment deposits restricted to areas behind large boulder or other obstructions to flow. <u>Lamprey habitat value: intermittent spawning habitat, larval habitat very limited</u>

Flat: Relatively shallow low gradient section at tail of pool where considerable deposits of silt and sand results in optimum habitat conditions for sea lamprey larvae. Lamprey habitat value: prime habitat for large ammocoetes (>100 mm) and pre-transformers

Glide: Relatively shallow (0.1 to 0.3 m) medium gradient riffle sections generally found only in the lower gradient stretches of streams. Substrate particle sizes generally ranging from mixed sand/fine *grave* to fine gravel. In many cases elodea beds are found associated with this water type. Lamprey habitat value: prime habitat for transforming sea lampreys

Pool: Deeper slow moving stretches of stream with depths generally between 0.5 and 0.75 m. Substrate particle size generally sand or sand/silt combination. Lamprey habitat value: good larval habitat along inside meander bend of pool and in sediment along edges of either bank

Deep Pool: Deep slow moving stretches of stream with depths greater than 0.75 m. Substrate particle size variable but generally sand or sand/silt combination. Lamprey habitat value: limited larval habitat within pool. (Difficult to assess due to water depth)

In stream having low densities of ammocoetes and transformers the relationship between habitat and transformer densities is less clear, although for the most part highest densities occur in the swifter flowing waters between pools. The first riffle area of these streams also contains the highest densities of transformers to be found in the stream.

Within pools in the lowland sections of streams, in many instances the distribution of large ammocoetes is restricted to a narrow strip of sediment accumulation 0.3 to 1.0 m in width along either bank. Electroshocking surveys conducted after mid-July have shown the vast majority (>80%) of the large ammocoetes and transformers inhabiting a typical lowland stream section habitat unit (which includes: pool-flat-glide) occur in the vicinity of the shallowest stretches of the unit, the flat-glide interface.

Greatest numbers of large (>100 mm) larvae are encountered in a band of habitat at the lower end of pools in a habitat type herein designated as a flat. This may be due to a combination of factors, among them accumulation of substantial consolidated sediment beds of a particle size preferred by larger larvae, concurrent with an increase in water velocity due to the gradual shallowing of the flat. The buildup of larval populations in these areas may be related to an increase in the water current velocity, which would allow for a higher carrying capacity of larvae in the sediment beds due to better oxygenation. Transformer populations are high in the downstream portion of the flat, although as a rule the majority are found in the fine gravels which occur in habitat found in the glide section.

In streams having long stretches of a low gradient nature, with few riffle breaks, the distribution of large ammocoetes and transformers follows a slightly different pattern. A much larger percentage of the population resides in mid-channel deposits or behind obstructions and in the sediment deposits along the inside meander bends.

Importance of Developing Population Estimates of the Transformer Stage Versus Ammocoetes

Because small-sea lamprey larvae can be found settled throughout a stream system and in very high numbers, it would be an almost impossible task to attempt to make population estimates including all age classes on a streamwide basis. Heimbach and Youngs (1982) targeted the production of transformers as being a most important parameter to measure. From our experience in making annual transformer surveys on Lake Champlain tributaries, we have found that during the months of July through September while sea lampreys are undergoing transformation and before emigration occurs, accurate population estimates can be made because of the tendency of the lampreys to congregate in certain definable habitat types within streams. Past experience in sampling transformers at the population levels at which they occur in Lewis Creek and elsewhere in the Lake Champlain basin gives us confidence that using the methodology discussed in this proposal, streamwide population estimates can be accomplished.

SAMPLING DESIGN

Sea Lamprey Transformer Population Inventory in Lewis Creek

It will be necessary to conduct a physical survey of the portion of the stream system accessible to sea lampreys so that the areas sampled can be used as a basis for the calculation of complete population estimates. The survey must include total length and total areas of water types (pool, riffle, etc.).

Because of the tendency of large ammocoetes and transformer populations to collect in the lower reaches of streams, the system of stratified random sampling would be more appropriate than simple random sampling where each unit has an equal and independent chance of being selected. In stratified random sampling the' stream is divided into subpopulations and a simple random sample of at least two units is selected from each subpopulation. In the following example of stratified random sampling in Lewis Creek, the stream is divided into three sections or zones based upon the longitudinal profile where three distinct gradient types have been identified.

During survey work conducted on Lewis Creek since 1978 all riffles/glides and pools have been documented and their respective areas roughly estimated. These surveys provide the data background for the following exercise.

Methodology for Breakdown of Sea Lamprey Transformer Habitat in Lewis Creek

Total Area of Stream

A rough estimate of the total area of the sea lamprey inhabited portion of Lewis Creek has been calculated at 23.19 acres. This can be broken down in turn by zones as follows:

Upper high gradient section	Zone 1	1.86 ha
Middle moderate gradient section	Zone II	2.87 ha
Lower low gradient section	Zone III	4.65 ha

Area of Transformer Habitat

Of the sea lamprey transformer habitat (pools and, glides) the breakdown is as follows:

Zone I	0.37 ha
Zone II	0.56 ha
Zone III	3.80 ha

Approximately equal areas of pool versus glide habitat are found throughout the stream thusly the breakdown by habitat type is:

	Pools	Glides
Zone I	0.19 ha	0.19 ha
Zone II	0.23 ha	0.23 ha
Zone III	1.90 ha	1.90 ha

Number of Samples Needed

In planning a survey of this type, the formula used in calculating the necessary sample size requires that an estimate of the standard deviation of the population be made. Because of the wide variability in the catch rates in pools versus glides, sampling in each subpopulation will be necessary. This was accomplished by using previous transformer catch data from 14 glide water type survey sections, and six pool water type survey sections throughout Lewis Creek.

Data pertinent to the glide surveys include:

Number of sections	n = 14 sample units
Mean catch (transformers)	x = 23.07
Standard deviation	s = 11.47

These data reflected only one unit of electroshocking effort (one-half hour). However population estimate data for several of the sections yielded probability of capture estimates of 0.5. Using this correction factor, the transformer catch data when multiplied by two yielded "rough" estimates of population size. The revised data from the sections are as follows:

n = 14
x = 46.14
s = 22.94

A formula for calculating the required sample size (sampling units) for random sampling can be expressed as:

$$n = \left[\frac{(t)(CV)}{SE\%}\right]^2$$

where the standard error of the mean (SE) is expressed as a percent of the mean and t is from the table of t values. Using the above catch data, the coefficient of variation CV is calculated from:

$$CV = \frac{s}{\bar{x}}(100) = \frac{22.94}{46.14}(100)$$

Where: s = standard deviation

$\bar{x}$ = sample mean

EXAMPLE
Determination of number of samples required in the Stream Zones I to III inclusive, glide habitat only:

Determine the number of samples needed to estimate the population mean within ±20 per cent at a probability level of 0.80. In other words, the desired half width of the confidence interval is specified as 20 per cent of the mean. From a table of t values [infinite degrees of freedom (df)] and a probability of 0.2, the t value is 1.282.

Therefore the total number of sampling units required to achieve the specified precision from an infinite population is:

$$n = \left[\frac{(t)(CV)}{SE\%}\right]^2 = \left[\frac{(1.282)(50)}{20}\right]^2 = 10.3 = 11$$

However since the sampling is from a finite population (a limited number of sampling units in the stream) a finite population correction factor can be applied as follows:

$$nf = \frac{n_i}{1 + ni/N}$$

Where nf = required sample size from finite population
ni = sample size calculated from infinite population
N = population size (total number of sampling units available (calculated from total area of glide habitat divided by 5,000 ft^3 (plot size 50 by 100 ft).

Substituting in the formula we have:

$$nf = \frac{11}{1 + 11/41} = 8.7 = 9 = \text{samples required}$$

EXAMPLE
Determination of number of samples required in the Zones I to III inclusive, pool habitat only:

Determine the number of pool samples needed to estimate the population mean within l 20 per cent at a probability level of 0.80. In other words, the desired half width of the confidence interval is specified as 20 per cent of the mean. From a table of t values [infinite degrees of freedom (df)] and a probability of 0.2, the t value is 1.282.

Data pertinent to the pool surveys include:

Number of sections	n = 6 sample units
Mean catch (transformers)	x = 6.67
Standard deviation	s = 3.56

These data reflected only one unit of electroshocking effort (one-half hour). As in the glide sections mentioned previously, population estimate data for several of the sections yielded probability of capture estimates of approximately 0.5. Using this correction factor, the transformer catch data when multiplied by two yielded "rough" estimates of population size. The revised data from the sections are as follows:

$$n = 12$$
$$x = 13.3$$
$$s = 7.12$$

As in the previous case, the coefficient of variation (CV) is calculated as:

$$CV = \frac{s}{\overline{x}}(100) = \frac{7.12}{13.3}(100)$$

The calculation of the sample sizes for the pool sections as determined in the glide sections above is as follows:

$$n = \left[\frac{(t)(CV)}{SE\%}\right]^2 = \left[\frac{(1.282)(53)}{20}\right]^2 = 11.5 = 12$$

Once again since the sampling is from a finite population (a limited number of sampling units in the stream) a finite population correction factor can be applied as follows:

$$nf = \frac{n_i}{1 + ni/N}$$

Where: nf = required sample size from finite population
ni = sample size calculated from infinite population
N = population size (total number of sampling units available - same as glide habitat as above)

Substituting in the formula we have:

$$nf = \frac{12}{1 + 11/41} = 9.2 = 10 = \text{samples required}$$

Proportional Allocation of Samples by Zone

The number of sections to sample in each zone is determined by a process known as proportional allocation. This approach calls for the distribution of the 9 glide samples and 10 pool samples in proportion to the areas encompassed by each in each zone. The number of samples in each zone will be computed as follows:

	Glides
Zone I	0.46/5.8(g) = 0.7 = 1
Zone II	0.64/5.8(g) = 0.99 = 1
Zone III	4.7/5.8(g) = 7.3 = 8

Since statistical protocol requires that at least two units must be sampled from each subpopulation, the revised sampling design for glides becomes:

	Number of Samples	
Zone I	2	
Zone II	2	
Zone III	8	
Totals	12	samples required

For pool habitat the number of samples required will be computed as follows:

	Glides		
Zone I	0.46/5.8(10)	= 0.79	= 1
Zone II	0.64/5.8(10)	= 1.10	= 2
Zone III	4.7/5.8(10)	= 8.1	= 9

Again since at least two units must be sampled in each subpopulation, the revised sampling design for pools becomes:

	Number of Samples	
Zone I	' 2	
Zone II	2	
Zone III	9	
Totals	13	samples required

EXPANSION OF DATA ON A HABITAT WIDE AND STREAM WIDE BASIS

Results of the population estimate surveys can be expanded on a glide or pool basis, or both inclusive by standard area expansion techniques.

PROPOSAL NO. A-2

EFFICIENCY OF CONTROL AGENT EVALUATION OF SEA LAMPREY AMMOCOETE POPULATIONS

BACKGROUND

The U.S. and Canadian Sea Lamprey Control Agents annually select streams to be treated with lampricide. These decisions are constrained by budget but otherwise are based on the judgement of the control agents about the benefits of treatment. These judgements are based on knowledge of past lamprey infestation, on recent treatment of the individual streams and on sampling of candidate streams. Stream sampling is not randomized and is better characterized as a search for ammocoetes which is concentrated in areas with historically heavy infestation or in habitat which is judged to be good for lamprey. The efficiency of these judgements informed by search has been questioned (SLIS 1980, SLAT 1980, Heimbuch and Youngs 1982) on largely theoretical grounds. However, no systematic measurement of the efficiency of control agent evaluation vis'-a-vis scientific sampling has been made to resolve this issue.

OBJECTIVES

Test the efficiency of control agent evaluation of sea lamprey ammocoete populations by comparing stream rankings and expected control benefits based on:

1) historical data only,
2) historical data with ammocoete search,
3) random sampling,
4) random sampling with judgemental stratification of stream habitat, and
5) actual treatment outcome.

PROPOSED PROCEDURE

1) Control agents provide inventory of current lamprey streams.
2) Control agents rank streams for treatment in year "y" using historical data.
3) Control agents carry out ammocoete search in usual fashion and prepare final ranking for year "y", without knowledge of streams or activities in (4).
4) Special unit randomly selects at least 10 streams from (1) and samples randomly within those streams to obtain ammocoete density estimates, without knowledge of activities in (3).
5) Special unit from (4) resamples the same streams with control agents evaluating potential sampling sites for judgemental stratification.
6) All streams sampled in (4) and (5) are treated and estimates of kill are made by mark-recapture.
7) Residual populations are estimated.
8) Ranks of the sample streams and projected transformer numbers are compared where possible from (1) through (4).

All ammocoete density estimates should be done either by mark-recapture or depletion methods.

Procedures for judgemental sampling are as follows:

1) Select five potential sites at random.
2) Rank these sites in order of expected ammocoete density.
3) Sample the site ranked first.
4) Repeat steps 1-3 four more-times but sampling the 2nd, 3rd, 4th, and 5th ranked sites in the 2nd through 5th cycle, respectively.
5) Repeat 1-4 at least once.

The cycle of five ranked sites can be changed to any other number depending on available sampling effort and ability to rank sites.

PROPOSAL NO. A-3

TO ESTIMATE TRANSFORMER PRODUCTION FROM LARVAL SEA LAMPREY POPULATIONS - INSTREAMS TRIBUTARY TO A LAKE BASIN, LAKE SUPERIOR USED AS AN EXAMPLE

BACKGROUND

The "criteria for the selection of streams for stream treatment with lampricides" (see Appendix A-I) presented at the Great Lakes Fishery Commission's Annual Meeting, May 1985, stated that lampricide treatments are scheduled when significant escapement of transformed sea lamprey is expected to occur within the year of the proposed treatment (emphasis added). As a general rule, ammocoetes are expected to start the transformation process after they reach 120 mm in length. Stream treatments are scheduled for the year when a significant number of the larval sea lamprey populations present in the stream reach 120 mm in the spring of the year.

Unsubstantiated statements have been made that "in the Lake Superior drainage, ammocoetes in the length range of 90 to 100 mm in the autumn would not be expected to undergo transformation until a year later. In the lower Great Lakes however, where growth rates are more rapid, ammocoetes less than 90 mm long in the autumn may undergo transformation in the following year."

Growth rate studies of controlled larval sea lamprey populations, Big Garlic River, 1960-72 (Manion and McLain 1971, and Manion and Smith 1978) and five streams in the Lower Peninsula of Michigan (Morman 1987, In press) have demonstrated that transformation of these larval sea lamprey populations did not take place before an age of five years even though the mean lengths of the larvae had reached more than 100 mm as early as October of the second year of growth. The only populations from Lower Michigan (Morman 1987, In press) which had transforming larvae at age five were low density populations in the Jordan and White Rivers where 4.17 and 17.39% transformation occurred, respectively. For 207 larval sea lamprey carried through the five year study, only five had transformed (2.42%).

OBJECTIVES

To quantify numbers of transforming sea lamprey in any given year from:

(a) virgin populations;

(b) reestablished populations after chemical treatment;

(c) residual populations remaining after chemical treatment;

(d) lentic populations.

PROCEDURE

1. Divide the lake into recognizably distinct geographical areas. As an example in Lake Superior there can be five geographical areas described as A, B, C, D and E (Figure A-11).

2. Classify the streams in each geographical area in terms of sea lamprey production and available habitat, according to their history of larval sea lamprey abundance such as; negative, infrequent, low, moderate or abundant. Classification by larval habitat may involve the actual measurement of suitable habitat or more realistically a simple calculation of total surface area available in the stream for larval habitat. This would be calculated as a multiple of average stream width and stream distance requiring chemical treatment (Table A-XX).

3. Estimate the numbers and age of transforming sea lamprey killed during chemical treatments conducted in late summer or early fall. To evaluate 3, 4, 5 . . . years transformation in Lake Superior a stream treatment schedule should be established for streams with different density classifications from each geographical area on a rotational basis.

   With the existing stream treatment program it is possible to test four to six streams any given year for varying ages of transformation. This requires a minimum of two individuals on each side of the lake for every two to three streams, depending on physical size of the stream system. Two individuals on each side of the border are required for joint decision processes and to determine study areas and priorities.

4. The determination of residual populations and the numbers of transformers produced in any given year would be accomplished by surveys immediately following treatment and in the following year when the residuals can be easily identified by size.

5. Production from lentic populations would be evaluated in a similar procedure as used for streams.

6. The total production of transformers each year, for each geographical area, and the total lake basin, will be estimated from data generated over a six year study of stream and lentic populations. It will be assumed that streams within the same classification will show similar rates of transformation at the same ages, and that the relative numbers produced will remain relatively consistent until altered by chemical treatment.

Figure A-11. Map of Lake Superior divided into management zones.

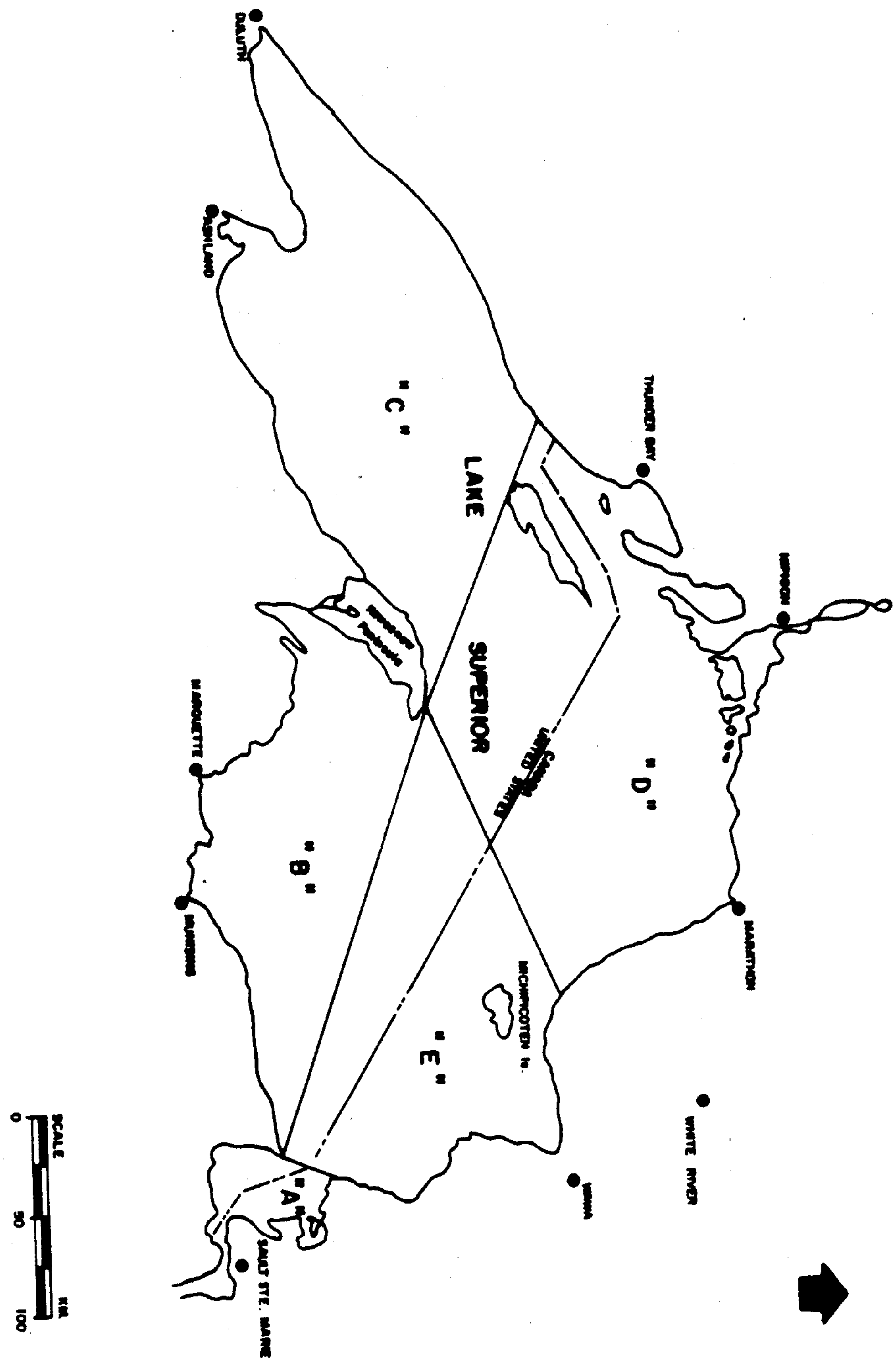


Table A-XX. Lake Superior tributaries with a history of sea lamprey production and an arbitrary rating of their potential production.

Name	Treated Length km	Average* Width m	Potential* Production
	Canadian Tributaries Area "A"		
East Davignon Creek	4.5	3	infrequent
West Davignon Creek	13.4	3	low
Little Carp River	9.3	3	low
Big Carp River	9.6	3	low
Cranberry Creek	7.6	3	low
Goulais River	143.4	18	large
Stokely Creek	1.0	5	low
Jones Creek	2.9	2	infrequent
Sawmill Creek	0.5	3	infrequent
Harmony River	2.9	27	moderate
Batchawana River	13.0	21	large
Carp River	1.0	6	low
Pancake River	9.2	5	moderate
	Canadian Tributaries Area "E"		
Agawa River	1.3	12	low
Sand River	0.6	5	infrequent
Michipicoten River	18.5	30	large
Dog River	3.2	3	infrequent
	Canadian Tributaries Area "D"		
White River	4.8	55	low
Pic River	112.6	30	low
Little Pic River	47.0	24	low
Prairie River	3.9	15	infrequent
Steel River	10.1	18	low
Pays Plat River	6.0	15	infrequent
Gravel River	16.0	12	moderate
Little Gravel River	6.9	3	low
Cypress River	5.1	3	low
Jackfish River	9.8	12	low
Nipigon River	17.9	46	large
Cash Creek	22.5	5	infrequent
Polly Creek	2.7	3	infrequent
Stillwater Creek	4.5	5	low
Otter Cove Creek	0.5	2	infrequent
Black Sturgeon River	16.2	21	moderate
Big Squaw River	7.4	3	infrequent
Wolf River	11.3	8	large
Pearl River	3.9	8	low
Blende Creek	3.2	3	infrequent
McKenzie River	1.1	5	infrequent
McIntyre Creek	7.7	9	infrequent

Table A-XX. (Cont'd) Lake Superior tributaries with a history of sea lamprey production and an arbitrary rating of their potential production.

Name	Treated Length km	Average* Width m	Potential* Production
(Continued)	Canadian Tributaries Area "D"		
Neebing River	17.4	5	low
Kaministikwia River	58.1	24	moderate
Cloud River	7.4	3	infrequent
Pine River	3.5	3	infrequent
Pigeon River	5.8	24	low
	United States Tributaries Area "A"		
Waiska River	40	8	moderate
Pendills Creek	2	8	low
Grants Creek	5	4	infrequent
Naomikong Creek	3	6	infrequent
Ankodosh Creek	3	5	infrequent
Galloway Creek	5	4	low
Tahquamenon River	32	61	moderate
Betsy River	16	15	moderate
	United States Tributaries Area "B"		
Three Mile Creek	3	3	infrequent
Little Two Hearted River	48	12	moderate
Two Hearted River	128	23	large
Dead Sucker River	6	8	infrequent
Sucker River (Alger Co.)	64	9	large
Sable Creek	2	3	low
Hurricane River 1	2	5	infrequent
Sullivans Creek	2	3	low
Seven Mile Creek	6	4	infrequent
Beaver Lake Outlet	3	5	low
Mosquito River	5	5	infrequent
Miners River	3	8	low
Munising Falls Creek	2	4	infrequent
Anna River	10	8	infrequent
Furnace Creek	2	3	low
Five Mile Creek	2	3	infrequent
Au Train River	29	15	low
Rock River	26	9	low
Deer Lake Outlet	2	6	infrequent
Laughing Whitefish River	10	9	low
Sand River (Alger Co.)	10	8	low
Chocolay River	55	11	moderate
Carp River	2	12	infrequent
Dead River	2	18	infrequent
Harlow Creek	5	9	moderate
Little Garlic River	8	6	moderate

Table A-XX. (Cont'd) Lake Superior tributaries with a history of sea lamprey production and an arbitrary rating of their potential production.

Name	Treated Length km	Average* Width m	Potential* Production
(Continued)	United States Tributaries Area "B"		
Big Garlic River	18	8	low
Iron River	5	14	moderate
Salmon Trout R. (Marquette Co.)	11	9	moderate
Pine River	3	9	infrequent
Huron River	10	12	moderate
Ravine River	5	6	low
Slate River	1	5	low
Silver River	5	12	moderate
Falls River	2	8	infrequent
Six Mile Creek	3	3	infrequent
Sturgeon River	153	18	large
Pilgrim River	8	8	infrequent
McCallum Creek	3	5	infrequent
Mud Lake Outlet	5	5	infrequent
Traverse River	24	6	moderate
Little Gratiot River	3	5	infrequent
Eliza Creek	2	3	low
Big Gratiot River	3	6	infrequent
Smith Creek	2	2	infrequent
Boston-Lily Creek	2	6	infrequent
Trap Rock River	10	6	infrequent
	United States Tributaries Area "C"		
Salmon Trout R. (Houghton Co.)	2	9	low
Graveraet River	8	6	infrequent
Elm River	3	6	infrequent
Misery River	19	8	large
East Sleeping River	16	8	moderate
Firesteel River	19	8	moderate
Ontonagon River	241	30	large
Potato River	19	5	moderate
Cranberry R. (Ontonagon Co.)	13	5	moderate
Little Iron River	10	5	infrequent
Union River	5	3	infrequent
Black River	0.8	21	low
Montreal River	0.8	23	infrequent
Bad River	185	30	large
Fish Creek (Eileen Twp.)	40	12	low
Raspberry River	8	3	infrequent
Sand River (Bayfield Co.)	3	6	infrequent
Cranberry R. 1 (Bayfield Co.>	3	6	infrequent
Reefer Creek	10	5	infrequent
Fish Creek (Orienta Twp.)	6	5	infrequent
Brule River	88	21	large

Table A-XX. (Cont'd) Lake Superior tributaries with a history of sea lamprey production and an arbitrary rating of their potential production,

Name	Treated Length km	Average* Width m	Potential* Production
(Continued)	United States Tributaries Area "C"		
Poplar River (Douglas Co.>	10	9	moderate
Middle River	29	9	moderate
Amnicon River	16	11	moderate
Nemadji River	64	15	moderate
St. Louis River †	†† 27	183	moderate
Sucker R. † (St.Louis Co.)	0.8	6	infrequent
Split Rock River	5	8	infrequent
Gooseberry River	2	9	infrequent
Poplar River (Cook Co.>	0.8	12	infrequent
Arrowhead River	2	23	low
Washington Creek	3	5	infrequent

† Streams have never been treated. "Treated length" is based on the distribution of the few sea lamprey larvae that have been found.

†† Treatment would be from a barrier dam about 27 km above mouth, but chemical would probably not carry more than 10 or 11 km downstream because of lake seiche and expansive estuary and harbor.

* Average widths and potential production are subjective values estimated by personnel familiar with the tributaries. These values are for demonstration purposes only and are subject to error.

SCHEDULE

Lake Superior: 6 years of study with the option of continuation as managerial requirements predict.

<u>Personnel and Resources,</u> (U.S. funds)

2 professional @ $40,000. x 6 years	480,000.
2 Technicians @ $20,000. x 6 years	240,000.
Room & Board in travel status	
6 weeks/stream x 3 streams x $700./week x 4 men/year x 6 years	302,400.
Vehicle rentals (or permanent costs)	
18 weeks x $150./week x 2 units x 6 years	32,400.
Back-pack electro-fishing units	
3 units x $500./unit x 2	3,000.
Administration $500./year/unit	6,000.
Boat and motor plus safety equipment, trailer, etc.	
$2,500. x 2	5,000.
Marking equipment, specimen jars, paper, forms, repairs	
$200./year x 2 x 6 years	2,400.
Total Cost	$1,071,200.

PROPOSAL NO. A-4

TO ESTIMATE SEA LAMPREY PRODUCTION (LARVAL, TRANSFORMER, PARASITIC AND ADULT) IN A LAKE BASIN AND EVALUATE THE RELATIONSHIP OF ONE LIFE PHASE TO TEE OTHERS

BACKGROUND

During the Workshop to Evaluate Sea Lamprey Populations the larval/ transformer group reviewed the proposals and combined them to coordinate estimates of lamprey numbers in a lake basin.

OBJECTIVES

To quantify numbers of transforming sea lamprey in any given year from all larval habitats and to compare this value with annual estimates of parasitic and spawning adult sea lamprey (in order to estimate the costs of managing sea lamprey numbers and to review scheduling of chemical treatments to further reduce recruitment of sea lamprey to the lake).

PROCEDURE

1. Divide the lake into recognizably distinct management units based on geography, fishery management zones or any other divisions presently employed by Great Lakes managers associated with sea lamprey evaluations.

2. Estimate the numbers of parasitic phase sea lamprey in each management unit yearly.

3. Estimate the numbers of spawning phase sea lamprey in each management unit. yearly.

4. Estimate larval populations and project transformer production from these larval populations by management unit by:

   (a) inventorying larval sea lamprey habitat (stream, lentic, etc.) in each management unit in terms of potential sea lamprey production (transformation of larval lamprey into parasitic animals);

   (b) subjectively catagorizing larval habitat in terms of sea lamprey production, e.g.:

      i) non-producing
      ii) marginal
      iii) producing transformed lamprey within projected time to chemical treatment, 4 years, 3 years, 2 years, 1 year, panic,

   and within each category randomly selecting sample sites, estimating populations in each sample site, e.g.:

      i) mark-recapture estimates
      ii) direct count
      iii) removal or depletion estimate
      iv) quadrate sampling, etc.,

   and project, transformation from these populations;

(c) estimating numbers of sea lamprey killed during chemical treatments and project transformation that would have or had occurred in these populations dependent on the time of year when treated;

(d) estimating numbers of sea lamprey escaping chemical treatment (residual populations) and project annual transformation that will provide recruitment to the lake;

(e) estimating numbers of sea lamprey present in areas where no chemical treatments are affected (relic populations) and estimate annual transformation that will provide recruitment to the lake;

(f) comparing estimated annual transformer production from larval populations with the following year's estimated parasitic population and the subsequent year's estimated spawning population of sea lamprey.

SCHEDULE

This proposal would be an ongoing assessment of sea lamprey numbers much as is currently in effect.

PERSONNEL AND RESOURCES

There is no projection of additional personnel or resources at this time since it is assumed that present personnel and resources would continue in their positions with reordered priorities, improved information gathering techniques, and revised formats for summarizing and reporting data. It would be preferrable that one person should be assigned the task of coordinating all assessment data from all sources (U.S.A. or Canada) on at least a lake basin or even all lakes combined.

APPENDIX A-I

PROCEDURAL DOCUMENT: April 19, 1984

CRITERIA FOR THE SELECTION OF STREAMS FOR STREAM TREATMENT WITH LAMPRICIDES

OBJECTIVE

The purpose of treating streams and other areas with lampricide is to prevent or minimize the recruitment of parasitic-phase sea lamprey to the Great Lakes by eradicating or reducing populations of larval sea lamprey.

DECISION PROCESS

There are two stages in the process of making the decision to treat a stream with lampricide: first is the scheduling of the stream for future treatment, which depends on a biological assessment that includes an estimate of the probability that escapement of sea lamprey to the parasitic population would otherwise occur; and second the decision - usually made in the field - as to the feasibility of treatment under prevailing conditions.

Several levels of responsibility within a sea lamprey control unit are involved in the decision to schedule treatments. Although the procedures involved are generally comparable, because of the different organization of Control Units in both countries, the procedures are not identical. Field Biologists responsible for larval assessment on the individual Great Lakes submit their initial recommendation for treatments based on survey results and other factors, as detailed below. These recommendations and the supporting data are then reviewed with other biologists and technicians, including the treatment supervisors to develop a list of streams, on all of the lakes, that will require treatment during the next field season. At the same time treatment priorities, general treatment requirements, including anticipated problem areas, are addressed and tentative application schedules *are* formulated. The list is then submitted for approval of the Control Unit's Director/Supervisor. Following such approval, the list of candidate streams for treatment is submitted annually to the Great Lakes Fishery Commission, and, upon acceptance, is incorporated into the Memorandum of Agreement signed with the two member countries.

SELECTION OF STREAMS FOR LAMPRICIDE TREATMENT

It is essential to recognize that the decisions to schedule streams for lampricide treatment are based on a number of factors, many of which are unquantifiable. Therefore, the decision process involves informed judgement based on professional training and experience, although due consideration is also given to measures such as abundance estimates and length-frequency distributions. The following factors, not necessarily listed in order of priority, are normally taken into account when selecting streams for treatment.

(i) Expected transformation of ammocoetes

A stream is scheduled for lampricide treatment when, on the basis of the results from ammocoete surveys, or similar evidence, there is reason to believe that significant escapement of transformed sea lamprey from the stream would occur within the year of the proposed date of treatment. The prediction of imminent transformation is based on the sizes of ammocoetes found in the stream, together with other information relating to their likelihood of transformation, such as the date of a previous treatment, if there was survival of sea lamprey ammocoetes, and knowledge of factors influencing their development. As a general rule ammocoetes are expected to start the transformation process after they reach 120 mm in length. A prediction of the time at which this length may be attained depends on the maximum lengths of the ammocoetes collected, the date, and the location of the collection. In the Lake Superior drainage ammocoetes in the length range of 90 - 100 mm in the autumn would not be expected to undergo transformation until a year later. In the lower Great Lakes however where growth rates are more rapid, ammocoetes less than 90 mm long in the autumn may undergo transformation in the following year.

(ii) Abundance of ammocoetes

Estimates of the abundance of ammocoetes of transformation size present in a stream can influence the decision to treat it with lampricide. Where the potential for production of transformed sea lamprey is extremely low, treatment--particularly if costly or difficult--may not be warranted.

(iii) Survival of sea lamprey from previous treatment

As a special case of the foregoing considerations, the existence of significant numbers of residual sea lamprey following a treatment would be reason enough for rescheduling the treatment as soon as possible.

(iv) Potential escapement of ammocoetes

In some rivers, treatments are performed on an accelerated schedule (irrespective of transformation), in order to control ammocoete populations in the river proper. These ammocoetes would otherwise be flushed into the lake where they are difficult to control.

(v) Interval since previous treatment

For streams that are habitually re-populated with sea lamprey after treatment, a re-treatment after a period not exceeding the anticipated minimum duration of larval life (3 - 4 years) is expected. Although this criterion is not used without verification by other factors as outlined above, it is useful for the long-range forecasting of required stream treatments.

(vi) Number of adult sea lampreys and/or impact on local area fisheries

The presence or indication of large numbers of spawning- or parasitic-phase lampreys in localized areas of the lakes is considered in context with many of the foregoing factors and may influence the decision to recommend a stream treatment. This decision to treat is most likely to occur if the quality of larval assessment data for a particular stream is questionable.

(vii) User group or public concerns

If user groups of a fishery resource or the public in general perceive that a serious conflict exists, stream treatments may be altered to accommodate their concern.

ANALYSIS AND DOCUMENTATION

With the inability to quantify all factors contributing to decisions to schedule streams for treatment, there is no comprehensive mathematical approach to analyze the information provided. Relevant data are usually listed in tabular form to facilitate review and analysis.

FACTORS INFLUENCING THE DECISION TO TREAT STREAMS

Events or conditions arising at or near the intended time of treatment may cause rescheduling or cancellation of the treatment. Such decisions usually are made by the supervisor in charge of the treatment unit from observations just prior to the scheduled treatment, Factors taken into account in making such decisions include the following:

1. Probability of Significant Mortality of Important Non-Target Organisms

From experience gained in the field and from knowledge of the results of relevant laboratory tests and field trials, the field supervisor in charge of treatments is able to recognize situations that could result in unacceptable non-target mortalities. Such mortalities may be predicted from the following indications:

presence of sensitive species and/or especially sensitive life stages of non-target organisms

extremely high or low water temperatures

adverse water chemistry conditions, especially dissolved oxygen

occurrence of pollutants or contaminants that are expected to cause incidental non-target mortality, or likely to interact adversely with lampricide

2. Probability of significant survival of sea lamprey ammocoetes

Although some areas are chronically difficult to treat with complete effectiveness; there are a number of conditions that may adversely affect the outcome of any treatment in terms of the survival of sea lamprey. Such survival could arise from:

very low water temperatures

heavy precipitation

irregularities in water chemistry data (e.g. high pH)

thermal stratification in estuaries

3. Operational Complications

Normally Stream treatment Operations are not seriously hindered by natural complexities of the watershed, or even by minor man-made complications. Occasionally however factors such as the following may force postponement of scheduled treatments:

large-scale alterations of stream channels

conflicting water-use interests such as hydro-electric power generation, other industrial and domestic uses

floods, droughts and other extreme flow regimes

adverse public reaction to the program

"stop" or "control" orders by regulatory authorities

(Original copy signed by Dr. Tibbles and Mr. Daugherty)

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April 19, 1984

Signed copy submitted to the G.L.F.C. at their May 1985 Annual Meeting.

SECTION B

SUMMARY OF EVALUATION METHODS AND POPULATION STUDIES OF PARASITIC PHASE SEA LAMPREY

by

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5. Investigate the roles of biological and environmental factors in evaluating the impacts of predation.

6. Develop a statistical design as a basis for statements of criteria and guidelines.

7. Indicate possible resource requirements (dollars and person/years).

The purpose of this Group is to review present methods and practices employed in assessing populations of parasitic phase lampreys, to investigate needs, to suggest ways to upgrade and expand evaluation strategies, and to develop and recommend alternate methods to collect, interpret, and present the data. Emphasis is on quantitative rather than qualitative measures, and on establishing criteria for the reliability and precision of the data. The ultimate goal is to develop an improved measure of the effects of sea lamprey management on populations of parasitic phase sea lampreys.

PAST AND PRESENT PRACTICES OF ASSESSING THE PARASITIC PHASE POPULATION

INTRODUCTION

Initial attempts to estimate the abundance of parasitic phase sea lamprey were for the most part confined to indirect methods such as the enumeration of wounds or scars and the estimation of lamprey induced mortality. This is due to the difficulty of observing the parasitic stage directly. There are several problems associated with the use of wounding data as a means of assessment but improvements have been made such as the establishment of a standard wound classification system (King and Edsall 1979). Recently, lamprey induced mortality has been estimated through mathematical equations derived from biological information (Koonce 1985).

Since the mid 1960's a direct method of enumeration of the parasitic phase population has been possible through the collection of lamprey by commercial and recreational fishermen. Attempts have also been made to conduct mark recapture studies (Heinrich, Anderson and Oja 1985).

WOUNDING DATA

1. Participation and Coordination

The incidence of sea lamprey wounds and/or scars on specified host fishes has been reported by, or under the auspices of a number of fishery management agencies, including the following:

Illinois Department of Conservation
Indiana Department of Natural Resoures
Minnesota Department of Natural Resources
New York State Department of Environmental Conservation
Ontario Ministry of Natural Resources
U. S. Fish and Wildlife Service
Wisconsin Department of Natural Resources

Two major problems have impeded the application of sea lamprey marking data to estimate abundance. The first was a lack of commonly accepted criteria for identifying and reporting marks, and the second was an absence of agreement on a method for assessing impacts (mortality) from marking data. Attempts to resolve the first problem were made by King and Edsall (1979) who established a marking classification system, and by Eshenroder and Koonce (1984) who recommended a common reporting format. The second problem is less tractable, but the GLFC is currently supporting research (Principal Investigator, J. F. Koonce) to examine and hopefully resolve the "impacts" problem as it relates to lake trout.

Despite these problems studies have been conducted relating wounding data to lake trout, Salvelinus namaycush, mortality. Pycha and King (1975) examined lake trout data (wounding and scarring rates, catch and effort statistics and stocking rates) from southern Lake Superior between 1950 and 1970. They concluded that,

> "...although the evidence linking sea lamprey wounding to this high mortality is largely circumstantial, the consistency of the relation between lamprey wounding rates and mortality, the inverse relation between lamprey wounding and scarring rates, and the lack of evidence of any other source of high mortality of lake trout, leads us to conclude that sea lamprey predation was a major factor and probably the principal factor limiting abundance and size of lake trout spawners in 1962-1970."

Lawrie and Rahrer (1972) showed that for the Canadian waters of Lake Superior, a strong positive correlation existed between the number of wounds per lake trout observed in one year, and the numbers of sea lamprey captured in electrical barriers the following year. They stated that,

> ". . . the excellent agreement between these independent statistics support the belief that the relative abundance of sea lamprey in Lake Superior has been reasonably accurately estimated...."

The GLFC has attempted to coordinate and standardize the interpretation and reporting of marking information in several ways. Lake Committees (one for each of the Great Lakes) were organized beginning in 1965, and these provided the means for the fishery management agencies in all concerned jurisdictions to compare and coordinate their plans and procedures, including the enumeration of sea lamprey marks on fish. The GLFC supported the research (King and Edsall 1979) to develop standardized methods for classifying such marks, and also the work of the Ad Hoc Committee to Recommend Standards for Reporting Sea Lamprey Marks (Eshenroder and Koonce 1984). The Sea Lamprey International Symposium (SLIS), sponsored by the GLFC in 1979, included a section dealing with the parasitic phase of the sea lamprey. Among the SLIS presentations were papers describing lamprey predation on Lake Ontario fish (Christie and Kolenosky 1980); discussing the rehabilitation of lake trout in Lake Superior (Lawrie and MacCallum 1980); on lamprey induced mortality of lake trout in Green Bay (Moore and Lychwik 1980); and on mortality of lake trout in Michigan waters of Lake Superior (Pycha 1980). There were also papers by Spangler and Collins (1980) discussing predation on Lake Huron lake whitefish, Coregonus clupeaformis; by Swanson and Swedburg (1980) on the role of sea lamprey in the decline of the lake trout on Gull Island Reef, Lake Superior; and by Wells (1980) describing predation on Lake Michigan lake trout.

In characterizing the available data on sea lamprey marks, the Ad Hoc Committee referred to a number of categories relating to the collection of the information, and noted that, in spite of the past efforts to standardize the procedures of the reporting agencies: "the interpretation of sea lamprey marking data has been confounded by *a* lack of consistent reporting criteria among agencies and lakes."

2. Recording Wounding Data

a) Host Species

Wounding and scarring rates have been reported for various species of fish including lake trout, other trout, splake, salmon, chub and whitefish. Table B-I lists the fish species by lake that are useful indicator host species.

Differing objectives in restoring desirable fish stocks, and the slowness of rehabilitating certain favoured species -- particularly lake trout -- have hampered and delayed the attainment *of* basin-wide uniformity in adapting a single indicator species. It was suggested by the Ad Hoc Committee that lake trout would be the most useful species for this purpose, but that others may have to be used on an interim basis.

Table B-I. Utility of eight host species for meeting assessment objectives for a> locating lamprey infestation sources and revealing differences in lamprey activity, b) between, and c) within lakes. (from Eshenroder and Koonce 1984)

Species	SUPERIOR	MICHIGAN	HURON MI	HURON ONT	ERIE	ONTARIO
Lake trout	a,b,c	a,b,c	a,b,c	b	b	a,b,c
Whitefish		b	t!	a,b,c	b(?)	-
Chubs		b	b,c	b,c		
Coho salmon		b			**a,b,c**	**a,b,c**
Chinook salmon	-	b,c	b			b
Brown trout						a,b,c(NY)
Rainbow trout	b	b(MI)	-	b,c	b,c	b
Sucker						

b) Method of Collecting and Reporting Wounding Data

The Ad Hoc Committee indicated that there were problems associated with the collection of wounding data, particularly that there may be incompatability between wounding indices obtained from catches made by differing types of gear - especially commercial nets as compared to angling methods. In the New York waters of Lake Ontario, however, similar indices were obtained from brown trout, Salmo trutta, caught in assessment gill nets and by angling.

There are several other areas of concern in relation to the reporting of wounding data. One of these concerns is the difficulty in establishing the type of wound. Although a biologically rational basis for identifying the types and stages of healing lake trout wounds has been established by King and Edsall (1979), not all agencies have adopted the same criteria in differentiating between "fresh wounds", "old wounds", or "scars". In an experiment to show the consistency of recognizing difference stages of wounds on fish, the Ad Hoc Committee found (Table B-II) that identification was not precise among different investigators. The Committee therefore recommended that reporting standards, based on a mark-of-the-year concept should be developed.

Another problem that was identified was the need to differentiate between the two year classes of parasitic phase sea lamprey that are present in the Great Lake in the winter and early spring. The Ad Hoc Committee recommended that agencies recording the incidence of wounds on fish should distinguish between large and small wounds on the basis of wound diameter. However due to differences in the growth of sea lamprey within the Great Lakes the adoption of a single diameter may not be feasible for all lakes.

A third difficulty is that in most Great Lakes waters, the incidence of sea lamprey wounds shows seasonal fluctuations in frequency, with peaks occurring typically in spring and fall. In Lake Superior it was found that spring wounding data were most closely correlated with other evidence of sea lamprey abundance. The ad hoc committee suggested that there may not be a single best season for recording lamprey wounding rates throughout the Great Lakes, but encouraged the achievement of within-lake uniformity among agencies in such record keeping.

Since observed wounding rates are dependent on the size of the host fish, it was recommended that a standard length range (53 to 64 cm for lake trout) be adopted for reporting marking rates. In distinguishing between stages of healing and in reporting different sizes of wounds, uniform reporting criteria are also required. With regard to the interpretation of multiple marks on fish, the Ad Hoc Committee reviewed some previous studies of the theoretical frequency distribution of multiple and single attacks, and considered some predictive models relating such attacks to fish mortality rates (Table B-III).

The Ad Hoc Committee's report contains a review of the statistical basis setting minimum sample sizes for certain levels of confidence in reporting marking rates. The report concludes with a series of recommendations for achieving greater consistency and reliability in reporting sea lamprey marking rates.

Table B-II. Frequency distribution of observer identifications of sea lamprey marks on lake trout and whitefish in relation to reference states given in Special Publication 79-1. (from Eshenroder and Koonce 1984)

		OBSERVER IDENTIFICATION FREQUENCIES															
		LARGE MARK								SMALLMARK							
		TYPE A				TYPE B				TYPE A				TYPE B			
Reference[1] type/stage	Number observations	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Lake trout																	
Type A																	
stage II	10		.50	.40							.10						
stage III	20			.35	.40		.05	.05				.15					
stage IV	70				.36			.14	.19				.01				
Type B																	
stage 11	20			.15	.10	.10	.25	.10							.10		
stage IV	30				.33		.03	.07	.23								.03
Whitefish																	
Type A																	
stage II	10	.20	.80														
stage III	10		.10	.20	.20		.10	.30	.10								
stage IV	10			.30	.40		.10		.10								
Type B																	
stage III	30		.03		.10	.03	.07	.23	.20								
stage IV	10				.10			.10	.40								

1 All reference marks were large.

Table B-III. Summary of tests of Poisson model of mark frequency distribution. Data for white sucker marking are taken from Fig. 1 in Farmer and Beamish (1973), and the Cayuga Lake data are for various mark stages (King and Edsall 1979) for lake trout. Test statistics are either chi-square goodness-of-fit or heterogeneity. The heterogeneity statistic is the ratio of variance to mean times the degrees of freedom (from Eshenroder and Koonce 1984).

OBSERVED MARKS PER FISH							STATISTICS	
Data Source	0	1	2	3	4	Mean	Chi-Square	Hetero-geneity
Farmer and Beamish (1973)	78	92	51	18	5	1.10	0.29 $(p > .1)$	222 $(p > .1)$
Cayuga Lake								
A1	270	80	9	0	-	0.27	1.49 $(p > .1)$	327 $(p > .1)$
A2	269	71	17	2	-	0.31	3.38 $(p > .1)$	396 $(p > .1)$
A3	259	84	11	5	-	0.34	7.89 $(p > .1)$	3.92 $(p > .1)$
A1-A3	798	235	37	7	-	0.31	2.99 $(p > .1)$	1,126 $(p > .1)$

SEA LAMPREY-INDUCED MORTALITY OF FISH

1. Field and Laboratory Studies

Predator-prey relationships in the Great Lakes are both dynamic and complex. Generally, stocked fish are not self-sustaining and the role of the sea lamprey in this conundrum is unclear. Information on the component of natural mortality of Great Lakes fish attributable to sea lampreys is obscure.

Field studies of sea lamprey predation on Great Lakes fish have been undertaken by various investigators. Lennon (1954) observed the effects of sea lamprey predation on their prey in the Michigan waters of Lake Huron. Parker and Lennon (1956) investigated the biology of parasitic phase lamprey and attempted to deduce estimates of prey mortality from the incidence of attack. Fry (1953) and Fry and Budd (1958) studied the survival of planted lake trout in South Bay, Lake Huron and the role of sea lamprey in their disappearance. Pycha and King (1975) investigated the effects of several factors including sea lamprey predation on survival of lake trout in Lake Superior. Berst and Wainio (1967) studied lamprey wounding on rainbow trout, Salmo gairdneri, collected in the Nottawasaga River (Georgian Bay).

Few laboratory studies of sea lamprey predation on fish have been undertaken. Farmer and Beamish (1973) studied the prey preference of lamprey and the effects of lamprey predation in a series of laboratory experiments. King and Edsall (1979) studied lamprey predation on lake trout in the laboratory in order to describe the types and healing stages of wounds. In general, the laboratory approach has been unable to account for the large-scale effects of aquatic habitat factors and relative population densities.

In his report of the "Population Dynamics and Species Interactions Section" of the 1983 Conference on Lake Trout Research (CLAR), Hatch (1984) summarized the results of past efforts to estimate lamprey induced mortality of lake trout as follows:

> ". . . Most of the evidence linking sea lamprey attack marks to lake trout mortality is circumstantial because lake trout killed by lampreys are seldom found and little is known about lake trout survival after the lamprey detaches. Wounding levels may not reflect the same mortality from year to year if the fraction surviving attack is some function of time, or of size of fish or of lamprey (Youngs 1980). More precise estimates of lamprey-induced mortality require information on the relation between lamprey wounds and their lethality.
>
> The selection of optimal strategies for rehabilitating lake trout is hindered by our inability to predict the magnitude of reduction of lamprey-induced mortality on lake trout that results from a given increase in sea lamprey control effort. Sea lamprey populations in the upper Great Lakes have been reduced to less than 10% of their peak abundance of the late 1950's through the use of chemical control (Smith and Tibbles 1980). Although the present level of control appears adequate to allow restoration of some important stocks of fish [e.g., lake whitefish (Coregonus clupeaformis) and bloaters (Coregonus hoyi)], significant natural reproduction of lake trout has been limited to Lake Superior. Many biologists attribute this failure to a lack of

significant multi-age stocks resulting from exploitation and predation by residual sea lampreys. The degree to which survival of lake trout might be increased by intensified lamprey control (or, conversely, how much survival would decrease if lamprey control efforts were lessened) is not known." .

The CLAR group proposed a series of laboratory and field experiments designed to define the relationship between sea lamprey attack and lake trout mortality at various relative densities of predator and prey.

2. Mathematical Modeling

Since 1976, the GLFC has sponsored a number of research projects to aid standardization of observation and reporting of sea lamprey marking in the Great Lakes. Based on the mark classification system proposed by King and Edsall (1979), an Ad Hoc Marking Standardization Committee submitted several recommendations to the GLFC, and a set of standard recording and reporting procedures were adopted in May 1983. Eshenroder and Koonce (1984) summarized the findings and recommendations of the Committee, and this document serves as a reference for future reporting of marking data.

In parallel to these initiatives, the GLFC also sponsored two workshops to find ways of unifying fishery management and lamprey control efforts. As a direct result of studies at SLIS, these Adaptive Environmental Assessment and Management (AEAM) Workshops attempted to construct simulation models that would aid decision making about priorities in the rehabilitation of lake trout in the Great Lakes. Integrated pest management was a central theme in these workshops, and the current emphasis on individual management plans for each lake represents the first step in applying an integrated pest management system for sea lamprey in the Great Lakes.

Koonce's (1985) Special Report to the Lake Superior Committee attempted to unify efforts to develop a standardized recording and reporting scheme for marking data with the earlier modeling initiatives. Despite ambiguities surrounding reporting and interpretation, sea lamprey marking of lake trout still represents the only observable linkage between lamprey control and lake trout rehabilitation. The GLFC funded this work as a two-phase project to address the uncertainties in estimation of lake trout mortality due to sea lamprey predation. The first phase, which is partially reported here, dealt with resolving some of the technical uncertainties in the interpretation of marking data in Lake Superior. A basic objective of this work was to develop and to test a standard protocol for estimation of sea lamprey mortality. During the second phase, the simulation models developed in the earlier workshops were to be consolidated to support the systematic application of this protocol to the evaluation of various trade offs in sea lamprey control, fishery management, and stocking.

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 (Koonce et al. 1982). 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:

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

where qi 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,

$$\Sigma\ h\ q_i\ n_i >> 1, \text{ and}$$

equation 3 is approximated by:

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

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 are directly proportional to attack rate (Eshenroder and Koonce 1984), marking rates will also express these relations.

Using equations 1 to 4, Koonce and Pycha (Ms) suggest a simple protocol to estimate relative abundance of parasitic phase sea lamprey in Lake Superior and the lethality of an attack. Data required for this protocol include estimates of total mortality of the largest fish in assessment catches (estimated 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:

$$\text{Weighted } M = [\ \Sigma\ (CPE_i\ Mi)\ ]/[\ \Sigma\ CPE_i] \qquad (5)$$

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 43 cm 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.

Several assumptions were required to develop protocols for Lake Superior. There is substantial reason to believe, for example, that the lethality of an attack is size dependent (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 very interesting patterns in the marking data for Lake Superior.

Applying equation 2 to marking rates for lake trout 64 cm and greater reveals a surprisingly good association with total mortalities estimated from catch curves (Fig. B-l, data from Pycha 1980; and Pycha, Personal Communication). 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 importantly, the strength of this association implies that 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. B-2), the association between marking and CPE is not significant; accounting for less than 1% of the variability in marking rates. Wisconsin (Fig. B-3, coefficient of determination 0.74) and Minnesota (Fig. k-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 to 1969 and around 1972, Fig. B-5. Comparing this pattern of abundance with the runs recorded at six electric weirs operated in Michigan waters reveals a significant cotrelation that accounts for about 50% of the variability in weir catches (Fig. B-6). This agreement is also surprising given all of the possible sources of error and changing size structure of the lake trout population over this period.

Combining the estimated relative abundance of sea lamprey for Michigan, Wisconsin, and Minnesota reveals an even more interesting pattern (Fig. B-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.

Evaluation of the effectiveness on an integrated pest management program for sea lamprey in the Great Lakes requires observable lake trout mortality due to sea lamprey predation. The results' of the first phase of this research indicate that marking, CPE, and estimates of total instantaneous mortality can be combined to obtain this necessary mortality estimate. Plans for the second phase of this work will continue to emphasize analysis of Lake Superior data. The protocols, however, seem ready to apply to other lakes as well. The major thrusts in phase two, therefore, will involve:

A. Additional applications to Lake Superior.

B. Incorporation of findings of phase 1 into workshop models and development of a procedure- to examine the linkage between the Lake Superior fisheries management plan and sea lamprey control.

C. Applications of these techniques to Lakes Huron, Michigan, and Ontario.

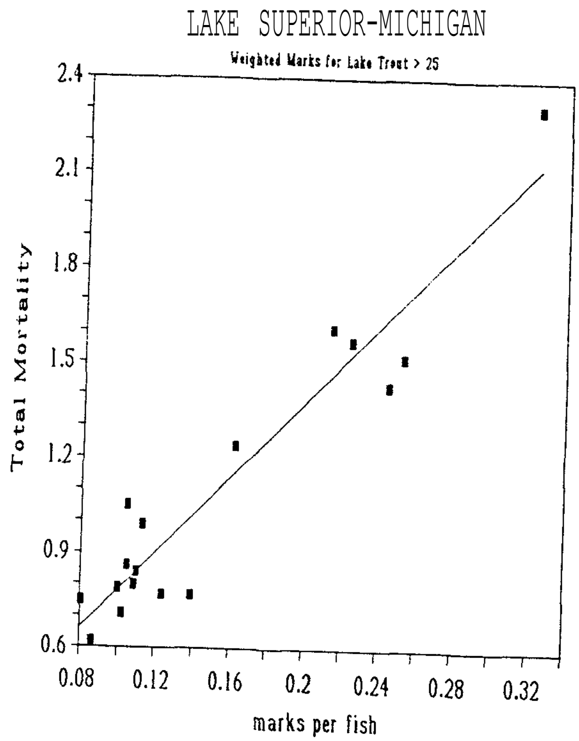


Fig. B-1. Relation between total instantaneous mortality and mean marks per fish, weight by CPE for lake trout 25 inches in length and larger. Data are for Michigan waters of Lake Superior and are drawn from Pycha (1980) and Pycha (personal communication). Intercept of regression is 5.99, and coefficient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

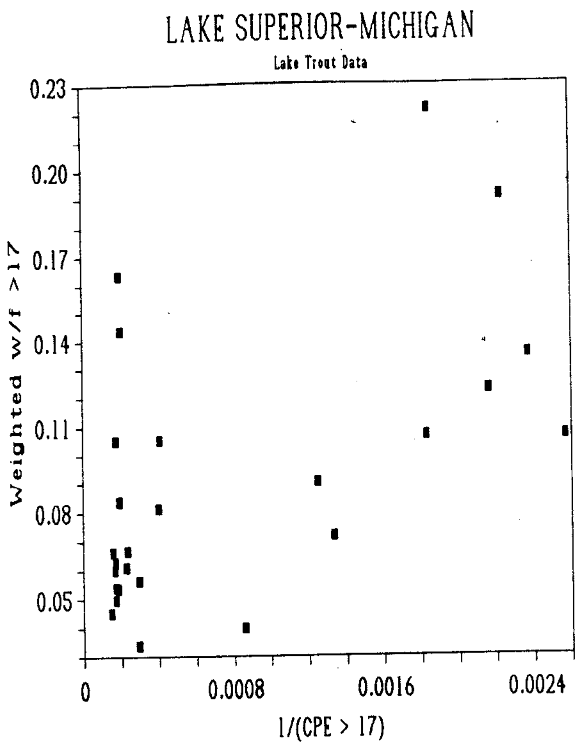


Fig. B-2. Correlation of weighted marks per fish and 1/CPE for lake trout 17 inches and larger in Michigan waters of Lake Superior. Coefficient of determination is 0.0055.

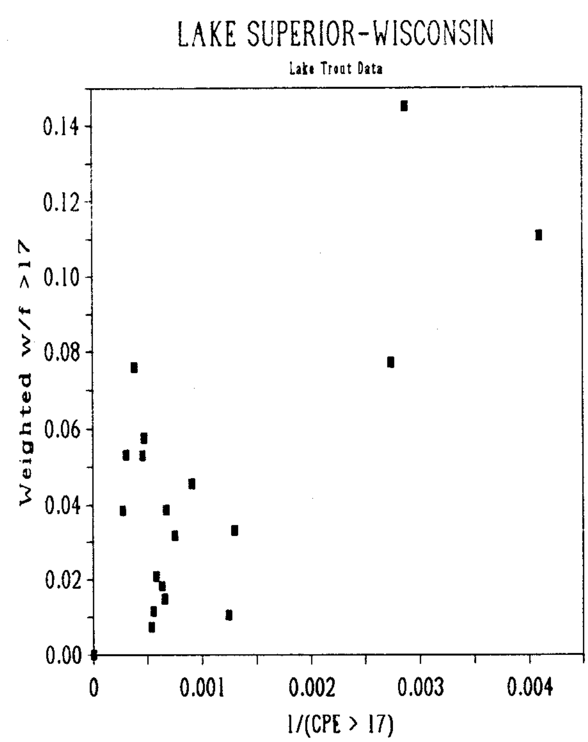


Fig. B-3. Correlation of weighted marks per fish and 1/CPE for lake trout 17 inches and longer in Wisconsin waters of Lake Superior. Coefficient of determination is 0.74.

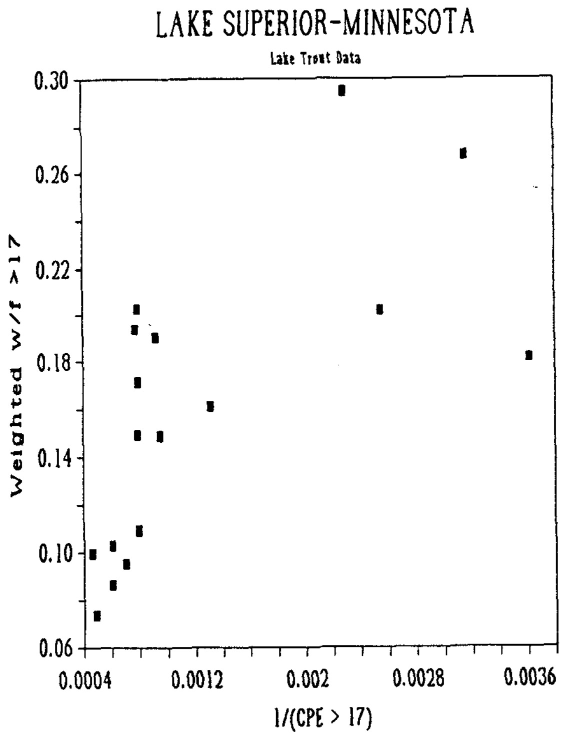


Fig. B-4. Correlation of weighted marks per fish and 1/CPE for lake trout 17 inches and larger in Minnesota waters of Lake Superior. Coefficient of determination is 0.45.

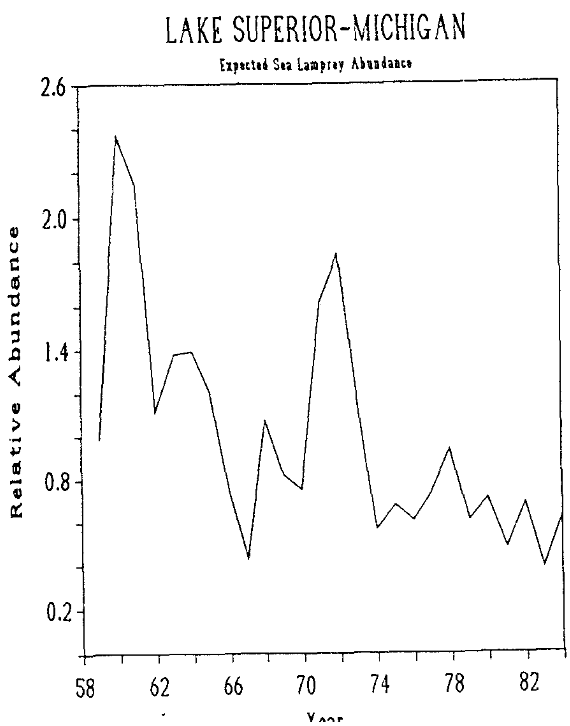


Fig. B-5. Changes in estimated relative abundance of parasitic phase sea lamprey in Lake Superior waters of Michigan over the period 1958-1984.

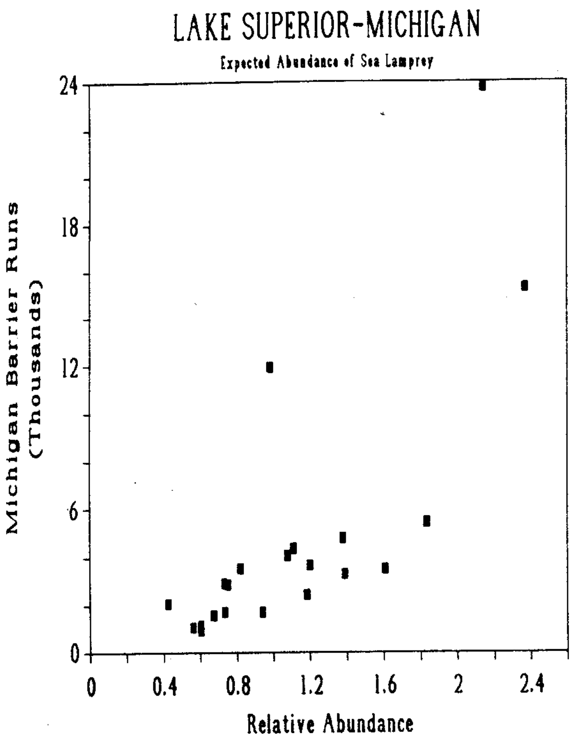


Fig. B-6. Association of estimated relative abundance of sea lamprey with runs at electric weirs (barrier dams) at 6 rivers on the Michigan shoreline of Lake Superior from 1958-1978. Coefficient of determination is 0.50.

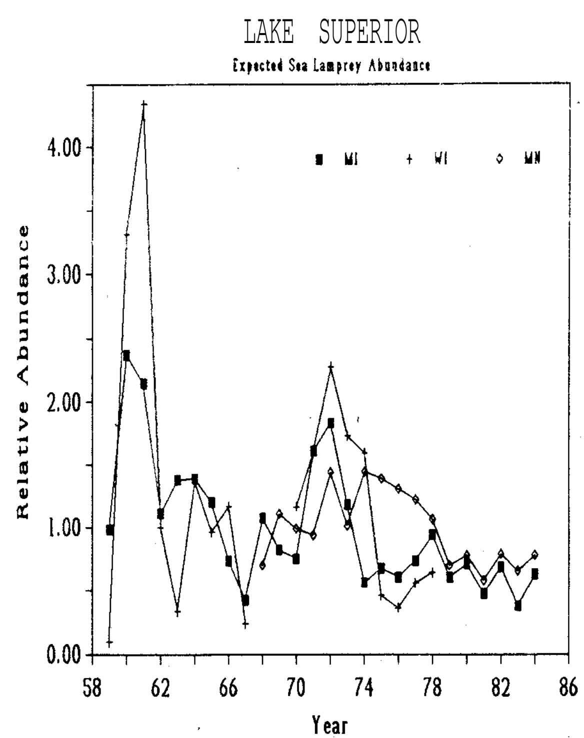


Fig. B-7. Patterns of estimated relative abundance of sea lamprey in waters of Michigan, Wisconsin, and Minnesota for the period 1958-1984.

COLLECTIONS OF PARASITIC PHASE SEA LAMPREY

1. Commercial Fisheries

Since 1967 and 1969, respectively, the sea lamprey control units (Sea Lamprey Control Centre in Canada, and Marquette Biological Station in the U.S.A.) have been collecting sea lamprey specimens and associated catch information from Great Lakes commercial fishermen, in return for rewards. Between 1969 and 1978 parasitic phase sea lamprey were collected from all five of the Great Lakes (Tables B-IV and B-V). They were weighed and measured; examined for sex, maturity and stomach contents; and for United States catches, fishing effort was estimated in relation to the numbers of sea lamprey caught. Johnson and Anderson (1984), reporting on the results of the joint projects, showed that sea lamprey are distributed, with respect to their prey and within their habitat, in non random fashion with spatial and seasonal variations, and an apparent segregation of the sexes. In particular they found that recently metamorphosed sea lamprey caught in the spring tended to occur in deep water in association with species such as chub; whereas later in the season they were more frequently found in shallower water with catches of whitefish or lake trout. The proportion of male sea lamprey in the catches decline from spring through summer in most offshore gear sets. Feeding activity of sea lamprey appeared to reach a peak in late summer and fall. Many of these observations have implications for the interpretation of sea lamprey marking indices. The Canadian and United States Control Units are continuing their collections of parasitic phase sea lamprey from the fisheries, and periodic updates of these projects may be found in the annual reports of the Control Units to the GLFC and in minutes of the meetings of the Lake Committees. In a personal communication for this Workshop, Johnson and Anderson (1984) have stated:

> "In this investigation an attempt has been made to describe some of the physical and biological attributes of predatory phase sea lamprey as they relate to the characteristics of the commercial fisheries from which they were obtained. Although we have not tried to develop a rigorous analysis of the prey-predator relationships; our data, and the inferences drawn from them, indicate some of the factors that may influence these interactions. It must be apparent to the reader that in order to evaluate sea lamprey abundance from evidence of their occurrence in the commercial fisheries, a broadly representative segment of the fishery must be sampled systematically and consistently through time. Furthermore the species and size composition of prey fish stocks should remain stable if reliable trends are to be established.
>
> The United States Control Unit has obtained positive information in the past through sampling the U.S. commercial fisheries in certain areas of the lakes (western Lake Superior and northern Lakes Michigan and Huron). This, in conjunction with the sport fisheries program initiated in 1984, is intended to provide a fairly comprehensive evaluation of parasitic phase sea lamprey populations in most areas. Direct counts and catch-per-unit of effort of predatory phase sea lampreys, together with assessment of spawning runs, have been shown to reflect fluctuations in sea lamprey populations of Lakes Superior, Michigan, and Huron. Because each method used in monitoring sea lamprey populations has its geographical, physical, and biological limitations, there is opportunity for improvement. To assess more accurately the relation between lamprey

Table B-IV. Number of predatory phase sea lampreys collected by United States and Canadian fishermen combined, by length interval, and commercial fishing gear in the Great Lakes, 1967-78 [from: Johnson and Anderson (1980)].

Length Interval (mm)	Gill* A	Gill* B	Gill* C	Gill* D	Gill* E	Type of Net: Pound	Trap	Trawl	Drop	Fyke	Seine	Hoop	Trammel
200		172	21			4	10						
201-249		100	21	2		11	17						
250-299		53	13	5		60	41						
300-349	2	65	66	12		116	51						
350-399	6	123	24[illegible]	15		97	25						
400-449	16	163	524	12		83	17	2[b]					
450-499	15	56	304	4		34	8	3'					
499	3	15	43			5	1						
Total	42	747	1235	50		410	170	5					
Lake Michigan													
200		164	60			816	95	8	2				
201-249		69	46			1105	153	29	1				
250-299		8	37			694	208	43					
300-349		4	53			311	162	94					
350-399		8	87			238	109	107	1				
400-449	1	20	128			401	62	132	2				
450-499	3	26	156			568	35	148	3				
499	3	26	100	1		331	17	107	7	2			
Total	7	325	667	1		4464	841	668	17	2			
Lake Huron													
200		280	77	11			66						
201-249		442	161	13	1	6	198						
250-299		352	368	40		6	307						
300-349		88	695	115		5	250						
350-399		41	793	186	2	1	196						
400-449		21	707	206	8	2	99						
450-499		8	419	137	9	3	55						
499		1	237	39	18	2	21						
Total		1233	3457	747	38	25	1192						
Lake Erie													
200		1					1				3		
2011249				2			3						
250-299				1				1					
300-349						1		3					
350-399						2		28					
400-449								73					
450-499						1	1	163			1		
499								164			5	2	2
Total		1		3		4	5	432			9	2	2
Lake Ontario													
200	1	41	14	3				1			6	2	
201-249		89	25	6							40	1	
250-299		124	110	30			12	4			127	5	
300-349		247	204	83				2				13	
350-399	4	397	377	139			E	3			[illegible]	74	
400-449	3	264	338	80			15	2			29	65	
450-499	6	107	143	82			2				17	32	
499		59	73	79			3				6	5	
Total	14	1328	1284	502			71	12			404	197	

*Mesh sizes (stretched) in millimetres and (in parentheses) in inches -- A = 25-60 (1-2¾); B = 63-88 (2½-3½); c = 92-120 (3¾-4¾); D = 124-200 (4-7/8-7-7/7); E = 203 (8).

b = Lamprey taken by research personnel.

Table B-V. Annual numbers of predatory phase sea lampreys taken by United States and Canadian commercial fisheries of Lakes Superior, Huron, Michigan, Erie, and Ontario, 1967-78. [from: Johnson and Anderson (1980)]

	Lake Superior		Lake Huron				Lake Michigan	Lake Erie	Lake Ontario	TOTALS	
			Lake Proper		North Channel	Georgian Bay					
YEAR	Canada	U. S.	Canada	U.S.	Canada	Canada	U.S.	Canada	Canada	Canada	U.S.
1967	73		1,572		227	5		3	301	2,181	
1968	35		1,245		168	487		5	553	2,493	
1969	24	118	918		371	138		117	1,279	2,847	118
1970	22	255	303	93	176	20	194	160	1,815	2,486	542
1971	29	639	367	202	137	3	1,086	150	1,089	1,760	1,927
1972	18	452	284	120	59	1	978	27	789	1,178	1,550
1973	15	390	78	39	71		730	3	47	214	1,159
1974	20	225	35	22	88		647		115	258	894
1975	9	195	137	140	92		482		213	451	817
1976	34	167	194	130	74		404		13	315	701
1977		215		270			1,355				1,840
1978		118		329			202				649
Total	279	2,774	5,133	1,345	1,463	654	6,078	465	6,214	14,183	10,197

and prey numbers, a better accounting of species and size compositions of harvest is needed (particularly lake trout) in the commercial fisheries and state-wide fish (by species) catch records in the sport fisheries.

The Canadian Control Unit also monitors sea lamprey in selected sport fisheries of Lake Superior, in addition to the ongoing collection of information from the commercial fisheries of all Canadian Great Lakes waters. Insofar as these data are concerned, the Canadian Unit considers them inadequate as precise indicators of sea lamprey abundance, although in certain instances they may provide a rough measure of major trends in relative abundance."

A number of factors influence the consistency and coverage of sea lamprey data obtained from the fishery. These include economic conditions affecting fishing effort and target species; and regulatory measures affecting, in addition to these, the locations and seasons of fishing. The current number of commercial fishermen who cooperate in the Control Units' projects are shown in Tables B-VI (for Canada) and B-VII (for the U.S.A.).

2. Sport Fisheries

Both the Canadian and United States sea lamprey control units have recently (since 1983) begun gathering information on parasitic sea lamprey from anglers, similar to that collected from the commercial fishery. The Canadian unit has dealt with sports fishermen's association in Sault Ste. Marie, Thunder Bay, and Michipicoten, Ontario, which act as intermediaries for member anglers. Anglers in Batchawana Bay (Lake Superior) in 1983 and 1984 and in Thunder Bay in 1984 have provided sea lamprey and related information to the Canadian Control Unit. The program has so far been limited to Lake Superior, with the possibility of expansion into the other lakes. In the U.S.A. a similar project was initiated in 1984 by the U.S. Control Unit for Lakes Superior, Michigan, and Huron, but in this case the existence of a widespread charter boat industry provided the intermediary for contacting individual anglers. Both Control Units gather information on fishing dates, location and effort, target species, number and sizes of fish caught, and the occurrence of sea lamprey marks or attached lamprey. Tables B-VIII and B-IX list, for Canada and the U.S.A., respectively, the numbers of anglers or operators involved in these projects.

Table B-VI. Numbers of individual commercial fishermen involved in the parasitic phase project of the Canadian Control Unit in 1983 and 1984.

Lake Superior -	west of Marathon	3
	east of Marathon	6
Lake Huron	North Channel & north main basin	9
	Georgian Bay	1
	central & southern main basin	3
Lake Erie	west of Erieau	8
	Erieau to Long Point	0
	east of Long Point	2
Lake Ontario -	west of Cobourg	1
	east of Cobourg	0

Table B-VII. Number of United States commercial fishermen in the Great Lakes that participate in the program to monitor the abundance of parasitic phase sea lampreys: 1984

Lake and Statistical District	Number of Commercial Fishermen		
	Gill	Impoundment	Net Type Trawl
Lake Superior			
M-1	-	-	-
M-2	7	-	-
M-3	4	-	-
Wis.	8	3	-
MS-1	-	-	-
MS-2	1	-	-
MS-3	1	1	-
MS-4	2	2	-
MS-5	1	-	-
MS-6	1	2	-
Total	25	8	-
Lake Michigan			
MM-1	-	7	-
MM-2	-	-	-
MM-3	-	5	-
MM-4	-	-	-
MM-5	-	-	-
MM-6	-	-	-
MM-7	-	1	-
MM-8	-	2	-
MW-1	-	-	1
MW-2	3	1	-
MW-3	-	1	-
MW-4	1	1	1
MW-5	-	1	-
MW-6	-	-	-
Ill.	-	-	-
Ind.	-	-	-
Total	4	19	2
Lake Huron			
MH-1	-	5	-
MH-2	-	1	-
MH-3	-	-	-
MH-4		2	-
MH-5	-	-	-
MH-6	-	-	-
Total	1	8	
GRAND TOTAL	30	35	2

Table B-VIII. Numbers of individual anglers involved in the parasitic phase project of the Canadian Control Unit in 1983 and 1984.

Batchawana Bay (Sault & District Anglers Association out of Sault Ste. Marie, Ontario)	19
Michipicoten Bay (Michipicoten Rod & Gun Club out of Wawa, Ontario)	28
Thunder Bay (an unaffiliated group out of the City of Thunder Bay, Ontario)	28

Table B-IX. Total number of sport fishing charter operators and those willing to participate or enrolled in a program to collect information on the abundance of parasitic phase sea lampreys in U.S. waters of the Upper Great Lakes as of July 20, 1984.

Lake and Statistical District	Sport Fishing Charter Operators		
	Total	Number willing to participate	Number enrolled in program
Lake Superior			
M-1	2		2
M-2	?		
M-3	?		
Wis.	20	15	9
MS-1	1	0	-
MS-2	8	5	0
MS-3	2	1	0
MS-4	4	2	2
MS-5	0	-	-
MS-6	0	-	-
Total	37	23	13
Lake Michigan			
MM-1	0	-	-
MM-2	0	-	-
MM-3	3	2	2
MM-4	4	0	
MM-5	36	6	5
MM-6	64	34	0
MM-7	49	36	28
MM-8	44	36	35
MW-1	la	2	0
MW-2	22	22	0
MW-3	3	3	1
MW-4	116	56	17
MW-5	126	55	20
MW-6	75	32	28
111.	150	a5	a5
Ind.	75	56	32
Total	785	425	253
Lake Huron			
MH-1	1	1	1
MH-2	1	1	0
MH-3	44	41	39
MH-4	14	a	7
MH-5	7	4	4
MH-6	6	6	4
Total	73	61	55
GRAND TOTAL	a95	509	321

MARK RECAPTURE POPULATION ESTIMATES

There have been relatively few attempts to conduct Petersen type estimates of populations of parasitic phase sea lamprey, because of uncertainties as to the geographical range of their movements, and the difficulties of carrying out unbiased collections of specimens. For such estimates to be strictly valid immigration to and emigration from the area of concern must be minimal, and all members of the population must be equally vulnerable to capture. A reasonably good numerical estimate of the parasitic phase may be obtained, however, if it can be assumed that the initial population is not significantly altered by removals or additions between the times of marking and recapture, and that nearly all of the marked and unmarked animals are subject to the recapture process.

In a study conducted in northern Lake Huron between 1981 and 1982 (Heinrich, Anderson and Oja 1985), 830 parasitic phase sea lamprey captured incidentally by commercial trap net fishermen in the De Tour-Mackinaw City-Rogers City area were marked by subcutaneous dye injection and released: 398 in the northern portion, and 432 in the southern portion of the area of capture. A total of 101 marked lamprey were recaptured: 9 as parasitic adults in commercial fishing gear in 1981, and 92 as spawning adults in sea lamprey traps set in three tributaries of Lake Huron, and in five Lake Michigan streams in 1982. A large proportion (78.8%) of the recaptures were within 100 km of the point of release. The single Petersen type estimate based on the pooled catches yielded a population size of 250,000 sea lamprey in northern Lake Huron.

Although the foregoing study may have been subject to some degree of bias due to straying of the animals between the area of concern and other waters, it provides a useful example of how such a population estimate could be designed to minimize these sources of error. It may be possible to define the geographical extent of reasonably discrete sea lamprey populations through preliminary tagging or telemetry studies. A comprehensive pattern of releases, based on a density dependent system of stratification, would help to reduce bias resulting from non representative recapture effort. Since studies such as this require large inputs of human resources, they would not be expected to be employed routinely. Their value would be to yield absolute numerical estimates for use in predictive models of prey predator interactions, or to provide baseline statistics in the development of "effectiveness indicators" for sea lamprey management.

BIOLOGY OF PARASITIC PHASE SEA LAMPREY - A REVIEW OF INFORMATION PERTINENT TO THE EVALUATION OF SEA LAMPREY POPULATIONS

INTRODUCTION

The effective management and assessments of sea lamprey populations must be based on a sound knowledge of the biology and habits of the lamprey. Management practices may have a profound effect on the biology of parasitic phase lampreys and this effect must be taken into account when reviewing management results.

DISTRIBUTION AND MOVEMENTS

Parasitic phase lampreys occur throughout the Great Lakes but probably are relatively uncommon in the oxygen-depleted deep waters of western and central Lake Erie in the summer (Morman et al. 1980). The major factors affecting parasitic phase distribution are probably the distribution of preferred hosts and the proximity of spawning streams.

If data on predatory phase lampreys are to be effectively interpreted and put to best use, it is important to delineate the separate populations. Although Krueger and Spangler (1981) and Brussard et al. (1981) indicated that genetically distinct populations may occur both within and among the Great Lakes, the findings of Jacobson et al. (1984) suggest that further work is needed to resolve doubt as to the validity of the distinctions. The degree of geographic overlap among populations during the parasitic phase should also be evaluated, since heretofore populations have been distinguished solely on the basis of ammocoete collections.

Regardless of whether discrete populations of lampreys exist, individual lampreys are capable of extensive movements, as indicated by their rapid colonization of the Great Lakes and by the results of tagging studies (Smith and Elliott 1953; Moore et al. 1974). Passive dispersal by attachment to fish and boats apparently contributes to this movement. The result is that the interpretation of data for individual populations may be compromised by exchange between stocks.

TIMING OF THE PARASITIC PHASE

For all practical purposes, the parasitic phase begins with downstream movement of the recently metamorphosed individuals to the lake. Typically this occurs in a seasonally bimodal fashion, with peak movement during late fall and early spring (Applegate 1950). Presumably fall migrants enter the lake with greater energy reserves and an opportunity to feed earlier than spring migrants (Potter 1980). To what extent such "headstarting" affects the size attained by individual lampreys and their resulting impact on hosts has not been examined, but this could be evaluated through the use of a bioenergetics model (Kitchell and Breck 1980). If this effect is indeed substantial, it may be useful to know if management activities affect the seasonal distribution of downstream migrants.

The parasitic phase ends with the upstream spawning migration, which typically peaks in the Great Lakes during June-July (Manion and Hanson 1980). The average length of the parasitic phase in the Great Lakes is 18 months, although feeding apparently declines some time before the actual onset of migration (Johnson and Anderson 1980).

SIZE AND SEX RATIO

Size and sex ratio are potentially useful indices of trends in abundance of feeding phase lamprey and consequently of the effectiveness of management activities. Heinrich et al. (1980) presented evidence that mean sizes (length or weight) and weight at a given length were negatively related to lamprey abundance and positively related to host abundance. They pointed out that at least three factors (lamprey abundance, availability of suitable hosts, and chemical control) affected lamprey size. Moreover, sex composition changed from a preponderance of males when lamprey numbers were high to a preponderance of females when lamprey numbers were low. The effects of such compensatory changes must be taken into account when evaluating the results of management practices.

FEEDING BEHAVIOUR

1 Habitat

From studying collections of sea lamprey from commercial fisheries, Johnson and Anderson (1980) generalized that small recently transformed lampreys in fall, winter, and early spring are found primarily in deep water, perhaps because the warmest water is available at great depth during that time of year. From late summer until the following spring, lampreys tend to be found in inshore waters. Exceptions to these generalities occur in such areas as Green Bay, where small lampreys do not have access to deep water, or where concentrations of preferred hosts are located near the mouths of streams from which lampreys disperse. Both the generalities and exceptions must be kept in mind when interpreting such phenomena as species selective attack.

2. Size Selectivity

Both field and laboratory evidence indicate that parasitic lampreys selectively attack larger fish (Farmer and Beamish 1973; Cochran 1985). Some evidence suggests that size preference may depend on availability of hosts. In Michigan waters of Lake Superior in 1961, when sea lampreys were abundant but lake trout were scarce, the minimum length of marked trout in samples was about 33 cm (Pycha and King 1975). In 1970, when lake trout were more abundant, the minimum length of marked trout was about 47 cm. Foraging theory predicts that the range of resources used should increase with decreasing resource abundance and that the use of less preferred food should depend on the abundance of more preferred prey but not vice versa. Thus, marking frequencies on smaller fish may prove useful in assessing abundance of hosts relative to that of the lamprey.

3. Species Selectivity

Except for small lampreys that feed on deep water ciscoes, lake trout are generally considered to be the preferred hosts of the sea lamprey in the Great Lakes (Johnson and Anderson 1980). However, field data are confounded by such factors as (1) size selectivity and (2) habitat differences among host species that contribute to differences in relative availability. Only one study of host preference in the laboratory has been reported (Farmer and Beamish 1973) and the preference that they observed was not completely consistent with that seen in the lake. Given the current mix of host species in the Great Lakes, there is a particular need for laboratory studies of selection among comparably sized lake trout and Pacific salmon to answer the question of whether lake trout are indeed preferred or simply more vulnerable to attack due to greater habitat overlap with the lamprey. As in the case of size selection, marking rates on less preferred host species may prove useful in assessing trends in the abundance of hosts relative to that of the lampreys.

4. Attachment Site Selectivity

Sea lampreys generally tend to attach ventrally on their hosts, especially in the vicinity of the pectoral fins (Potter and Beamish 1977; Cochran 1986). However, distributions of attachment sites can vary greatly and may be influenced by such variables as host species, and in the laboratory, tank size (more dorsal attachments in smaller tanks). Attachments to the head and pectoral regions probably are associated with greater host mortality and may be under-represented in field samples; this may be confounded by the effect of attachment duration. If marking data are to be used to evaluate lamprey populations, it may be valuable to partition such data according to attachment site or to focus on a particular region of the host (e.g., a preferred area such as the pectoral region, or alternately, a region such as the caudal area that may be associated with relatively low host mortality regardless of attachment time).

5. Attachment Duration

At a given rate of host blood removal, longer attachment durations are associated with a greater likelihood of host mortality (Farmer et al. 1975). One suggested explanation for wide lake-to-lake variability in the impact of lampreys on host populations is the possibility that attachment duration varies in response to host availability (Kitchell and Breck 1980; Cochran 1984). As the quality of its host's blood declines, a lamprey may detach and seek a new host sooner when alternate hosts are more readily available. A preliminary laboratory experiment to test this hypothesis was inconclusive, primarily because of high variability in attachment times (Cochran 1984). Cochran and Kitchell (Personal communication) provide one explanation for this variability: rates of net energetic return to the lamprey appear to be relatively insensitive to attachment times over a broad range of attachment times. Regardless of any relationship between attachment time and host abundance, however, a knowledge of attachment duration in the field is critical to the interpretation of marking data.

MORTALITY

There is no available information on sea lamprey mortality rates during the parasitic phase, much less on how lamprey numbers change seasonally between the time of entry into the lake and the upstream spawning migration.

THE QUESTIONNAIRE

INTRODUCTION

The development of methods to control the sea lamprey is hampered by the lack of certain key information. In order to determine which gaps in the current knowledge are most significant to researchers in this field a questionnaire was developed and sent to 99 individuals, of whom 45 responded. The questionnaire asked what types of measurements of lamprey populations were most needed, and invited the identification of areas for which information is lacking or data collection may be improved. The questionnaire dealt with all life stages of the lamprey, however, only the responses dealing with the parasitic phase of the life cycle are reported here.

SUMMARY OF RESPONSES

Question #1(a):

What measures of (parasitic phase) sea lamprey populations are wanted?

Only 16 individuals responded to this question. Most answered in very general terms and stated that "some" measure of parasitic phase lampreys is necessary. Several felt that while a quantitative estimate of the population was desirable, it may be very difficult or impossible to obtain.

Two points of view emerged from the responses, depending on whether the writers were concerned mainly with monitoring fish or lamprey populations. Fisheries investigators stressed the need to derive a measure of lamprey induced mortality on fish (responses 1-10), while sea lamprey control personnel wanted a reliable measure of lamprey abundance either in relative or absolute terms (responses 11-16).

Responses:

Since determining the number of parasitic phase individuals is virtually impossible, they must be estimated from some index, such as numbers of spawners or lamprey wounding rates on prey.

Population estimates would be desirable but may not be possible.

From my perspective, 'the most important measures are not of lamprey population size but of the effect on food/sport fish populations.

Any measure of lamprey abundance that can be converted to mortality rates would be most helpful.

Quantitative measures are needed.

The estimation of stocks in the parasitic stage must be a "guesstimate" based on the rates of feeding, i.e., number and size of fish attacked - if we can estimate the total fish numbers available to the sea lamprey.

Ideally, we want to measure the whole population of the Great Lakes - preferably at or near the adult phase.

We now work with relative measures of abundance (wounding rates) and we would be reasonably content with these if we could better account for the biases.

I would like to see reliable estimates of parasitic phase sea lamprey abundance so that the impact on sport and commercial fish can be assessed.

Ideally, we should quantify numbers of parasitic phase sea lamprey present in the lake, or if this is impossible, provide a direct measure of the impact of sea lamprey on valued fish stocks, such as numbers of lake trout killed by sea lamprey.

I feel that an adequate measure of all phases of the sea lamprey life cycle needs to be evaluated to determine a more precise known inter-relationship between these phases.

Parasitic and spawning phase sea lamprey populations may require quantitative estimates to satisfy the goals set by the Great Lakes Fishery Commission.

We need to upgrade the relative abundance measures to all areas of the lakes with an ultimate goal of estimating numbers basinwide.

An estimate of the predatory population (either as downstream migrants, or as active feeders) is required at the lowest practicable level of spatial resolution.

In terms of sea lampreys in the Great Lakes, enumeration as to numbers of predatory phase animals in the lakes at any given point in time and the corresponding year class structure of this population are desirable.

I believe the number of sea lampreys must be measured as accurately as possible.

Question #1(b):

At what level of detail (precision, spatial/temporal resolution) should the measures be provided?

Only four of the participants responded to this portion of Question 1. It is obvious from the lack of response that most of the participants had no idea what level of detail would be necessary.

Responses:

In considering the precision of any population measurements, various levels could be aimed at: 50%, 25%, 10%, 5%, 1%, etc. Experience suggests that the aim should not be too high - 10% might be realistic, and 10-25% is much more likely to be achieved than 5-10%.

Spatial resolution should presumably be on a lake-by-lake basis. Within lake separation seems unrealistic in view of the potential movements of migrants and feeders.

Temporal resolution, other than for detailed ecological studies of mortality, etc., need not be high. Presumably an annual measurement is desirable, but a biennial or triennial measurement is more realistic as it should, logistically, be a more accurate one.

Given marking rate as the index, we would like to be able to detect 100%, 50%, and 30% changes from initial rates of .03, .10 and.30 marks per 100 fish, respectively, with 95% confidence.

Anything within 25% would probably be adequate, but this is pure speculation on my part.

Several geographic strata should be provided for each Great Lake, and estimate precision should probably be at least +50% of mean values for whatever is used to estimate abundance.

Question #2:

Based on your knowledge of current methods, should present (parasitic phase) data collection practices be changed in order to satisfy the stated needs in terms of precision, reliability and detail?

Ten individuals responded to this question. One stated that present data collection practices may be adequate for parasitic phase lamprey and that what is inadequate is knowledge of what the data mean. All others felt that present data collection practices should be changed but they differed in what changes were needed or how they should be accomplished.

Fisheries investigators usually commented on the collection of wounding data (responses 1-7), while lamprey control personnel usually limited their comments to the collection of lamprey from commercial fishermen (responses 8-10).

Responses:

Present measures of wounding, in my experience, are not presented as lakewide pictures. They tend to be tabular and not made independent of prey densities. We left SLIS, still arguing about buffering effects of alternate prey species because people hadn't made enough simultaneous comparisons of all prey species. The statistics as presently calculated, are insensitive to switching within salmonid size classes. Not enough use is made of wound:scar ratios.

Present data collection practices may be adequate for parasitic phase lamprey. What is inadequate is knowledge of what the data mean.

The present data collection practices should be improved - but this may well be impossible if the cost is to remain within reason, especially during this period of financial constraint.

The present information relies heavily on the commercial fishery for data on number of feeders and incidence of lamprey wounds. The basis of this fishery should be clear and comparable for each year in terms of fishing effort, method (including mesh size), sites fished, etc.

Lamprey abundance indices derived from marking data for single host species (e.g., lake trout) suffer in their reliability if there is no accounting of the frequency and distribution of marks across alternate hosts.

One statistic that is used as an index to the relative abundance of parasitic phase lampreys is the wounding rate on lake trout. The present practice of collecting wounding data in September in Lakes Michigan, Huron, and Ontario (?) leaves a great deal to be desired. Wounding rates are so low in September that lamprey predation is almost ignored.

I think we have relied too heavily on wounding statistics. They are cheap and easy to obtain and in some ways I think we would have been better off if sea lamprey never left a scar. That way we would have been forced to develop another, hopefully better, method of estimating sea lamprey abundance.

Monitoring of the parasitic phase has been primarily limited to collections by commercial fishermen. This could easily be expanded to include the charter (sport) industry.

The predatory phase appears particularly difficult to assess because of the occurrence of size and species preferences, and density-dependent factors that may determine prey/predatory interactions. The consistency and reliability of wounding data are also questionable in many instances.

Our challenge is to improve the precision of the data gathered by developing new or refining existing tools and techniques of collection.

Question #3:

Are there any techniques or approaches that could improve the quality of (parasitic phase) sea lamprey evaluation?

Responses were received from 15 of the participants to this question. In general, fisheries investigators suggested ways of improving current methods of collecting wounding data and proposed studies designed to measure the impacts of lamprey on fish, while sea lamprey control personnel proposed studies designed to measure parasitic phase sea lamprey populations, either in absolute or relative terms.

The following studies, designed to measure the impacts of lamprey on fish, were received:

Three respondents suggested the possibility of being able to quantify the numbers of lake trout killed by sea lamprey, by collecting dead lake trout in trawls.

One person suggested using a deep, trap net type enclosure for conducting a lamprey lake trout interaction study in either a deep inland lake or a Great Lakes bay.

Two respondents suggested that modeling and simulation techniques, including decision analysis, seem most appropriate. However, one person believed that we do not have the necessary information to model lamprey predation realistically.

One respondent believed it might be possible to directly estimate mortality due to lampreys from a well-designed tagging study.

Several approaches were suggested for improving current methods of collecting wounding data used for obtaining measures of relative abundance of parasitic phase sea lamprey. These included the following:

One respondent suggested converting catch effort data to an abundance index by considering temperature and also area in the section of the lake where nets are set. He believed that this is an improvement over the unadjusted catch data generally used in other lakes. When these abundance indices are multiplied by the sea lamprey wounding rates, an index of numbers of sea lamprey attacks is derived. These indices may be a better indication of how many sea lampreys are present than simple wounding rates, since abundance of hosts is considered.

Another approach suggested was to set standard assessment nets in representative areas and look at the number of Al - A3 wounds per gill net foot for all fish species collected. This could automatically account for absolute and relative changes in prey density and differences in prey selectivity. This would provide, at best, a relative index of lamprey density, but might be as useful as species specific wounding rates.

One person suggested that wounding data be collected at a time of the year when the wounding rate is the highest.

TWO respondents suggested improving current methods of collecting parasitic phase sea lamprey from commercial and sport fishermen:

- Monitoring of the parasitic phase has been primarily limited to collections by commercial fishermen. This could easily be expanded to include the charter (sport) industry. There are hundreds, if not thousands, of these people fishing the Great Lakes and many of them are working in areas where there are not commercial fishermen. Beyond that there are the individual sport fishermen. Lots of these people keep very through records of the fish (including scarred fish) they catch and more effort could be made to get the information (and incidentally captured lampreys) from them. These types of data would increase our knowledge of the relative abundance of parasitic lampreys and give more areas to mark/release and recapture lampreys for population estimates.

The largest single improvement in current techniques or approach (as they apply to predatory or spawning phase lampreys) would be to intensify the sampling effort. One of the most troublesome aspects of sampling sea lampreys, especially in respect to numbers, is their tendency to arrange themselves in space in relation to their prey, each other, or to features of the environment, rather than at random. Due to this, the normal assumption of sample independence fails and must be

> corrected. One way to minimize the effects of "patchiness" in the samples is to randomize the sampling locations. Traditional sampling has heretofore been at areas that are convenient or best suited for the purpose. We must look beyond this. Beginning in 1984, we are expanding the collection network for predatory phase lampreys into the sport fishery through charterboat operators basinwide. Expansion in this manner, i.e., increasing the number of sampling locations should result in decreased size of each sample, thereby reducing the overall variance of the data. The proportionality between mean and variance in estimating the number of individuals caught in a sample allows population estimates to be made with small samples (i.e., numbers caught per fishermen) as well as with large and special probability models may be found which fit the data well and can be used to calculate more reliable confidence intervals.

Only two respondents suggested methods for obtaining actual population estimates of parasitic phase sea lamprey. One suggested that mark and recapture studies conducted systematically within defined regions and selected tributaries of the Great Lakes may provide the necessary information to evaluate adult sea lamprey populations. After several consecutive years of mark and recapture studies, regression analysis may provide the data necessary to formulate accurate quantitative estimates of the number of adult *sea* lampreys simply by employing the present methods of data collection.

The other person stated, however, that while mark and recapture studies may be useful, he had not been able to find a formula that could reliability estimate a population of parasitic phase lamprey.

Question #4:

Is there a problem in interpreting sea lamprey evaluation data with regard to measuring the impact of sea lamprey predation on fish populations?

The answer is clearly "yes" and all 24 respondents noted the lack of a clear understanding of the relationship between observed lamprey wounding rates, or other measures of lamprey abundance, and lamprey induced mortality. Pycha (1980) perhaps summarized the problem best when he stated:

> "A number of difficulties have plagued all workers who have attempted to evaluate the effects of sea lamprey predation on lake trout. Foremost is that usually only the survivors of lamprey attacks bearing wounds *or* scars are seen. The incidence of wounds on lake trout is obviously related in some way to attack rates, but the relation of wounding rates to either attack rates or mortality is unclear. Wounding rates vary with time of year, size of lake trout, and almost certainly the predatory/prey ratio. The relation of wounding to mortality of prey may also vary with any or all of these variables."

RECOMMENDATIONS FOR ADDITIONAL STUDIES

In order to implement integrated pest management (IPM) concepts in the control of sea lamprey populations with any degree of success, both effectiveness and efficiency measures of current management techniques are needed, Effectiveness is related to measures of the actual accomplishment of IPM goals, which for the sea lamprey program is the predation impact of the pest on selected host species. The kind of assessment that directly measures program effectiveness should, for example, involve marking rates and captures of lamprey attached to host species. On the other hand, annual estimates of program effectiveness would not provide the information needed to administer the sea lamprey control program most efficiently. In order to effect the control decision-making process, estimates of the parasitic phase population in either qualitative or quantitative terms are needed. It is interesting to note that the respondents to the questionnaire tended to provide answers that reflected their professions. Fishery management personnel were concerned with the need for better effectiveness measures, i.e., host wounding or mortality, while sea lamprey control respondents stressed the need for accurate efficiency measurements. However, it is possible that without the integration of these two definitions of assessments into management practices, the control program may be quite efficient but ineffective or vice versa. The point here is not to construct artificial categories (effectiveness versus efficiency), but to help answer the question of why a particular type of assessment is necessary and how it can expedite decision-making.

An example of the effectiveness/efficiency argument as applied to integrated management of sea lamprey is provided here to clarify the concept. In northern Lake Huron's Statistical District 2 (MH-2) the primary fishery goal in terms of lake committee policy is the rehabilitation of lake trout. Progress towards this goal is good in that substantial natural reproduction has been documented, and to this extent the control program can be termed effective. However, the stocking of Pacific salmon has recently been intensified in this area, and this action, together with the recovery of native species (whitefish and chubs), creates a potential buffer for lake trout against sea lamprey predation. Therefore, it is expected that the effectiveness measures should soon improve without any changes in control. In contrast, assessments that measure efficiency (abundance of sea lampreys) are not expected to change much. Thus the two types of assessment are necessary, although they measure different things.

The parasitic phase study group has made prioritized proposals designed to improve measures of the efficiency and effectiveness of sea lamprey control. The study group identified the need to expand current measures of relative abundance of lamprey as being the most crucial step in improving assessments. This will be carried out through collections of lamprey by both commercial (Proposal B-1A) and sport (Proposal B-1B) fishermen, and by using lamprey wounding rates (Proposal B-1C). The second type of assessment that is most needed is a mark recapture study for quantitative population estimates (Proposal B-2).

The study group's third choice was a proposal designed to determine the stream of origin of individual lamprey (Proposal B-3). It is thought that trace elements which characterize specific streams may be deposited within the statoliths of lampreys during larval development. Therefore, by determining the elemental composition of the statolith, the natal stream may be identified. Lastly, the study group identified the need to examine the relationship between wounding rates in areas of a lake and treatment of specific streams (Proposal B-4). All available wounding data will be analyzed by computer to ascertain any changes in wounding rates in particular lake areas following stream treatments.

Editor's note:

The following proposals were developed more or less independently by individual members of the Parasitic Phase Group, or its correspondents. To that extent the details cited may relate only to circumstances peculiar to the areas or jurisdictions of the proponents. Usually, the proposals can be generalized, with minimal modifications, to apply to all areas and jurisdictions of *the Great Lakes.*

PROPOSAL NO. B-1A
USE OF COMMERCIAL LARGE-MESH TRAP NETS TO DETERMINE ABUNDANCE OF PARASITIC SEA LAMPREYS

BACKGROUND AND JUSTIFICATION

Evaluation of sea lamprey populations began with the implementation of sea lamprey control measures. Electrical barriers, portable assessment traps, selective toxicants, and electrofishing gear provided investigators with opportunities to study the stream-dwelling larval stage and anadromous spawning phase of sea lampreys. Since parasitic sea lampreys are frequently an incidental catch in the commercial fisheries, a reward was offered to fishermen for these lampreys; collections began in 1968 and 1969 on Lake Superior, in 1970 on Lake Michigan, and in 1968 and 1970 on Lake Huron. Parasitic phase sea lampreys were taken in U.S. waters in various commercial fishing gear (gill nets, pound nets, trap nets, and trawls) up to 1974 when the State of Michigan banned the use of large mesh gill nets. The ban led to an increase in trap net fisheries in Lake Michigan, providing an opportunity to sample systematically the population of parasitic sea lampreys in this basin. In Canadian waters of the Great Lakes gill nets and pound nets remain legal fishing gear with certain restrictions.

Effort statistics provided by the Michigan Department of Natural Resources are used by the U.S. agent of the GLFC to determine catch per unit effort (CPE) of parasitic sea lampreys captured in commercial trap nets set for lake whitefish. For 1971-84, CPE of sea lampreys captured in trap nets set for lake whitefish has been used as an indicator of changes in abundance of adult sea lampreys (Table B-X).

SPECIFIC OBJECTIVES

1. Develop a system to monitor the commercial trap net fishery for parasitic sea lampreys that will provide an early and reliable index to significant trends in abundance and locate concentrations of feeding sea lampreys.

2. Establish a network of sampling sites along Lake Michigan to provide quantitative measures of abundance of parasitic sea lampreys and establish criteria for the reliability, accuracy, and detail of data.

3. Evaluate and assess significant changes in sea lamprey populations which would require alteration or modification of present control measures.

4. Assess changes in biological characteristics of sea lampreys such as length, weight, sex ratio, and parasitic/host interactions as associated with variations in population density, fish stocks, and ecology.

5. Determine the impact of new control strategies and integrated pest management.

6. Determine whether the established monitoring system involving the commercial trap net fishery can be a reliable index to trends in the populations of parasitic sea lampreys.

Table B-X. Mean numbers of parasitic phase sea lampreys captured per trap net lift in Statistical Districts of Lakes Superior, Michigan and Huron, 1971-84.

	Lake Superior			Lake Michigan			Lake Huron		
Year	MS-3	MS-4	MS-6	MM-1	MM-3	MM-7	MH-1	MH-2	MH-4
1971		0.03					0.14		
1972		0.03					0.14		
1973		0.01					0.05		
1974		0.03	0.04				0.03		
1975		0.01	0.02				0.15		
1976		0.03	0.04				0.13		
1977		0.01	0.07				0.33		
1978		0.00	0.05				0.53		
1979		0.00	0.02				0.49		
1980		0.01	0.02				0.59		
1981		0.01	0.02	0.02	0.03		0.80	0.38	0.27
1982		0.02	0.01	0.01	0.01		0.40	0.29	0.19
1983	0.02	0.03	0.04	0.05	0.06	0.05	0.43	0.36	0.49
1984	0.01	0.02	0.05	0.03	0.01	0.09	0.41	0.36	0.35

GENERAL PROCEDURE

A. Selection of Lake Basin

In 1974, the State of Michigan banned the use of large mesh gill nets in favour of impoundment gear (e.g., trap and pound nets), with a subsequent increase in the number of trap nets used by the commercial fisheries. Trap net fisheries increased in all the upper lakes, with Lake Michigan having the largest number (35 trap net fisheries) over the widest area (six Statistical Districts). By using this large trap net fishery to systematically sample in Lake Michigan, a reliable index to significant changes in abundance of parasitic sea lamprey populations may be possible.

B. Locations for Fishing Trap Nets

Annual sampling of the 16 Statistical Districts of Lake Michigan, with at least one sample site in each District, is recommended. Commercial trap net fisheries in three Statistical Districts presently collect parasitic sea lampreys. However, the other 13 Statistical Districts would require contracting of commercial trap netters to sample these areas. Sampling sites could be determined for each Statistical District through communication with commercial and sport fishermen and Department of Natural Resources personnel. Considerations in selecting sample sites include: state regulations, sport fishing activity, presence of lake trout, depth, and season. Areas under consideration which are closed to commercial fishing may require special research permits from state jurisdictions, whereas others with intense sport fishing activity may require sampling after cessation of the fishing season.

Presently the primary target species of the commercial trap net fishery is lake whitefish; however many fishermen have commented that large numbers of sea lamprey are collected when lake trout are in their nets. Therefore, in order to sample sea lamprey populations, fishermen would be instructed to fish areas where lake trout are concentrated. Because there are seasonal variations in the bathymetric distribution of lake trout, locations of sampling sites will vary according to season and depth. Consistency of data would require annual sampling of similar sites and temporal resolution of the data.

C. Number of Trap Nets and Fishing Effort Required

In 1984, 11,392 adult sea lampreys were captured in Lake Michigan by commercial and sport fishermen (parasitic phase) and the assessment trap network (spawning phase). Commercial trap nets fished in areas with large numbers of lake trout captured one sea lamprey per 11 trap nets lifted. The number of nets and the fishing effort (number of net lifts) required in each Statistical District to obtain accurate measurements of abundance are not known, but may be acquired from a pilot study. By contracting one commercial trap net fisherman to fish a predetermined area the information needed to determine the amount of nets and effort to obtain the required sample size may be provided.

With the above information, to provide 1% (114) of the total number of adult sea lampreys captured in 1984, 80 trap net lifts per Statistical District and a total of 1,254 trap net lifts lakewide would be required. To provide 5% (570) of the total would require 392 lifts per District and a total of 6,279 lifts lakewide. A cost/benefit ratio is almost certain to be considered in determining the amount of effort needed.

D. Determining Abundance

The abundance of parasitic phase sea lampreys may be estimated by summing the units of sea lamprey catch and fishing effort (one unit of effort constitutes one trap net lifted) in each Statistical District. Individual measurements from each Statistical District may provide an early index of increases in local lamprey populations or unknown populations and indicate a need for changes in control measures.

Predator/prey ratios have a significant impact on the number of sea lampreys captured in trap nets, therefore, CPE would be determined for each size class of host species. Species and size compositions of prey fish stocks then may permit accurate assessment of the effects of residual sea lamprey populations on stocks of lake trout and other prey and establish reliable trends in sea lamprey abundance.

SCHEDULE

January - April:

1. Meet with Lake Michigan commercial and sport fishermen and State Departments of Natural Resources to determine sampling sites, obtain special research permits, etc.
2. Contact commercial trap net fishermen and enter into contract.
3. Distribute materials to commercial fishermen (recording and reporting materials, measuring boards, etc.).
4. Develop computer programs.

May - October:

1. Scheduled field trips to review assessment procedures and collect sea lampreys.
2. Laboratory examination of sea lampreys.
3. Data entry.

November:

1. Final field trips to collect sea lampreys.
2. Laboratory examination of 'sea lampreys.
3. Determine reliability, accuracy, and detail of data base to evaluate parasitic sea lamprey populations.

Successive Years:

1. Begin program in other Great Lakes.
2. Work under WESLP guidelines.
3. Complete quantification of parasitic sea lamprey populations by lake.

PROJECTED FUNDING

Communication with two commercial trap net fishermen indicates that a conservative estimate to contract a trap net fishery would be about $100 per hour. The cost quoted would be for periods of little or no fishing activity, such as early spring or late fall. Distance to fishing areas is another consideration, with time and fuel consumption being the cost factors.

Two to three trap nets can be set or pulled per day and between 10 to 15 trap nets can be lifted per day, depending on weather conditions. Ultimately, the cost would be determined by the number of net lifts needed to provide an accurate measurement of abundance. However, costs may be reduced by permitting fishermen to harvest some fish species.

Supplies and Services	Quantity	Unit Price	Amount
Contract fisheries (13)			
at 5% rate	6,144 hrs	$ 100./hr	$614,400.
at 1% rate	2,048 hrs	100./hr	204,800.
Fishery biologist	1	40,000.	40,000.
Fishery technician	1	20,000.	20,000.
Per diem	20 days	50./day	1,000.
Vehicle expenses	6,450 km	0.125/km	800.
Measuring fish box	16	50.	800.
		Total at 5% capture rate	$677,000.
		Total at 1% capture rate	$267,400.

PROPOSAL NO. B-1B
ABUNDANCE OF PARASITIC PHASE SEA LAMPREYS AS DETERMINED BY LAMPREYS COLLECTED FROM SPORT FISHERMEN

BACKGROUND AND JUSTIFICATION

Present methods to measure abundance of larval and spawning phase sea lampreys have been reasonably reliable, but for the parasitic phase in the lakes, direct measurement of abundance has been difficult. Since 1969, commercial fishermen in Michigan, Wisconsin, -and Minnesota voluntarily collected parasitic phase sea lampreys captured incidentally in their fishing operations. Their cooperation provided some data on parasitic phase lampreys, but many gaps remain in the information. In 1984, commercial fishermen from 19 U.S. Statistical Districts used three types of entrapment gear to collect sea lampreys in Lakes Superior, Michigan, and Huron. However, of the 32 U.S. Statistical Districts within Lakes Superior, Michigan, and Huron, data were not collected from 13 due either to a lack of commercial fisheries or, if present, the commercial fisheries were unable to provide enough sea lampreys primarily because they were not catching the preferred prey, i.e., lake trout. In addition, parasitic phase sea lampreys were not collected from the U.S. Districts of Lakes Erie and Ontario.

The increased numbers of trout and salmon in the Great Lakes led to a tremendous upsurge in the popularity of sport fishing in most areas. Because of high costs of equipment to fish the open lakes, many anglers employ charterboats. Presently, charter operators are represented in nearly all U.S. Statistical Districts of the Great Lakes and capture tens of thousands of fish annually. Sea lampreys, or evidence of their presence, are frequently observed, and this information, as well as numbers and species of fish boated, goes unreported. Therefore the sport fishery and, in particular, the charterboat industry, may provide the means to monitor populations of parasitic phase sea lampreys in a manner more responsive to the needs of the control program. The potential to gain much information from this source is limited only by the amount of effort that can be expended.

SPECIFIC OBJECTIVES

1. Continue the program with charter and sport fishery to monitor parasitic phase sea lampreys that will provide a reliable index to significant trends in abundance and locate concentrations of feeding sea lampreys.

2. Provide quantitative measures of abundance of parasitic sea lampreys and establish criteria for the reliability, accuracy, and detail of data.

3. Establish a network of sites along the Great Lakes for charterboat captains and sport anglers to deposit adult sea lampreys.

4. Assess changes in biological characteristics of sea lampreys such as length, weight, and sex ratios or parasite/host interactions.

5. Evaluate and assess significant changes in sea lamprey populations which would require alteration or modification of present control measures.

6. Determine whether the monitoring program established with the charterboat operators can be a reliable index to trends in populations of parasitic phase sea lampreys.

7. Develop capabilities for logistic support, data entry, and analysis of information received from the Sportfishing assessment network.

GENERAL PROCEDURE

In February 1984, introductory letters and questionnaires (Appendix B-I) were distributed by the U.S. agent of the GLFC to charterboat operators along the Great Lakes either by direct mail or through local charterboat associations. The letters explained the sea lamprey control program, stressed the need to monitor populations of feeding phase lampreys further, and stated that information from this assessment effort could lead to better control and more fish. Individual captains were queried on their fishing effort, numbers of fish caught, and most importantly, the number of sea lampreys observed *or* boated each year in their respective charter areas. Each was asked to volunteer to record observations of sea lamprey abundance in the catch and to retain any boated lampreys. For those agreeing to participate in the program, materials and instructions were provided.

Positive responses were received from 453 (49%) of the fishermen initially contacted by letter. The recording and reporting materials with instructions to participate in the monitoring program were personally delivered, when possible, to develop a cooperative relation with the fishermen. Because of the number of fishermen and their varying schedules, only two to five fishermen could be contacted in a day. However, since many of the fishermen belonged to charter associations, time was arranged at one of their monthly meetings to ask for participation in the program. This arrangement allowed for distribution of materials to a large number of participants at one time. Other operators, such as those residing outside of the areas in which they fished, were mailed materials and instructions.

Of the 453 charterboat operators willing to participate in the program, 396 were contacted. Materials and instructions given to the fishermen included a booklet which contained data sheets to record the following: lampreys boated, lampreys lost, fish and fresh marks (AI - AIII), fish with old marks, total fish boated by species, total hours and lines fished, and area of lake fished (Appendix B-II). Data sheets returned by individual captains were examined for completeness and for information on lampreys observed or captured. These data were entered into the computer. A letter of acknowledgement was sent to each captain, and fishermen were given a lure as a reward for each lamprey recorded.

To supplement the charter program, we collected lampreys captured incidentally by the general Sportfishing public. Sites were established at local marinas, harbors, and stores to collect lampreys. Signs were posted around waterfronts to notify the public of the reward and where to deposit the lampreys (Appendix B-III). Collections of lampreys at the various sites along with associated data forms (Appendix B-IV) completed by sport anglers were made periodically throughout the summer. Final collections of the season were completed by the second week of November.

RESULTS

Information on sea lampreys was returned from charter captains and noncharter fishermen in 1984. Of the 396 charter captains contacted, 168 captured 190 feeding lampreys and returned data on thousands of fish (primarily lake trout and chinook salmon), including marking rates of sea lampreys on these fish. A total of 1,423 parasitic lampreys also were turned in for a reward by noncharter fishermen.

Since this was the first year that an attempt was made to monitor the incidence of sea lampreys in the charter fishery, a specific approach to measure abundance was not set. Possible combinations within the data are: total count of lampreys, lampreys/total fish caught, lampreys/total number of a fish species, and lampreys/fishing line hour. The recording of lamprey marks on fish will be in the same manner as other agencies report the data, i.e., the percentage marked of a fish species. Areas of coverage will be either a Statistical District, or a combination of several. It is doubtful that reporting on a lakewide basis will be adequate.

SCHEDULE IN 1984

January - April:

1. Prepare letters and questionnaires and mail.
2. Organize field schedule.
3. Order and prepare materials for distribution.
4. Contact charterboat organizations and attend meetings as possible.
5. Develop computer programs for data.

May - June:

1. Set up collecting stations or sites.
2. Distribute materials to interested charterboat operators.

July - September:

1. Regularly scheduled visits to all collecting stations and cooperating charterboat operators.
2. Process collected lampreys.
3. Data entry.

October - November:

1. Final collections made from all collecting stations and charterboat operators.
2. Reminders sent to cooperators for return of data.

Successive years:

Automatic enlistment of charterboat operators in all lakes, working under WESLP guidelines, and complete quantification of parasitic sea lamprey populations by lake.

PROJECTED FUNDING (U.S. waters of the upper Great Lakes)

Supplies and Services	Quantity	Unit Price	Amount
Fishery biologist	1	$40,000.	$40,000.
Fishery technician	2	20,000.	40,000.
Per diem	120 days	50./day	6,000.
Vehicle expenses	36,200 km	0.125/km	4,500.
Fishing lures	2,000	0.82	1,640.
Binders	1,300	0.48	624.
Pails, 6-gal.	200	2.48	496.
Tags, waterproof	5,000	0.08	400.
Signs (reward)	500	0.80	400.
Envelopes	5,000	0.06	300.
Sacks, shipping	3,300	0.09	297.
Formaldehyde 5-gal. container	6	46.96	282.
Containers, l-gal.	400	0.70	280.
Container lids	400	0.25	100.
Postcards	5,000	0.27	1,350.
Clipboards	100	0.68	68.
			$96,737.

PROPOSAL NO. B-1C
ESTIMATION OF RELATIVE ABUNDANCE OF PARASITIC PHASE SEA LAMPREY FROM LAKE TROUT ASSESSMENT DATA

BACKGROUND AND JUSTIFICATION

The derivation of the model for estimating sea lamprey abundance from marking rates and fishery statistics (Pycha and Koonce; Ms) was outlined in this report (pages 9 to 15 inclusive, Section B). The analysis reveals a good correlation between the observed marking rates in the United States waters of Lake Superior and the estimates of sea lamprey abundance obtained from the electrical barriers during their period of operation. Furthermore the predictions of sea lamprey induced mortality are consistent with other measures of mortality. It is believed therefore that this protocol may provide reliable indices of sea lamprey abundance in other Great Lakes where a preferred prey species hold a dominant position in the fishery.

OBJECTIVES

1. General Objective: To continue testing and refining the protocol for estimation of relative abundance of parasitic phase sea lamprey.

2. Specific Objectives:

   a) Attempt a finer spatial scale of analysis for Lake Superior.

   b) Extend the analysis to Lakes Michigan, Huron, and Ontario.

GENERAL PROCEDURE

Because the analysis protocol has already been developed and documented in Koonce and Pycha (Ms), the procedures for this project concern the development of a data base for marking and CPE statistics of lake trout in the Great Lakes. Of necessity, these data must be less aggregated than they have been in past reports to Lake Committees of the GLFC. The work will occur in two phases:

Phase I. Documentation of existing data sets and design of data base. Working through biologists on the Technical Committees for each lake, project personnel will obtain descriptions of marking and lake trout assessment data sets; conditions of availability; and key agency contacts for access. From this survey, a common data base format will be developed for microcomputer applications (i.e., IBM-PC, Apple IIE, etc.). An interim report concerning the data base will be submitted at the conclusion of this Phase, and it will be circulated along with an analysis plan for Phase II to correspondents in the survey and other interested parties.

Phase II. Using the protocol tested on selected data from Lake Superior, the second phase of the project will reconstruct historical patterns of relative abundance of parasitic phase sea lamprey for at least three levels of spatial resolution: whole lake; major geographical units; and the smallest possible Statistical District representation. These patterns will be reported in a final report along with comparisons, where possible, to other indications of abundance of sea lamprey.

SCHEDULE

This project should require only one year to complete. An interim report on Phase I should be done in six months, and the final data collation, data base preparation, and analysis should be complete by the end of 12 months of work.

PROJECTED FUNDING

BUDGET

PERSONNEL		
Principal Investigator (2 months)		$ 7,400.
Technician (12 months)		20,000.
	Total Personnel	$27,400.
COST COMPONENTS		
Travel		$ 5,000.
Communication		1,000.
Printing and Reproduction		750.
Data Base Software License		1,500.
Telecommunication Equipment		3,000.
	Total Cost Components	$11,250.
ADMINISTRATIVE COSTS		
Overhead and Indirect Costs		$32,000.
TOTAL BUDGET		$70,550.

PROPOSAL NO. B-2
MARK AND RECAPTURE STUDY FOR POPULATION ESTIMATES OF PARASITIC PEASE SEA LAMPREYS

BACKGROUND AND JUSTIFICATION

Previous mark and recapture studies in northern Lake Huron showed extensive movement of parasitic sea lampreys with frequent interchange among the lakes, but without apparent pattern (Smith and Elliott 1953; Moore et al. 1974). Although electric barriers were operated to capture spawning run sea lampreys in many rivers at that time, few of the marked lampreys were recovered in streams; most were recaptured in the lakes (Petersen disc tags used to mark the lampreys became entangled in commercial fishery nets). These studies were conducted when lake trout were virtually extinct in Lake Huron and before completion of the first round of lampricide treatments in 1967 (Smith 1968).

Since the earlier studies, conditions have changed. Massive numbers of lake trout have been planted in Lake Huron annually beginning in 1973 (Great Lakes Fishery Commission 1983) and sea lamprey populations have been reduced through periodic applications of TFM.

A study conducted on the movement of parasitic sea lampreys marked in northern Lake Huron in 1981 to 1982 and their use of spawning streams showed that a reasonably good return of marked adults could be expected (12.2%). A total of 830 parasitic phase sea lampreys were marked and released in May to October 1981 in northern Lake Huron. Of these, 101 were recaptured - 9 as parasitic adults in commercial nets in 1981, and 92 as spawning adults in sea lamprey traps set in three tributaries of Lake Huron and five tributaries of Lake Michigan in 1982. Although a few marked sea lampreys moved long distances (maximum, 534 km), 72% of the recoveries were in tributaries of northern Lake Huron. A population estimate using the number of sea lampreys marked in 1982 (83) and the number recaptured in tributaries of northern Lake Huron in 1982 (66) with the number examined for marks in these tributary streams (20,246), suggests a population of about 250,000 spawning phase sea lampreys in northern Lake Huron in 1982.

SPECIFIC OBJECTIVES

1. Provide quantitative measures of abundance of parasitic phase lampreys and establish criteria for the reliability, accuracy, and detail of data.

2. Establish a network of sites along Lake Huron to mark and release parasitic sea lampreys,

3. Determine whether an assessment program involving a mark and recapture study can be a reliable index to trends in the population of parasitic sea lampreys.

4. Assess changes in the biological characteristics of sea lampreys such as length, weight, and sex ratio and parasite/host interactions.

5. Evaluate and assess significant changes in sea lamprey populations which would require alteration or modification of present control measures.

6. Development of total automatic data processing capabilities 'for logistic support, data entry, and analysis of information generated from the mark and recapture study.

7. Develop an assessment program for parasitic sea lampreys by monitoring the catch and making observations in the commercial and sport fisheries, to provide a reliable index to significant trends in abundance and to locate concentrations of feeding sea lampreys.

GENERAL PROCEDURE

A. Selection of Lake Basin

Sea lamprey population estimates on a lakewide basis will require large numbers of adults to be marked and released. Optimistically, the estimated numbers of parasitic sea lampreys that may be expected to be marked and released in Lakes Superior, Michigan, and Huron are 200, 400, and 2,600, respectively. Because more parasitic sea lampreys are available from Lake Huron, this lake basin is being selected for a proposed mark and recapture study for population estimates. In 1984, 3,831 parasitic sea lampreys were captured in Lake Huron by the commercial and sport fisheries of the United States and Canada (Table B-XI), and of these it is estimated that 2,640 (69%) could be marked and released. Presently, most commercial and many sport fishermen are collecting parasitic sea lampreys for the sea lamprey control agents in response to a reward. However, through a concentrated effort to contact and enlist the cooperation of additional commercial and sport fishermen, and by increasing the reward, additional sea lampreys may be obtained.

B. Collecting Live Sea Lampreys

Incidentally caught parasitic phase sea lampreys have been obtained from the commercial fisheries of Lake Huron since 1969 (Canada) and 1970 (United States). Trap net fisheries in northern Lake Huron and gill net fisheries in the western end of the North Channel have provided consistently most of the sea lamprey from Lake Huron. Live sea lampreys for a mark and recapture study could be obtained from trap net fisheries (number in parentheses) in Statistical Districts of MH-1 (5), MH-2 (1), MH-4 (1), NC-2 (1), OH-1 (2), OH-5 (1) and from gill net fisheries in Statistical Districts of MH-1, MH-4, and all Canadian Statistical Districts (Figure B-8). As an incentive toward cooperation by the fishermen, a reward of $5. would be paid for each sea lamprey captured alive. Insulated containers and wire mesh cages would be provided to the fisheries to transport and hold the live sea lampreys at dockside until they could be marked and released.

In 1984, sport fishermen from eight ports along the western shore of Lake Huron captured parasitic phase sea lampreys in five Statistical Districts. These ports in Michigan (Rogers City, Harrisville, Oscoda, Tawas City, Port Austin, Grindstone City, Harbor Beach, and Port Sanilac) along with Alpena and Port Huron could become collection sites for live sea lampreys. Live sea lampreys could be held in wire mesh cages at marinas or in facilities used to hold fish bait at sport and bait shops.

C. Mark and Release Methods

Sea lampreys captured by commercial gill netters and in the sport fisheries would be marked at the holding sites (marinas or sport and bait shops). As commercial trap netters capture large numbers of sea lampreys agency personnel should accompany the fishermen when lifting nets to mark captured lampreys and release them near the point of capture.

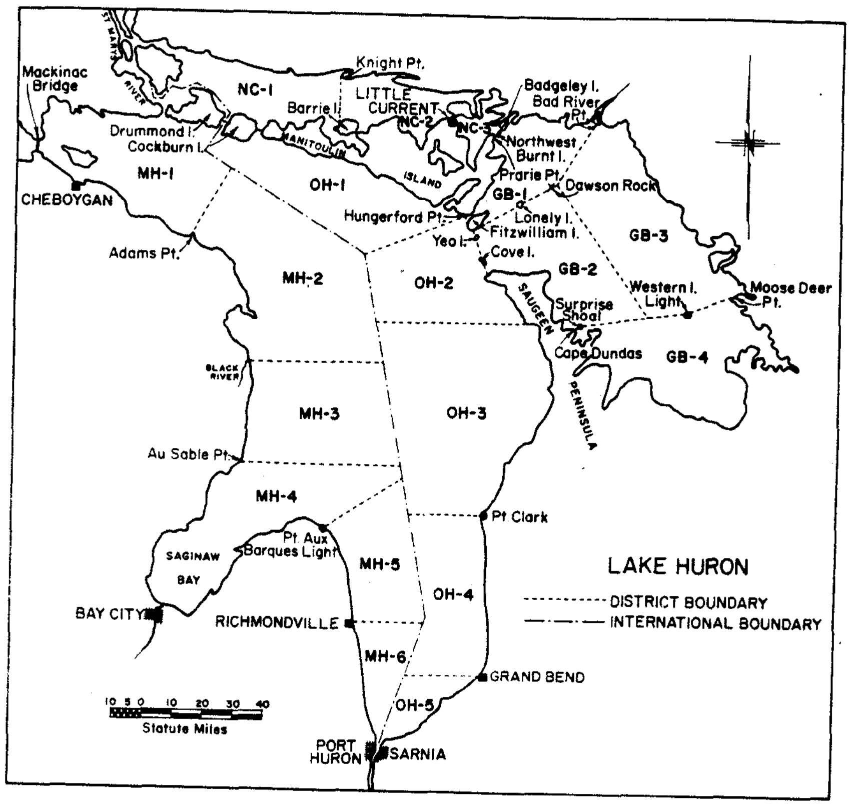
Table B-XI. Number of parasitic phase sea lampreys captured by the commercial and sport fisheries, estimated number of parasitic phase sea lampreys that could be marked and released, and the number of spawning phase sea lampreys captured in assessment traps by Statistical District of Lake Huron, 1984.

	Commercial and Sport Fisheries Parasitic Sea Lampreys		Assessment Trap Spawning Sea Lampreys
Statistical District[a]	Number Captured	Estimated number for marking and release	Number Captured
	United States		
MH-1	1,067	860	20,747
MH-2	158	155	-
MH-3	764	380	-
MH-4	266	150	-
MH-5	149	75	-
	Canada		
NC-1	821	600	5,359
NC-2	237	175	-
NC-3	0	0	-
OH-1	299	220	71
OH-2	0	0	-
OH-3	0	0	-
OH-4	0	0	-
OH-5	20[b]	0	-
GB-1	0	0	-
GB-2	0	0	-
GB-3	0	0	-
GB-4	0	0	-
Total	3,831	2,640	26,177

[a] Boundaries are defined in "Fishery Statistical Districts of the Great Lakes", by S. H. Smith, H. J. Buettner, and R. Hile, Great Lakes Fishery Commission Technical Report No. 2, 1961.

b Estimated number.

Figure B-8. The Canadian and United States Statistical Districts of Lake Huron.



After capture, lampreys would be anesthetized in a 75-g/L solution of tricane methanesulfonate, measured (total length in millimeters), injected with dye, revived in fresh water, and released. Sea lampreys would be marked by injecting rose and kelly green pigments into the posterior dorsal fin. From *two* to five stripes of pigment could be injected into each dorsal fin to identify the area of release. Rose pigment is more visible than kelly green and should be used in at least one of the stripes. Lampreys that are not marked and released immediately (commercial trap net operations) would be transported in an insulated container to holding facilities, marked at a later time, then transported and released near the point of capture. Transport to the release site could be provided by either the captor or sea lamprey control personnel.

D. Recapture Methods

Marked sea lampreys would be recaptured in commercial or sport fisheries (parasitic phase), or in the assessment trap system (spawning phase). Since the assessment trap system in central or southern Lake Huron is not sufficiently extensive to provide the necessary returns for these areas, it may be necessary to expand the system or employ alternate methods to capture spawning sea lampreys. It may be possible to contract commercial pound net fishermen to fish near mouths of streams infested with sea lampreys. One commercial pound net fisherman along Lake Michigan captures many spawning sea lampreys (40 to 235) annually off the mouth of the Ahnapee River.

E. Population Estimates

Estimates by the adjusted Petersen method could be made on a geographical or regional basis. Regions would include the marking area or areas and the recapture areas and monitored rivers. Lampreys that strayed considerable distances however, would not be included. A major problem in most population estimates is to correct for bias created by immigration and emigration of marked and unmarked animals to and from a study area. Parasitic phase sea lampreys marked in Lake Huron could be captured in any of the Great Lakes, and if these were included, the geographical boundaries of the population would be difficult to define. To minimize the effects of straying however only those collected in Lake Huron would be considered, The number of parasitic phase sea lampreys in Lake Huron could be estimated by summing the estimates of the populations in smaller geographical or regional areas. In this manner, the sum of estimates for groups of parasitic phase sea lampreys may be compared with the summed estimate for spawning run adults. Discrepancies among individual or grouped estimates may serve to detect unknown populations or identify disturbing factors (e.g., a small estimate for spawning adults in comparison to the estimate of parasitic adults may be the result of mortality in the parasitic phase).

After mark and recapture studies have been conducted for a number of years, analytical models could be developed, whereby the number of sea lampreys captured in the commercial and/or sport (charterboat) fisheries of a region would be related to population estimate of sea lampreys in that region. An estimate for the lake basin probably would be derived through summing regional or geographical estimates.

SCHEDULE

January - April:

1. Enlist cooperation of commercial and sport fishermen in collecting and releasing live parasitic sea lampreys.

2. Construct wire mesh cages for holding live parasitic sea lampreys.

3. Order and purchase needed supplies (insulated containers, anesthetic, marking dyes, etc.).

4. Develop computer program for data.

5. Distribute wire mesh cages (marinas, docks, bait shops, etc.) and insulated containers (commercial and charterboat fishermen).

May - October:

1. Conduct field marking of parasitic sea lampreys and record data.

November - March:

1. Evaluate data collected.

2. Send reward monies to fishermen.

April - August:

1. Conduct intensive assessment trapping operation in all applicable streams for spawning sea lampreys.

2. Possible contracting of commercial fisheries to fish near the mouths of sea lamprey streams that are not included in the assessment trapping operation, or alternate methods.

September:

1. Analysis of data.

2. Determine reliability, accuracy, and detail of data base to evaluate parasitic sea lamprey populations.

PROJECTED FUNDING (U.S. and Canadian waters)

Supplies and Services	Quantity		Unit Price	Amount
Fishery biologist	2		$40,000.	$ 80,000.
Fishery technician	2		20,000.	40,000.
Lampreys (reward)	2,640		5.	13,200.
Per diem	170	days	50./day	8,500.
Vehicle expenses	64,500	km	0.125/km	8,000.
Wire mesh cages	30		50.	1,500.
Insulated containers	18		33.	594.
Total				$151,794.

Possible additional costs to recapture spawning phase sea lampreys off the mouths of four U.S. streams (Carp, Pine, Au Sable, and Rifle Rivers).

Contract fisheries	270	hours	100./hour	$ 27,000.

PROPOSAL NO. B-3
THE USE OF SEA LAMPREY STATOLITH COMPOSITION TO DETERMINE STREAM OF ORIGIN

BACKGROUND AND JUSTIFICATION

If the origin (natal stream) of parasitic phase animals could be determined, control measures could be focussed on major problem areas - an approach that would considerably enhance program efficiency and effectiveness. Of the two general approaches to determining origin of parasitic phase animals, marking sub-adults in streams or analyzing natural marks, only the latter approach will be discussed here.

Differences in elemental composition (trace elements) of ammocoetes caused by chemical differences in watersheds may be measurable and so provide a basis for determining the origins of adult lamprey. This approach is apparently successful for striped bass in the Atlantic. The equipment used in the striped bass analysis is an X-ray technique which could be undertaken by examining the first 3 to 4 years of statolith deposit. If sufficient trace elements are found in the statoliths, then animals from several watersheds would be compared for significant differences in composition.

Even if the elemental composition technique will not generally work because of high intrinsic variance, it still might be practical, for example, for separating St. Marys River populations from lamprey originating elsewhere. This might work on the St. Marys because of upstream industrial effluents (steel mill) that could uniquely mark downstream ammocoetes with various metals. The St. Marys problem is of sufficient scale to warrant the research for this single purpose, and accordingly it is recommended that feasibility research be initiated.

SPECIFIC OBJECTIVES

1. To determine the elemental composition, particularly of trace elements, of sea lamprey statoliths.
2. To separate Lampreys of St. Marys River origin from other populations.
3. In the long term, to use the elemental composition of statoliths to separate lampreys as to stream of origin.

GENERAL PROCEDURE

For purposes of a pilot or feasibility study, it would be adequate to test a single. batch of 10 larger ammocoetes collected from the St. Marys River. Statoliths would be removed from the study animals and forwarded to a laboratory for examination by X-ray microprobe and subsequently by electron scanning microscopy. A report of elemental composition will then be prepared to complete the contract.

SCHEDULE

Once the collections are made, the laboratory work and write-up could be completed within a month. The collections would be made by the control units, and statolith removal could be undertaken either by sea lamprey control or research personnel or by the principal investigator.

PROJECTED FUNDING

Because this is only a pilot study involving a few specimens, the laboratory and write-up costs should not exceed $2,500.

PROPOSAL NO. B-4
EXAMINATION OF LAMPRICIDE TREATMENTS AND SUBSEQUENT EFFECTS ON LAMPREY WOUNDING OF LAKE TROUT FOR DETERMINATION OF ORIGINS AND MOVEMENTS OF PARASITIC PHASE SEA LAMPREYS

BACKGROUND AND JUSTIFICATION

Most aspects of the biology and effects on fish populations of parasitic phase sea lampreys are incompletely known. Among the poorly known aspects of the lamprey's life history are the natal stream of parasitic lampreys in the lake and the movements from the natal stream to various places in the lake. Whether these movements are widespread and random or systematic is unknown. Attempting to determine dispersal of lampreys by mark and recapture methods is impractical because of the difficulty of obtaining transforming individuals in streams and of capturing significant numbers of parasitic individuals in lakes. Attempts to relate wounding rates in the lake to catches of spawning run lampreys in a particular stream are invalid since lampreys do not home to their natal streams.

One method of gaining insight into the origins and movements of parasitic phase lampreys is to systematically examine changes in lamprey wounding rates in various localities following treatments of streams. Some work of this kind done during the 1960's (H. H. Moore, USFWS, Marquette, Personal communication) achieved some success in scheduling stream treatments in response to reported areas of high wounding on lake trout and subsequent elimination of these "hot spots". The lamprey wounding data were hand summarized by ports and fishermen. In some cases, the locality of high wounding was readily apparent, but the summaries for some ports included data from as much as 80 km of shoreline. Data from five sampling areas in Wisconsin were pooled, and few if any data were available from the entire Minnesota shore. Wounding data since 1970 from U.S. waters summarized by states cover such broad geographical areas as to be worthless for the purpose of this proposed study. Wounding rates in the 1960's were not reported by size of lake trout and differences in abundance of lake trout in various localities could not be accounted for. Interpretation was, therefore, difficult.

SPECIFIC OBJECTIVES

1. To examine the entire stream treatment schedule and subsequent changes (reductions) in - lamprey wounding rates on lake trout at individual fishing grounds.

2. If possible, to pinpoint the areas that most lampreys from given streams or groups of streams move to for all U.S. and, if data are available, Ontario waters of Lake Superior.

3. To determine, from observed effects on wounding rates, which streams are the major producers of sea lampreys for comparison with similar evaluations from stream treatment and surveys.

4. If and where possible, to develop a generalized pattern of movements of lampreys from streams in all areas of the lakeshore.

GENERAL PROCEDURE

All raw and computerized data on lamprey wounding versus size and abundance of lake trout, by statistical grids, would be obtained. This information includes the computer files of Wisconsin, Ontario and Michigan (1977 to 1984), the raw data summaries from all Minnesota sampling areas gathered during the early 1960's to 1984 and all information available from Michigan for the period 1959 to 1976. The data will be placed in a master file at the USFWS Marquette Biological Station. It will then be possible to summarize lamprey wounding rates by individual fishing grounds or by areas as small as sample sizes will allow. It will also be possible to standardize the wounding rates with the size of lake trout. The entire 1958 to 1984 stream treatment schedule can then be systematically examined to compare changes in lamprey wounding rates at any locality with control effort. An appropriate time delay between treatment and wounding rates will have to be established to attain these objectives. Most of the above procedure can be programmed and done by a computer. Appropriate restrictions on use of and release of data from the master file would be formulated and observed.

SCHEDULE

Work on data entry could probably begin at the Marquette Station after the lamprey control field season in 1985. Estimated time for data entry is six months or one year, depending on whether one or two data entry operators were available. The estimated time for analytical work after all data are entered is six months.

PROJECTED FUNDING

Data entry personnel	1 man-year	$20,000.
Professional biologist	6 months	20,000.
		$40,000.

To make this study feasible, the biologist should be thoroughly familiar with sea lamprey life history, stream treatment schedules, problem streams, poor treatments, and the contents of data files on stream treatments, plus knowledge of programming and operation of the Marquette Biological Station's computers. Whoever is in charge of the study would require some help from biologists in Minnesota and Michigan and the USFWS Ashland Biological Station for coding locations to statistical grids and resolving mistakes or omissions in raw data.

Editor's Note:

The following report, white not a part of the original document of the Spawning Phase Sea Lamprey Group, was presented at the Plenary Session of WESLP and adopted as a Proposal for study. It is included here for the sake of Completeness.

PROPOSAL NO. B-S
ASSESSMENT OF LAKE TROUT CARCASSES IN LAKE ONTARIO[1]/

R. Bergstedt
U. S. Fish and Wildlife Service[2]/
Oswego, New York

Dead lake trout observed during 1984 supported our hypothesis that lamprey attacks cause most natural mortality of lake trout during fall. We recovered and examined 25 lake trout carcasses from Lake Ontario during October and November, Eight were recovered incidental to the October sculpin assessment, ten in down-the-bank tows made especially to recover carcasses during the sculpin assessment, six in additional down-the-bank tows made during November, and one was recovered in a trawl tow by the State University Research Center at Oswego. All 25 bore fresh lamprey wounds, which brought the number of consecutive carcasses bearing fresh wounds observed during fall of 1982 to 1984 to 45. Unless the actual proportion of natural mortality in fall caused by lamprey attacks was close to 100%, the probability of making such an observation would be negligible.

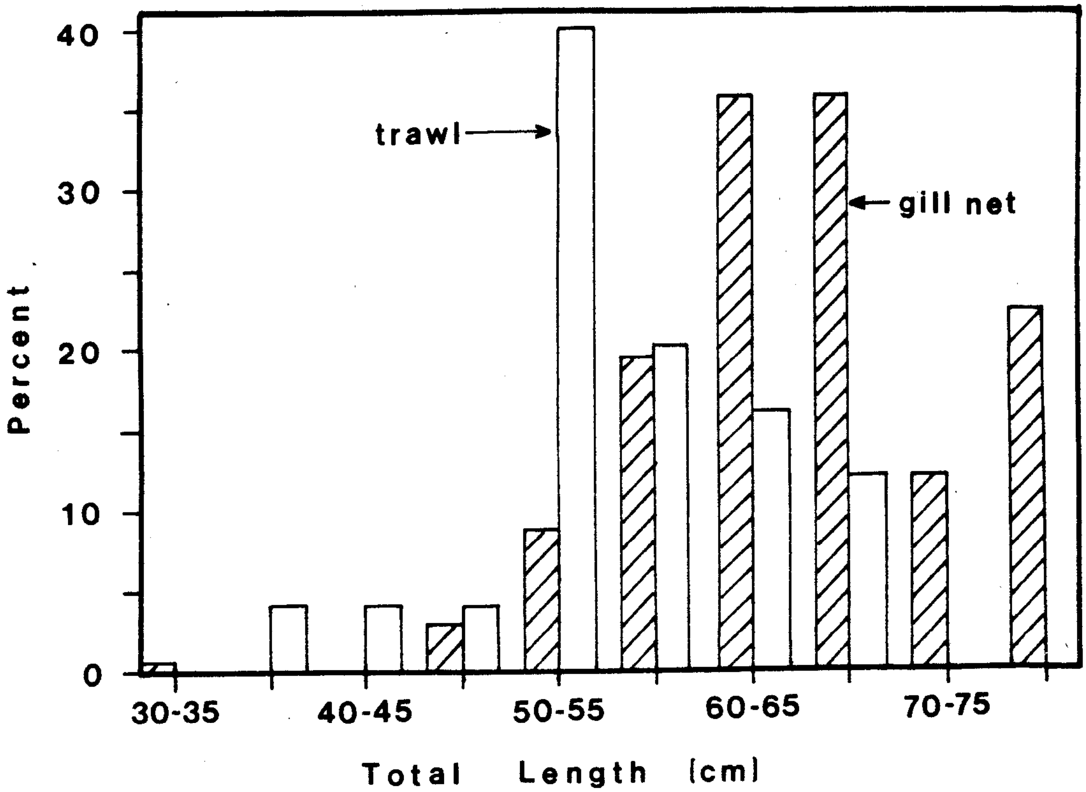
Assuming the 25 dead lake trout examined during fall 1984 died as a result of their wounds, this sample provided the first opportunity to examine the age and size distributions of lake trout that did not survive lamprey attacks. Younger (or smaller) lake trout were conspicuously absent from the sample (Figure B-9), suggesting that low wounding rates on juvenile lake trout reflected low attack rates and not low survival from attack. The number killed rose sharply at age IV+ (or 550 mm). Fish age VI+ or older (or longer than 750 mm) were also not present in the sample. Both the length and age distributions of dead fish were significantly different than those of wounded fish in the gillnet sample (Chi-square, $P<0.01$). Wounded fish were longer and older than dead fish. Analysis is not complete, but these data should yield further insights into the relation between size of host and probability of death from attack.

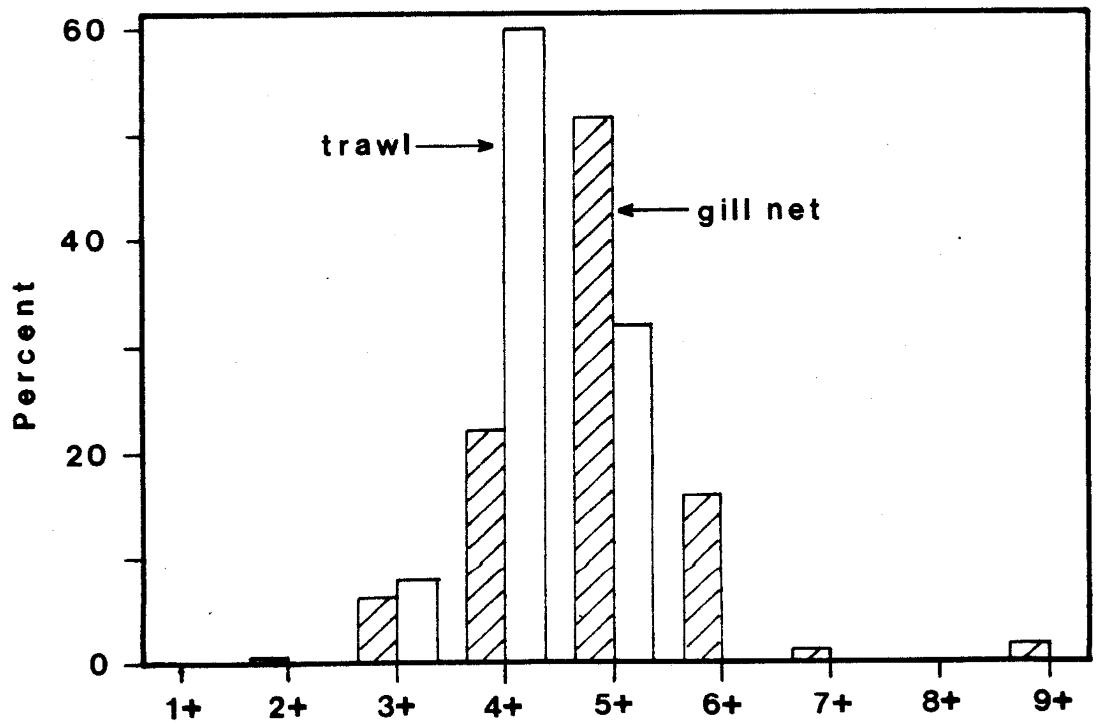
Provisional estimates of the number of carcasses were made from incidental catches during the 1982 and 1984 sculpin assessments and from seven down-the-bank tows during the 1984 sculpin assessment as follows: $P = (C \pm 1.96\ C)$ (total area)/(area swept), where C is the number of carcasses recovered and total area is the area between the 40-m depth contour and the deepest depth fished in each area of the lake (excluding the eastern basin) for the incidental catches and between the 30- and 100-m depth contours (excluding the eastern basin) for the down-the-bank tows. Confidence intervals were calculated using the Poisson distribution. The numbers of carcasses recovered and (in parentheses) estimated numbers of carcasses with 95% confidence intervals were: 13, (84,000 ı 45,000) from the 1982 incidental catch; 8, (72,000 ± 50,000) from the 1984 incidental catch; and 10 (67,000 ± 42,000) from the seven down-the-bank tows. Because the distribution of effort (and total area for expansion) differed, the estimates are not strictly comparable. However, the similarity between all three estimates suggests that carcass density in 1982 and 1984 was conservatively of the magnitude suggested by these samples.

1/ Presented at: Great Lakes Fishery Commission
Lake Ontario Committee Meeting
Niagara Falls, New York - March 5-6, 1985

2/ Present address: USFWS, Hammond Bay Biological Station
Rt. 1, Box 441, Millersburg, MI 49759

Figure B-9. Length and age distributions of 25 lamprey-killed' lake trout recovered with trawls and 172 lamprey-wounded lake trout captured with gillnets during fall, 1984.





APPENDIX B-I. Form letter sent to charterboat operators by the Marquette Biological Station.

1. Your name and address (please print)

____

____

____

2. Your port of call ______________________________

3. Vessel name ______________________________

4. Would you be willing to participate in the program outlined in the letter? Yes No

5. Approximate number of sea lampreys caught per year __________

6. Approximate number of hours spent fishing each year __________

7. Do you feel that sea lampreys in your area of fishing are: Increasing Decreasing Constant in numbers?

8. Time/location/phone number where you could be contacted during working hours to arrange for receipt of materials necessary for the program ______________________________

____

9. Member of local charterboat association? Yes No
Name of association, time and place of regular meeting?

____

____

10. Comments ______________________________

____

____

____

Please return this form in the attached envelope.
Thank you.

APPENDIX B-II: Record form issued to charterboat operators by the Marquette Biological Station, for recording sea lamprey information.,

MONTH ______ (first half)

Captain Name ______ Home Port ______

Vessel Name ______ Fishing Port During Month ______

Day	Hours Fished	Lines Fished	CHINOOK Total No.	CHINOOK Number with Sea Lamprey Wounds	CHINOOK Number with Sea Lamprey Scars	CHINOOK Number of Sea Lampreys Lost	CHINOOK Number of Sea Lampreys Caught	COHO Total No.	COHO Number with Sea Lamprey Wounds	COHO Number with Sea Lamprey Scars	COHO Number of Sea Lampreys Lost	COHO Number of Sea Lampreys Caught	LAKE TROUT Total No.	LAKE TROUT Number with Sea Lamprey Wounds	LAKE TROUT Number with Sea Lamprey Scars	LAKE TROUT Number of Sea Lampreys Lost	LAKE TROUT Number of Sea Lampreys Caught	TAG NOS.
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Day	Hours Fished	Lines Fished	BROWN TROUT Total No.	BROWN TROUT Number with Sea Lamprey Wounds	BROWN TROUT Number with Sea Lamprey Scars	BROWN TROUT Number of Sea Lampreys Lost	BROWN TROUT Number of Sea Lampreys Caught	RAINBOW TROUT Total No.	RAINBOW TROUT Number with Sea Lamprey Wounds	RAINBOW TROUT Number with Sea Lamprey Scars	RAINBOW TROUT Number of Sea Lampreys Lost	RAINBOW TROUT Number of Sea Lampreys Caught	OTHER Total No.	OTHER Number with Sea Lamprey Wounds	OTHER Number with Sea Lamprey Scars	OTHER Number of Sea Lampreys Lost	OTHER Number of Sea Lampreys Caught	TAG NOS.
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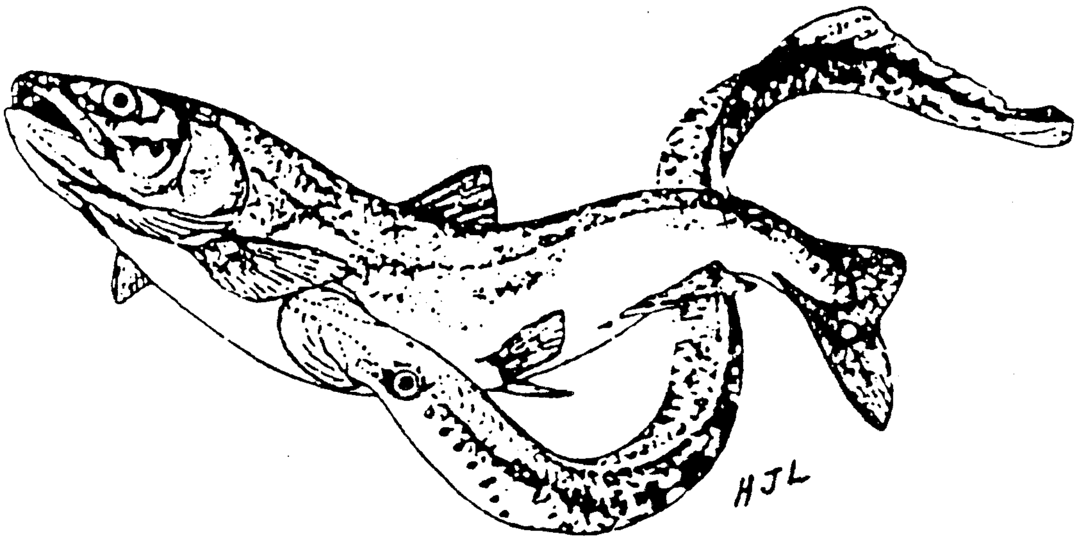
Appendix B-III. Sign posted at waterfronts by the Marquette Biological Station to inform the public about the sea lamprey bounty project.

R E W A R D

FOR SEA LAMPREYS



A REWARD

IS OFFERED FOR SEA LAMPREYS CAPTURED IN SPORT CATCHES OF TROUT AND SALMON

Please bring all lampreys to: ______________________

____

INFORMATION FROM THE SEA LAMPREYS CAPTURED BY SPORT FISHERMEN WILL HELP TO REDUCE POPULATIONS IN THE GREAT LAKES

For more information call USFWS at: 906 226-6571

United States Department of the Interior
FISH AND WILDLIFE SERVICE
Marquette Biological Station
446 E. Crescent St.
Marquette, MI 49855

Appendix B-IV. Data form issued by the Marquette Biological Station to sport fishermen to use in recording sea lamprey information.

SEA LAMPREY INFORMATION

The information will be used to monitor parasitic sea lamprey populations to learn more about the parasitic phase of the sea lamprey which may help to reduce populations further in the Great Lakes. A reward is offered for each sea lamprey captured.

PLEASE FILL OUT ONE FORM FOR EACH LAMPREY CAPTURED

Tag Number: ____________________ Date of Capture: ____________________
(Please attach tag to lamprey)

Location of Capture (City): ____________________

____

Method of Capture: Trolling __________ Casting __________

Species of fish lamprey is attached *to:*

Chinook __________ Brown Trout __________

Coho __________ Rainbow Trout __________

Lake Trout __________ Other (specify) __________

Number of fish caught on this day:

Chinook __________ Brown Trout __________

Coho __________ Rainbow Trout __________

Lake Trout __________ Other (specify) __________

Approximate length of fish lamprey was attached to: __________

Comments: ____________________

____

Name and address of fishermen *(please print):* ____________________

____

U.S. Fish and Wildlife Service
Sea Lamprey Control Station
229 South Jebavy Drive
Ludington, MI 49431 (phone 616-845-6205)

SECTION C

SUMMARY OF EVALUATION METHODS AND POPULATION STUDIES OF SPAWNING PHASE SEA LAMPREY

by

Harold A. Purvis
United States Fish and Wildlife Service
Marquette Biological Station
Marquette, Michigan 49855

and

Rodney B. McDonald
Department of Fisheries and Oceans
Sea Lamprey Control Centre
Sault Ste. Marie, Ontario P6A 1P0

EXECUTIVE SUMMARY

The report of the Spawning Phase Group of the Workshop to Evaluate Sea Lamprey Populations reviews present methods used to assess relative abundance of spawning phase sea lampreys, identifies the needs to upgrade assessment strategies, and recommends methods to improve collection and interpretation of the assessment data. The goal of the Group is to provide a rational basis for developing measures that more accurately estimate population abundance of sea lampreys and further demonstrate the effects of changed control levels or techniques on the populations of spawning lampreys.

Spawning phase sea lampreys have been systematically collected from Great Lake tributaries for about 40 years and the objectives for these collections have undergone several phases or changes over the years. Earliest control efforts used mechanical weirs installed in streams, but these later were replaced, beginning in 1952, by electric weirs. The weirs also were introduced as a control measure but, when the 'lampricide TFM was adopted as the principal control method in 1960, a select group was operated for assessment purposes. Portable traps, first tested in 1975, had, by 1980, replaced the electric weirs as the primary assessment device. Variations have been made in the design and use of the portable trap, while other methods are used at present to capture and count adult sea lampreys.

The Department of Fisheries and Oceans (DFO), Sault Ste. Marie, Ontario, and U.S. Fish and Wildlife Service (USFWS), Marquette and Ludington, Michigan, conduct the principal investigations of adult sea lampreys. Several state agencies also collect information on abundance of lampreys in some areas of the Great Lakes. Other branches of the USFWS monitor lamprey abundance in tributaries of the North Atlantic coast (in conjunction with Atlantic salmon restoration) and in Lake Champlain.

Sea lampreys are collected primarily as an indicator of relative abundance of the population. Ancillary information compiled from the lampreys are estimates of the average length and weight and the sex ratio of the population. Nest counts have been used as an index (or supplement to other information) to estimate the abundance of the lamprey population, while mark and recapture studies have also been used in the past for this purpose.

A comprehensive understanding of pertinent life history information on spawning phase sea lampreys is essential to formulating sound recommendations for future assessment strategies. We review the physiological changes lampreys undergo from the start of their spawning life until death, and discuss the mechanisms of pheromone communication, distribution, homing and water quality involved in the selection of spawning streams. Knowledge on the influence of physical factors (e.g., water temperature and stream discharge) on timing of the spawning run also are reviewed. Lampreys are capable of swimming many kilometers once in a stream. We list the known information on sustained swimming speeds of the adult and on the animals' reaction to instream barriers. An extensive section deals with the spawning act and includes separate segments on the maturation of gametes, fecundity, spawning habitat requirements, nest construction, and mate selection. We review past and present suggestions to inventory the amount of spawning habitat available to sea lampreys.

Early in the development of the Workshop, the Steering Committee prepared a four-part Questionnaire and mailed it to 99 people who were associated with sea lampreys or other fishery management in the Great Lakes. The questions addressed four areas : what measures of the sea lamprey populations are desired; are present data collections satisfactory; what techniques could be used to improve assessment; and, is there a problem in interpreting the impact of sea lamprey predation on fish populations? Of the 45 responses received, we review those that relate to assessment of spawning phase lamprey populations. The general consensus was that an improvement was needed in adult assessment, but no immediate solutions were available. Most felt that there were some problems in interpreting fish scarring data. We also list the questions that were raised by the respondents.

The Spawning Phase Group reviewed all recommendations to improve assessment and then developed a general list of informational needs and additional studies. These are primarily the types of information that can fill small gaps in existing information and are not large scale studies. Some examples include: correlation of lamprey stream selection and similar physical and chemical characteristics of spawning streams; inventorying spawning habitat in streams; relationship between sampling efficiency and spawning run size; further validation of nest counts; the effect of blocking spawning runs; and the optimum dimensions of traps.

The Group developed four proposals or alternatives for future assessment strategies. The first describes the present assessment system (i.e., counts of spawning phase sea lampreys obtained by index sampling). This approach, with assessment traps, barrier dom traps and nest counts, has proven a reliable indicator of relative abundance of lampreys for most areas of the lakes. The second presents the collection and tabulation of the biological characteristics of lampreys (this information is presently collected in conjunction with relative counts). We discuss the merits and drawbacks of this approach and show possible correlations with fish stock abundance. This is the least costly of the four and probably would be appropriate only during a time of extremely reduced funding. The third alternative suggests estimating the population of lampreys in a lake or region of a lake by the random mass release of marked spawning adults into the lake and their subsequent recapture at index sites in streams. The estimate would be based on the ratio of marked to unmarked lampreys captured at the present index sites.

The final proposal is two stepped and would estimate the total population of spawning adults in a lake. First, a stratified tag and recapture method would be used to estimate the number of lampreys in the spawning runs of all monitored streams. Next, common factors (e.g., stream flow, or certain water chemistry characteristics) would be used to predict the run sizes in unmonitored streams from those in monitored streams. Correlations are demonstrated for stream flow and run size. To estimate the take total, all individual estimates are summed. Several assumptions are necessary in this proposal and a few unknowns must be answered before the concept can be implemented. We prioritize these and suggest ways to meet the needs.

INTRODUCTION

The Great Lakes Fishery-.' Commission (GFLC) was established in 1955 following the Convention on Great Lakes Fisheries between agencies of Canada and the United States. The primary charge of the GLFC was to formulate and implement a comprehensive program to eradicate or minimize sea lamprey populations in the Convention Area. Following ratification of the Convention on October 11, 1955, the United States Department of the Interior, Fish and Wildlife Service, and the Fisheries Research Board of Canada (now Department of Fisheries and Oceans) were contracted by the GLFC as Agents to control the landlocked sea lamprey, Petromyzon marinus, in the Great Lakes area of Continental North America (Smith et al. 1974).

A recommendation of the Committee for the Review of Commonality in Sea Lamprey Control was to define more thoroughly the results expected in lamprey population assessment. As a result, the GLFC funded the Workshop for Evaluating Sea Lamprey Populations (WESLP) to explore the past, present, and to recommend for the future, methods of sea lamprey assessment in the larval, parasitic, and spawning life stages.

The primary purpose of monitoring spawning runs of adult sea lampreys is to measure the effectiveness of the control program. Annual catches of lampreys from index sites in streams are used to estimate the relative abundance of the spawning runs. While this proved adequate in the past, the present needs of assessment by the control program have become more demanding. Increasingly, the control agents have been asked to define the relation between stream catches and lakewide abundances, to predict the size of spawning runs, and to explain the meanings of the year to year variations. Also, the proposed integration of alternate control methods (e.g., the sterile male release technique) will require more quantitative measures of lamprey abundance in each lake basin.

The problem of existing assessment has often been discussed by the various fishery agencies. Each has suggested or taken steps to remedy the situation, but a more structured and coordinated approach based on an established set of priorities likely will deal more effectively with the situation.

In this report of the Spawning Phase Group (SPG) of WESLP are sections on: the history of adult lamprey assessment, including current practices; pertinent lamprey life history information; a summary of the responses to a questionnaire sent early in the development of WESLP; the identification of existing informational gaps; recommendations for additional studies; and proposals or alternatives for future spawning phase lamprey assessment.

PURPOSE AND GOALS

The purpose of this Group is to review present methods and practices employed in assessing populations of spawning phase lampreys, to investigate needs to upgrade and expand evaluation strategies, and to develop and recommend alternate ways to collect, interpret, and present the data. Emphasis is on quantitative rather than qualitative measures, and to establish criteria for the reliability and precision of the data. The ultimate goal is to develop an improved measure of the effects of control on populations of spawning phase sea lampreys.

PAST AND PRESENT PRACTICES OF SPAWNING PHASE ASSESSMENT

INTRODUCTION

Samples of spawning phase sea lampreys have been collected annually from Great Lakes tributaries by state, provincial, and federal fisheries agencies, beginning as early as 1944 in the United States (the Ocqueoc River, Lake Huron - Shetter 1949). By 1946, systematic collections were also being made from Canadian tributaries of the Great Lakes (MacKay and MacGillivray 1946). These initial efforts were intended as control measures using mechanical weirs and traps, but it was eventually realized that such devices could never serve effectively in this role. Following the development of electrical methods of control, an extensive network of electric barriers was installed in the upper three lakes, beginning on Lake Superior in 1952 (McLain et al. 1965; Smith and Tibbles 1980). Throughout the 1950's and into the early 1960's, to control sea lamprey, the U.S. placed electric barriers in 130 streams (Lake Superior, 61; Lake Michigan, 68; Lake Huron, 1) and Canada constructed 52 (Lake Superior, 40; Lake Huron, 12). However, mechanical check weirs continued to be used for assessment through the mid- to late 1950's (McCullough et al. 1955; Speirs 1956; Price 1956a; Hallam and Johnson 1957; Lawrie et al. 1958a; and Smith et al. 1974).

In 1960, the use of the lampricide TFM was adopted as the principal control method and a reduced system of index barriers was designated for assessment purposes, consisting of 24 electric barriers on Lake Superior, three on Lake Michigan, and one on Lake Huron. Following the 1966 field season all barriers on Lake Michigan were shut down. For 1968' the number on Lake Superior was reduced to 16 (by the termination of the eight Canadian barriers), followed by a further reduction to eight barriers for 1971, and the removal of all barriers after the 1979 season, On Lake Huron, with the introduction of five Canadian index barriers for 1965, the network count was increased to six, and peaked at eleven in 1967. The number gradually fell to five by 1978, two for 1979, and the last electric barriers (the Kaskawong and Ocqueoc Rivers) were permanently dismantled in 1980.

Measures of sea lamprey abundance and collections of biological information from these early sources have been described in part by many authors (MacKay and MacGillivray 1946; Whitefield 1948; Shetter 1949; Applegate 1950; Applegate and Smith 1951a; Applegate et al. 1952; Smith 1971; Smith et al. 1974; Heinrich et al. 1980), and in minutes and appendices of numerous meetings (Great Lakes Sea Lamprey Committee 1946 to 1951; Great Lakes Lake Trout and Sea Lamprey Committee 1952; Great Lakes Fishery Committee 1953 to 1957; Great Lakes Fishery Commission - Interim, Annual, and Lake Committee meetings - 1956 to 1984).

As the electric barriers were being phased out, mechanical collecting techniques were reintroduced (commencing in 1968), initially to supplement the barrier data, and ultimately to assume the principal assessment role. In addition to the portable trap, the primary collection device of the Control Agents (Schuldt and Heinrich 1982), other methods recently have been used in the field, including: mechanical weirs, permanent traps built into barrier dams, large traps similar to those used with electric barriers (not intended as complete barriers), and dipnetting. From 1968 to 1984 86 rivers have been tested for use of these techniques (Lake Superior 24, Lake Michigan 39, Lake Huron 25, Lake Erie 9, Lake Ontario 28). In 1984, traps were operated on an index network of 48 streams of the Great Lakes (U.S. 32, Canada 16, see Figure C-l). Artificial lights are now used as an aid to the trapping operations in some streams (Purvis et al. 1985). Table C-I provides the counts made from all methods between 1944 and 1985.

Adult sea lamprey populations are also monitored in tributaries of the Great Lakes, Finger Lakes, Lake Champlain, and the Atlantic Ocean by other federal and state agencies. Methods used include portable traps, traps or counting windows built into fishways, fyke nets, and nest counts.

All present methods used to count sea lampreys provide estimates of relative abundance on a trend-through-time basis. Condition of sea lamprey' populations in the Great Lakes is measured by trend-through-time series of changes in the biological characteristics of lampreys.

Past estimates of populations of spawning runs of sea lampreys in select tributaries of the Great Lakes have used the simple Petersen (1896) formula with electric barrier catches (Lawrie 1955a; Lawrie et al. 1958b; Skidmore and Lawrie 1959; Dustin et al. 1966) and assessment trap collections (GLFC 1980). A problem with these studies was that sea lampreys were marked, released, and recaptured at essentially the same site. While this approach has been used to obtain a rough idea of trapping efficiency, the Petersen method is unsuitable to estimate populations where continual recruitment occurs. The recommended approach is a stratified tagging and recovery system developed to estimate the number of fish in spawning runs of Pacific salmon (Schaefer 1951; Ricker 1975). This method has been applied to sea lampreys (Wigley 1959; Marquette Biological Station, unpublished data), but it is work intensive, and impractical in many Great Lakes situations. Under the section 'Mark Recaptures to Date', a field-tested modification to the method is suggested to meet our specific needs.

In this Section we further describe the various methods recently used to collect, count, or measure the relative abundance of sea lampreys, and detail the sampling sites and procedures employed by each of the federal and state agencies. We also outline the theories and examples of the use of the biological characteristics of sea lampreys as an indirect indicator of trends in the population.

DESCRIPTION OF RECENT COLLECTING METHODS

Portable traps - The portable trap (PAT) is the primary collection tool used by the Sea Lamprey Control Agents in the United States and Canada. The standard design and use have-been adequately described by Schuldt and Heinrich (1982). Modifications to the basic design have occurred to meet specific needs on particular rivers. The standard trap is rectangular, made of angle iron and hardware cloth, with dimensions of 1.2 m long x 0.6 m wide x 0.46 m deep. Modifications in trap dimensions (length x width x depth) range from 0.6 m x 0.6 m x 0.46 m to 1.8 m x 0.9 m x 0.9 m. Triangular traps are used in some streams. They have solid sides of aluminum or galvanized steel and their dimensions vary from 0.6 to 1.2 m in length with isometric ends of either 0.3 or 0.46 m. Some traps are collapsible whereas others have welded fixed frames. The effectiveness of the traps varies by site and is dependent on many factors.

Large traps - These devices are of a design generally used in connection with the former electric weirs and are too large to be considered portable. The dimensions range from 2.4 m long x 1.2 m wide x 1.2 m deep to 4.9 m x 2.4 m x 1.2 m and are wood framed with wings attached. The traps are used in two areas: 1) where sea lamprey runs are large and more than a thousand lampreys may be captured in a night, and 2) on large rivers where no barriers exist. On the latter type of river, the traps are intended to intercept a portion of the run because the wings do not form a complete barrier. The use of the large traps is presently limited to three rivers.

Mechanical weirs - Surface (1898, 1899), Applegate (1950), MacKay (1950) and Wigley (1959) described some of the first uses of mechanical weirs for sea lampreys. Present weirs use at least one large trap (the largest in use is 3.7 m x 1.2 m x 1.2 m) and wire mesh wings form a complete barrier across a stream. Mechanical weirs can be effective in capturing sea lampreys, but high water and debris make them difficult to maintain. Only one mechanical weir was operated in 1984.

Barrier dam traps - The emphasis on the integrated pest management approach to sea lamprey control has resulted in the recent construction of barrier dams on some Great Lakes streams. Permanent traps have been built into five of these structures. In addition, two permanent traps were built into a flood control dam on the Humber River. Barrier dam traps are constructed of steel sheet piling, steel sheet plate, or concrete and their design varies by site. Little work has been done to measure the effectiveness of the designs of each of the built-in traps.

Fishways - Trapping devices for sea lampreys were incorporated into three fishways designed to pass rainbow trout: the Saugeen River, Lake Huron; Ganaraska River, Lake Ontario; and Cayuga Lake Inlet, New York State. Only the fishway on Cayuga Lake Inlet is presently in operation. At the lower dam on the Connecticut River (Atlantic Ocean), a hydraulic lift passes Atlantic salmon and other anadromous species. The contents of a holding cage pass a viewing window and the fish are counted. Sea lampreys commonly occur among the species passed upstream. These designs, while expensive and labor intensive, remain effective.

Dip nets - Used with consistency on only one stream in the Great Lakes (the Humber River, Lake Ontario), this technique proved to be reliable under certain conditions. The Humber River operation (1968 to 1978 and again, on a lesser scale, in 1981; see appropriate Annual Reports of SLCC to the GLFC) was tested for collecting effectiveness by Johnson (1975, 1976). Dip-netting has not been conducted since 1981.

Fyke nets - They are used where no barrier exists, and are designed to intercept only a portion of the spawning run. An advantage to their use is portability, but high water creates problems. In low water, they can be very effective. Fyke nets are used only on a few tributaries of Lake Champlain.

Nest counts - A method commonly used on some tributaries of Lake Ontario, Lake Erie, the Finger Lakes, and Lake Champlain is to count spawning redds of sea lampreys over standardized sections of selected streams during a specific time each year. The total nests observed on each stream are compiled to show annual and long-term changes.

AGENCIES

U. S. Fish and Wildlife Service, Marquette and Ludington (USFWS) - In 1984, the USFWS monitored spawning phase sea lampreys in 32 tributaries of the five Great Lakes (Figure C-l). Portable traps were used in 29 of the rivers (streams 4-5, 7-14, 16-25, 31, 33-35, and 43-47) and the number of traps varied from one to six traps per site. Large traps with artificial lights were used in three rivers (streams 6, 15, and 32). Total counts of sea lampreys captured at each site are compared to past year's catches. Data on biological characteristics of lampreys were obtained from all but streams 44 and 47 where lampreys were released so as not to bias nest counts of the same streams.

Department of Fisheries and Oceans, Sault Ste. Marie, Ont. (DFO) - The DFO monitored spawning runs of sea lampreys in 16 tributaries of Lakes Superior, Huron, and Ontario in 1984 (Figure C-l). Portable traps were used in nine rivers (streams 3, 25, 6-8, 37, 39, 40, and 42), barrier dam traps in six (streams 1, 2, 26, 36, 38, and 41), and a mechanical weir at the remaining site (stream 30). Total catches and information on biological characteristics are compiled from each site.

Pennsylvania Fish Commission - In 1984, portable traps were used for the first time in three tributaries of Lake Erie in Pennsylvania--the Conneaut (East Branch), Crooked, and Raccoon Creeks.

New York Department of Environmental Conservation (NYDEC). - Since 1971, annual nest counts have been made in eight tributaries of Lake Ontario. A more detailed description is provided in the sub-section on nest counts. The NYDEC also operated portable traps in the Oswego River in 1984.

The NYDEC manages a fishway on Cayuga Lake Inlet, Cayuga Lake, that incorporates a trap for sea lampreys. Catches from 1970 to 1984 ranged from 1,431 to 6,026 (mean of 2,831). Nest counts in the river upstream of the fishway were made annually beginning in 1974, but few were found through 1982. In 1983 high lake levels apparently allowed many lampreys to bypass the fishway; 947 nests were located above the dam.

U. S. Fish and Wildlife Service, Lake Champlain - The Fisheries Assistance Office in Montpelier, Vermont has been evaluating the sea lamprey population in Lake Champlain since 1977 and uses several methods to monitor the spawning runs of adults on 10 streams (Figure C-2). Portable traps are used on three rivers (streams 2, 3, 7), nest counts on eight tributaries (streams 1-7, 10), and fyke nets on two others (streams 8, 9).

U. S. Fish and Wildlife Service/Connecticut River Anadromous Fish Program In cooperation with the States of Connecticut, Massachusetts, Vermont, and New Hampshire, the USFWS is involved in a program to restore anadromous fish runs into the Connecticut River. The procedure was described in the previous section.

THE USE OF RELATIVE NUMBERS

Present and historical methods used to count spawning phase sea lampreys measure relative abundance. In theory annual catches of sea lampreys, taken consistently from the same site or group of sites during the same time of the year, will vary in accordance with long-term changes in the population. These measures have proven adequate in the past, but the changing needs of the control program require more precise indicators of the total population. Table C-I provides the entire data set for the Great Lakes collections, while the following briefly discusses the merits of using a relative measure of abundance.

During the years that assessment traps and electric weirs were operated simultaneously (1977-79), it was hoped that both of these devices would provide corresponding trends in their catches. That this did not occur, was probably to have been expected since, with the sea lamprey population in Lake Superior at its lowest point since lampreys invaded the lake, the two different sources of data could not be expected to respond in exactly the same way. Present annual changes in the sea lamprey population are probably small and are not likely to be adequately defined in a measure of relative abundance. The two data sets show however that the assessment trap catches (weirs: 1961 vs. 1962 and 1962-72 vs. 1973-79) reflect large changes in abundance in Lake Superior and are likely to continue to do so.

Moore and Schleen (1980) suggested that the treatment of a stream with lampricide may have a direct impact on the magnitude of the spawning run the following year. This situation was evident in many electric weir catches from streams of Lakes Superior and Huron, but was not nearly as conclusive from those catches of Lake Michigan.

Information from assessment traps imply that treatments have little effect on lamprey catches. The TFM treatment years for all streams with weirs and traps also are noted in Table C-I.

BIOLOGICAL CHARACTERISTICS

1. Length and weight

Sea lampreys in the Great Lakes are smaller than those of the Atlantic Coast of North America. Lampreys collected in 1960-64 from Love Lake Outlet of the East Machias River in Maine averaged 663 mm and 737 g (Davis 1967). In the Great Lakes the largest verifiable spawning migrants recorded were taken from Lake Erie in 1980 and averaged 504 mm and 273 g, although MacKay and MacGillivray (1946) noted that, of 11,463 spawning adults collected from the North Channel, Lake Huron, only about 25 were classified as small, with a "majority" about 610 mm. These notations are not verifiable. In the following year from the Thessalon River, Whitefield (1948) noted a range of 279 to 660 mm and from the Ocqueoc River and Carp Creek, Lake Huron for the period 1948 to 1951 (Applegate and Smith 1951a) showed mean lengths ranging from 401 to 442 mm for combined sexes.

At least three interrelated factors have influenced sea lamprey size in the Great Lakes: 1) lamprey abundance, 2) the impact of the chemical control program, and 3) the availability of preferred host species. Sea lampreys entering the upper Great Lakes when food was abundant, grew to a substantial size, but their growth decreased as lake trout stocks were depleted and the abundance of lampreys increased. As the use of the selective lampricide began, large-scale stocking of trout and salmon also began to rehabilitate the salmonid stocks. The control program significantly reduced lamprey numbers and the salmonid stocking increased prey density. Lamprey size increased as a result, then stabilized after a period of years.

2. Sex ratio

Most authors have reported that in spawning populations of other species of lampreys, equal numbers of males and females or an excess of males is present (Hardisty and Potter 1971; Potter et al. 1974; Potter and Beamish 1977; Beamish 1980). Sea lampreys are relatively recent intruders into the upper' Great Lakes and the ratio of males to females in the population apparently varied in response to changes in lamprey abundance (Lawrie 1970). Comparisons of the data from Lakes Superior and Huron show that males were in excess when lampreys were abundant. In the three upper lakes, as the sea lamprey populations declined with the advent of the lampricide program, the sex composition began to shift from a preponderance of males to an excess of females. As the ratio approached 30 to 40% males, it stabilized. The application of lampricides reduced the population of sea lampreys in the lakes and contributed to the sequential shifting of the sex composition from a predominance of males to an excess of females.

An example of the data collected by the Control Agents on biological characteristics of sea lampreys in 1983 is presented in Table C-II.

THE USE OF NEST COUNTS

When sea lamprey assessment became a necessity for pre- and post-control evaluation in Lake Ontario, methods and techniques such as electric weirs were not available. Personnel of the NYDEC investigated nest counts as an index of spawning phase populations in Lake Ontario streams. Studies on Sterling and Skinner Creeks in 1971 showed the durability and seasonality of sea lamprey nests to be within acceptable limits. A comprehensive field survey of New York's Lake Ontario tributaries followed to select and standardize stream sections for an annual index of nest counts. Nest counts in New York streams were initiated in 1971 as an index of the Lake Ontario sea lamprey population, based on the following assumptions:

(1) There is a functional relationship between the number of sea lamprey and the nests they construct;

(2) The number of nests can be counted with an acceptable margin of error;

(3) Nests remain recognizable over a period of several weeks;

(4) Nest counts from index sites, when suitably modified by known relationships, accurately reflect real trends in the size of the spawning population.

From the outset, the NYDEC recognized that a field technique for counting lamprey nests was subjective and that there was a need to establish criteria for recognizing sea lamprey nests. Through a system of annual training workshops initiated in 1975, with a testing procedure added in 1979, the identification of nests was shown to be reasonably consistent.

Fishery personnel later adopted nest counts in tributaries of Cayuga and Seneca Lakes, Lake Champlain and Lake Erie because other indices of lamprey abundance were not readily available. From the results in Lake Ontario, personnel were provided the following basic guidelines:

(1) Survey all sea lamprey spawning streams;

(2) Select representative streams and index areas. for trend-through-time index counts;

(3) Exercise rigorous training of personnel;

(4) Use standard criteria for enumerating nests.

The enumeration of nests in Lake Ontario, Lake Champlain, Cayuga Lake, Seneca Lake, and Lake Erie for 1971 to 84 is shown in Table C-III. The following is a discussion of the type of data collected from each lake.

Lake Ontario

The data for Lake Ontario in 1971 represent pre-control information while those beginning in 1974 represent post-control conditions. The outstanding feature of the 1974 data is the reduction in nest counts in all index streams. Salmonid wounding similarly declined in 1973 and these indices can be regarded as a response to lampricide treatments which began in 1971. The picture is less clear in later years. From 1975 through 1977, counts remained considerably below 1971 levels, but in recent years (1979 to 1984) they have followed an erratic pattern, with some counts several times greater than pre-control levels (Jolliff et al. 1984).

Lake Champlain

The data from Lake Champlain (Baren and Gersmehl 1984) are from an uncontrolled lamprey population and suggest what normal variation can be expected. Annual variation between counts in Lake Champlain streams is no greater than 50% which is substantially less than the 86% reduction for Lake Ontario from 1971 to 1974.

Cayuga Lake

As many extraneous factors may have influenced the results of counts on most Cayuga Lake streams, only those from Salmon Creek and Yawger Creek are comparable.

Seneca Lake

Variation in nest counts has been high among the three lower subsections in Catherine Creek (Table C-III). This may be due to variation in migration distances as a result of changes in stream discharge from year to year, and it also may indicate that standardized stream sections should represent the entire stream (which this one does). The first post-control data from this lake will be from spring 1985 (first round of chemical treatments completed in 1983).

Lake Erie

The method of obtaining nest count data in Lake Erie was somewhat different from that of the other areas. The index is the number of nests per stream mile rather than nests for a fixed area. The data suggest an increase in the lamprey population from 1980 to 1984, but this has not been verified by other measures of abundance.

Analysis of the Method

Applegate (1950) and later Manion and Hanson (1980), indicated two general features of sea lamprey spawning habits that tend to support the concept of using nest counts as indicators of spawning populations:

(1) that males take a lead role in initiating nest construction and then become very defensive of intrusion by other males, with females joining males in a responsive rather than an initiative manner; and

(2) that nesting is mostly monogamous with some 85% of the visually observed matings consisting of a single male and a single female.

If these are real features of most spawnings, then changing sex ratios could lead to different lamprey/nest ratios. However, if males take the lead role and construct nests without females present, then the number of nests constructed should tend to reflect the number of males, especially when males outnumber females (as they do in Lakes Ontario and Erie).

Studies on the Big Garlic River and Cayuga Lake Inlet suggest the percentage of males in the population influences the number of lamprey per nest (Table C-IV). As the percentage of males increases the number of nests constructed per male also increases, while the number of lampreys per nest tends to decrease. Thus the number of nests may not be in direct proportion to the total population, and unless sex ratios remain stable over time, adjustments may be needed in a trend-through-time series. It must be noted however, that the above studies were not designed specifically for this type of information. Additional work is needed in this area.

Other data are available to examine the relationship between nest counts and relative abundance of spawning sea lampreys. Comparison of the number of nests with catches of lampreys from two Lake Ontario streams shows some correlation (Table C-V). Although the magnitude of change is not always similar, in most years, the year-to-year increase or decrease is reflected by both.

We previously noted the reduction in nest counts in Lake Ontario between 1971 and 1974 and the correlation with control effort. The more recent contrasts of very high and moderately low nest counts in Lake Ontario are problematical but at least one of these is corroborated by other evidence. In South Sandy Creek, observations suggested a rather small spawning run in 1981 and the dramatic increase in nest counts in 1983 was supported by reports from streamside residents who described "lampreys all over the place". Grindstone and Sterling Creeks are near the Oswego River, which has been a suspected major source of recruitment. Therefore, the very high nest counts in these streams could reflect actual increases in spawning runs. If such is the case, the 'lampricide treatments of 1984 in Oneida Lake should reduce Lake Ontario nest counts in 1986.

Erosion of nests by floods and the effects of chemical treatments of rivers during spawning runs were recognized early as a potential impediment to using nest counts. Lake Ontario tributaries traditionally have been treated during the spring.

Data from Cayuga Lake offer some additional evidence that may relate to the validity of nest counts. In 1983, many nests were counted in Cayuga Inlet (Table C-III). Migrating adult sea lampreys are captured, processed, and destroyed each year but occasionally, such as occurred in 1983, sea lampreys bypass the fishway. An estimated 1,700 adult sea lampreys (60% or 1,020 males) bypassed the fishway that year. The index areas comprise about 75% of the spawning habitat in the Inlet. There were 1,240 nests in the stream, or about 1.4 lampreys or 0.8 males per nests. Wigley (1959) estimated 6.6 lampreys per nest and 0.26 males per nest for a similar percentage of males.

Nest counts on the Bad River were compared to the electric barrier catches from eight Lake Superior tributaries from 1964 to 1974 (Table C-VI; for comparison with eight barrier catches, see Table C-I). Little correlation was evident between the nest counts and the totals from the eight barriers, or between the nest counts and the catch on any individual stream. It must be noted however that there is little correlation between the barrier catch on any one stream and the total of the eight barriers. Only the total barrier catch provides a reliable year-to-year index. While this does not address the question of validity of nest counts, it does suggest that nest counts, and any other stream-sited method for assessing spawning phase sea lamprey populations must include a large number of streams in order to counteract the effect of between stream variability of spawning runs and represent the population as a whole.

Costs to Employ Nest Counts

Nest counts are not expensive to obtain. The following is an estimate for the present work on Lake Ontario. Including the personnel training/testing workshop (which accounts for about 40% or more of the total), supervision and data tabulation, and assuming a full counting schedule, approximately 16 man-days are required. Using a figure of $200 per man-day for wages, fringe benefits, vehicle and per diem adds up to $3,200 per year. Vehicle cost would increase if two vehicles were used per two-person team to avoid walking back to point of starting. On West Branch Fish Creek, a canoe is used to traverse the large, deep pools between riffle areas, moving in a downstream rather than the usual upstream direction. Since much of this cost is fixed (personnel workshop and travel), the Lake Ontario counting schedule could be increased considerably at a relatively small increase in cost.

Conclusions

The following statements summarize the present knowledge of nest counts as an index to spawning phase sea lamprey populations.

1. Nest counts are employed in Lake Ontario, Lake Champlain, Seneca Lake, Cayuga Lake and Lake Erie as annual indices of spawning phase sea lamprey populations.

2. A single count of nests on previously selected standardized stream sections which represent a cross-section of lakewide available spawning habitat is taken at the end of the spawning season.

3. The technique is relatively inexpensive to implement in spite of a substantial cost component in annual training and supervision of personnel which is required because of the subjectivity involved in the field identification and enumeration of nests.

4. Counts in Lake Ontario seem to reflect the expected results of lampricide treatments.

5. Examination of electric barrier counts on eight Lake Superior streams, which are reliable indicators of stream spawning runs, reveals that each individual stream varied with respect to totals from all streams, and suggests that only totals from a large number of streams may reliably estimate the total population.

6. The technique is most applicable to small streams which lend themselves to visual observation, and have significant spawning habitat. It could be a valuable supplement to PATs and other assessment methods.

Recommendations

1. Nest counts should be investigated further as an alternative or supplement to other sea lamprey assessment methods because, even though they have not been validated, they are relatively inexpensive to implement and their plausibility is supported by observed habits and reasonable assumptions.

2. Because evidence from electric barriers indicates that spawning runs in individual streams fluctuate widely, the number of streams selected for standardized counts should be rather large, and the sections of adequate lengths to overcome this variability and to yield counts that represent total populations.

3. Index areas in presently monitored streams of Lake Ontario should be expanded and new streams added to the network.

4. A study should be developed to validate the method. This would probably best be done by well-planned and controlled releases of known numbers of adults of differing sex ratios in streams, followed by observation of the resultant nests such as was previously done on Big Garlic River and could now be done on Cayuga Inlet.

MARK-RECAPTURE STUDIES TO DATE

Throughout the history of the sea lamprey control program, mark-recapture techniques were used to measure the effectiveness of different methods of capture or estimate the sizes of individual spawning runs in Great Lakes tributaries.

1. Canadian Studies

The earliest investigations were associated with electric barriers, commencing in 1954 with a mark-recapture study by Lawrie (1955a) on three streams tributary to Batchawana Bay, Lake Superior. Using variables drawn from the information, and applying the simple Petersen Method (N=MC/R; where N represents the size of the population at time of marking, M the number of sea lamprey marked, C the sample taken for census, and R the number of recaptured marked members in the sample), the following results were obtained:

Stokely Creek	(43 x 49/16)
Harmony River	(10 x 19/3)
Carp (Sable) River	(32 x 39/15)

In 1957 (Lawrie et al. 1958b) lampreys were tagged in conjunction with the electric barrier on the Pancake River. Separate studies were made at a check weir located in the stream mouth and at the electric barrier.

Pancake River	
- check weir	(33 x 175/12)
- electric barrier	(142 x 1073/approx. 60)

A 1958 tagging study on the same stream (Skidmore and Lawrie 1959) was confounded by multiple recaptures, making it too difficult to isolate appropriate values for the variables.

The last known mark-recapture work conducted in conjunction with electric barriers occurred during 1965 at three sites on two streams of Lake Huron (Dustin et al. 1966). At the two electric weirs located in the Naiscoot River, a single night's catch served for recapture purposes, while an extended period of recapture was used at the site on the Still River. Best fit of the resulting data to the Petersen estimate gives:

Naiscoot River	
- main stem barrier	(8 x 17/5)
- Harris River	(6 x 41/4)
Still River	(92 x 87/59)

Work on Silver Creek, Lake Huron, in the late 1950's represents the, earliest known sea lamprey tag-recapture investigation on the Great Lakes in conjunction with a mechanical weir. Lamsa (1961) marked 776 specimens in 1958 and 434 in 1959 (initially trapped inside the two mouths of the stream and released upstream), followed by the subsequent recovery of 129 and 84, respectively. However, total numbers caught on resampling (both from the traps and the spawning grounds) are unavailable.

More recently, the dip-net operation on the Humber River, Lake Ontario, was tested as to its collecting effectiveness. Data from a study conducted in 1974 and 1975 by Johnson (1975, 1976) includes:

1974 -	Release site inside mouth	(100 x approx. 3350/55)
	Release site 1000 m outside mouth	(98 x approx. 3350/34)
1975 -	Release site 1000 m outside mouth	(100 x approx. 6848/44)

Since the reintroduction of mechanical trapping to the DFO assessment program, occasional mark-recapture work has been attempted. A 1976 study on the St. Marys River lacks data necessary for a population estimate. In 1977, an effort on Graham Creek, Lake Ontario, resulted in no recaptures, while a study on the Salmon River of Lake Ontario (Canada) provided information giving a rough estimate (90 x 260/4).

In 1982, mechanical weirs were fished downstream of three lowhead barrier dams. Sea lampreys caught in these devices were tagged and released upstream, and were recaptured by the trap associated with each dam. Basically, the information gave the following:

Pancake River -	(56 x 42/12)
Stokely Creek -	(11 x 5/2)
Kaskawong River -	(84 x 396/45)

In 1984, a joint study with the NYDEC measured dispersal of sea lamprey into the Oswego River system. A total of 617 tagged specimens (566 imported) were placed in the system between April 20 and June 8. A total of 75 lampreys were trapped at the lowest dam in the system, of which 23 were recaptures.

2. U. S. Studies

No mark-recapture studies are reported prior to 1976 from the U.S. control program. With the recent introduction of the assessment trap, measures to determine trapping effectiveness were initiated at nearly all assessment sites. The need to address absolute estimates of spawning populations later was recognized, and a search for better methods of estimation was stressed.

In 1976, spawning adults from four index streams were finclipped, released and recaptured at the same site. The simple Petersen estimate was used to obtain a rough estimate of the number of lamprey that reached the site. Use of this technique has continued to the present. The following lists by year, lake, and stream those assessment operations tested in this manner:

1976

Lake Huron

St. Marys River	(959 x 991/106)

Lake Superior

Big Garlic River	(82 x 90/21)
Rock River	(498 x 498/378)
Sturgeon River	(18 x 18/0)

1977

Lake Huron

Cheboygan River	(1064 x 3360/435)
Trout River	(39 x 39/2)

Lake Michigan

Ahnapee River	(1 x 1/1)
East Twin River	(21 x 21/3)
Manistique River	(1424 x 3273/215)
Menominee River	(375 x 714/128)
Oconto River	(6 x 7/0)
Peshtigo River	(488 x 644/179)

Lake Superior

Big Garlic River	(28 x 30/8)
Otter River	(25 x 33/2)
Rock River	(384 x 477/209)
Tahquamenon River	(169 x 170/24)

1978

Lake Huron

Cheboygan River	(2107 x 6489/1555)
Trout River	(40 x 40/0)

Lake Michigan

Bear Creek	(7 x 7/0)
Bear River	(4 x 4/0)
Betsie River	(430 x 451/60)
Black River, S. Br.	(7 x 7/0)
Boardman River	(58 x 62/3)
Boyne River	(28 x 29/2)
Deer Creek	(36 x 40/1)
Grand River	(28 x 28/2)
Kalamazoo River	(6 x 6/1)
Manistique River	(4687 x 5408/597)
Muskegon River	(67 x 67/5)
Paw Paw River	(13 x 13/1)
Pentwater River	(1 x 1/0)
Rabbit River	(9 x 9/0)
St. Joseph River	(879 x 8791229)
Swan Creek	(2 x 2/0)
White River	(11 x 11/0)

1978

Lake Ontario

Catfish Creek	(57 x 65/10
Fish Creek, W. Br.	(9 x 18/0)
Grindstone Creek	(260 x 315/32)
Little Salmon River	(150 x 242/17)
Oswego River	(81 x 81/6)

Lake Superior

Big Garlic River	(126 x 135/96)
Otter River	(5 x 5/1)
Tahquamenon River	(245 x 310/38)

1979

Lake Huron

Black River	(2 x 2/0)
Cheboygan River	(1062 x 8327/685)
St. Marys River	(922 x 1213/282)
Sturgeon River	(2 x 2/0)
Thunder Bay River	(2 x 2/1)

Lake Michigan

Carp Lake River	(67 x 68/13)
Manistique River	(4683 x 4948/1483)
Menominee River	(130 x 131/17)
Peshtigo River	(264 x 265/52)
Weston Creek	(145 x 146/42)

Lake Superior

Miners River	(11 x 12/0)
Rock River	(664 x 677/305)

1980

Lake Erie

Cattaraugus Creek	(168 x 1181/38)

Lake Ontario

Grindstone Creek	(164 x 311/5)
Sterling Valley Cr.	(143 x 324/40)

Lake Superior

Sucker River	(14 x 19/0)

1981

Lake Ontario

Grindstone Creek	(210 x 210/27)
Sterling Creek	(125 x 125/18)

Lake Superior

Sucker River	(166 x 166/25)

1983
Lake Ontario
Grindstone Creek (676 x 678/147)
Sterling Creek (173 x 174/7)

1983
Lake Superior
Sucker River (179 x 183/28)

1984
Lake Ontario
Grindstone Creek (126 x 128/4)
Sterling Creek (43 x 43/1)

From 1977 to 1980, consecutively numbered Floy tags were used with finclips to mark sea lampreys, in order to determine tag loss as. a means of learning how to insert these tags for best retention. Lampreys were released and recaptured at the same point in the stream. Simple Petersen estimates can be derived, but as with the previous examples these are not applicable to total stream runs.

1977
Lake Huron
St. Marys River (1229 x 1419/258)

1978
Lake Huron
St. Marys River (795 x 1148/291)

Lake Michigan
Yenominee River (1827 x 1840/692)
Peshtigo River (2360 x 2360/954)

Lake Superior
Rock River (499 x 508/243)

1979
Lake Superior
Rock River (664 x 677/305)

1980
Lake Superior
Rock River (324 x 329/140)

There are a few examples of studies where initial capture was made downstream of the primary capture site. Sea lampreys were captured at an electric barrier downstream of a dam, marked with a finclip, and recaptured at the dam as measures of trap efficiency. Data again can be fitted to the Petersen formula, but with limited applicability. More importantly, the use of two separate sites in a stream for capture and recapture, provides a more valid estimate of the entire spawning run of a stream.

1977
Lake Superior

Betsy River	(31 x 31/25)
Iron River	(46 x 46/7)
Silver River	(27 x 27/0)

1978
Lake Superior

Betsy River	(35 x 35/8)
Iron River	(10 x 10/3)

The search for a better method of estimating the total population of spawning phase sea lampreys in a stream led to the development in 1984 of a pilot study based on a method previously used for West Coast sockeye salmon. Originated by Schaefer (1951) for migratory populations, the technique was used in two streams. Sea lampreys were captured in fyke nets downstream of a barrier, marked with consecutively numbered Floy tags, and recaptured in assessment traps at the barrier. The model used to estimate the total population is:

$$N = N_{ij} = (R_{ij} \times M_i/R_i \times C_j/R_j) \text{ where:}$$

N = the total population

R_{ij} = number of fish marked in the ith marking period which are recaptured in the jth recovery period

M_i = number of fish marked during the ith week of marking

R_i = total recaptures of fish marked in the ith period

C_j = number of fish caught and examined in the jth period of recovery

R_j = total recaptures during the jth period

The information is tabulated for calculation of the population estimates. The results are given in Table C-VII for the Cheboygan River, Lake Huron, and Table C-VIII for the Manistique River, Lake Michigan.

To determine if a shortcut to the above approach could be used, lampreys captured at each of the upstream barriers were marked with Floy tags, transported downstream and released. Schaefer estimates were made of the populations based on these results. The computations are provided in Table C-IX for the Cheboygan River, and Table C-X for the Manistique River. Estimates using the two approaches were nearly identical.

PERTINENT SPAWNING PEASE LIFE HISTORY INFORMATION

INTRODUCTION

The spawning phase of Great Lakes sea lampreys has been studied and reported in the literature more than any other life stage. Even so, a number of misconceptions were popularized for long periods. Charles Fothergill, in an undated diary entry based on observations made in 1835 at Duffin's Creek, Lake Ontario, noted "This troublesome-formidable and most destructive fish is but too common in Canada, at least for the security of such Mill dams as are constructed chiefly of earth. In winter they are fond of burying. themselves in mud and will penetrate far into the banks of the streams they frequent. Like the common eel too they not infrequently leave the water and crawl on shore--going to a considerable distance from the water--and it is equally tenacious of life. Total length of the present specimen... - was 18 inches - . . . " (Lark 1973). Goode (1884), citing a number of studies, stated "It has been customary among writers upon fishes to class the Lampreys among the migratory fishes, and to describe the migrations of the sea Lampreys as beginning in the spring, when they are supposed to ascend the rivers for the purpose of spawning in their headwaters. This theory seems at present hardly tenable; so little, however, is known of their habits that the theory cannot be pronounced absolutely incorrect." These provide classical examples of the contradictory nature of the literature at the time. Another see-saw argument that persisted from the earliest writings (including those of Surface 1898, 1899; Coventry 1922; and Gage 1928) to more recent works, centered on 'death-after-spawning'. As recently as 1946 MacKay and MacGillivray said that "During the field operations there was no conclusive evidence of mortality of sea lampreys." Applegate (1950) wrote: "All of my evidence, from both field observations (direct evidence) and anatomical studies (indirect evidence), confirms the conclusion that sea lampreys die after spawning once". This statement seemed to end the controversy.

These early writings and other notable works (among them Jordan and Fordice 1885; Gage 1893; Hussakof 1912; Trautman and Deason 1938; Deason 1939; Shetter 1945 and 1949; Whitefield 1948; and Trautman 1949) and reports of the Sea Lamprey Committee (1946 to 1951), which was succeeded by the Great Lakes Lake Trout and Sea Lamprey Committee in 1952, and in turn by the Great Lakes Fishery Committee from 1953 to its dissolution after 1957 provide a historical perspective and considerable documentation of the spawning phase of the sea lamprey's life history. However, the paper by Applegate (1950) is regarded as the definitive work, and has served as the mainstay for many recent studies. Included among these are; basic research investigations (Skidmore 1959; Wigley 1959; Manion and McLain 1971); life history summaries (Hardisty and Potter 1971; Smith 1971; Manion and Hanson 1980); descriptions relating to spatial and temporal variations of spawning runs in the Great Lakes (Applegate and Smith 1951a; Applegate et al. 1952; Loeb 1953; McLain et al. 1965; Smith et al. 1974); and reports in the numerous minutes and appendices of meetings of the Great Lakes Fishery Commission and its sponsored committees held between 1956 and 1985 inclusive. The following comments about life history details relate specifically to WESLP.

ONSET OF THE SPAWNING PHASE

What triggers the lake-feeding sea lamprey to abandon this role and to seek out streams in which to spawn? When does this transition begin? These questions have not been answered explicitly, although various authors have discussed the subject. Gage (1893) noted for 'lake' lamprey populations in the Finger Lakes of New York State that the female 'ovary' and male 'spermary' increased in size with the approach of spring and that "...the ripening sexual products act as a stimulus in both sexes, urging them to complete the cycle of existence by seeking again the clear brooks, far from the lakes, where they themselves began an independent existence several years before." More recently, while discussing the possibilities of the thyrotropin-thyroid system or of 'critical' fat levels as mechanisms, Larsen (1980) concluded that "We really do not know what initiates the changes in behaviour and physiology which are characteristic of upstream migration", also noting "The possible endocrine control of this phase is not clear", and further "We know nothing about...how the secretion of hormones necessary for... sexual maturation is initiated."

However the genetically regulated process works, Johnson and Anderson (1980) suggest that the mechanism is triggered earlier in the parasitic male, leading to an increasing segregation of the sexes from early summer through the autumn months - with the females moving to deeper offshore waters while the males migrate inshore.

THE SPAWNING MIGRATION

1. Selection of the stream - Possible mechanisms for inter-stream distribution

Gage (1893) noted: "Apparently they [lake lamprey] start out independently from the various parts of the lake, each one forsaking its prey, and swimming vigorously or stealing a ride by attaching itself to the bottom of some boat moving in the right direction. On they go until the current of the inlet gives them the clue, and they follow it." Other investigations have been unable to elucidate the overriding parameters with any greater conviction.

The major hypotheses to explain inter-stream distribution Centre on stream temperature, stream discharge, pheromone signals, and the proximity of major concentrations of prey to streams when feeding activity is replaced "by pre-spawning migratory activity. Less accepted is the tendency to 'home'. The effects of water quality, in particular pollution (suspected as an important factor in specific cases) have not been well documented. Whitefield (1948) suggested that the general configuration of the lakeshore may play a key role in stream selection (apparently made without corroborating evidence). The Hammond Bay Laboratory presently is searching existing data (including United States Geological Survey records) to identify any physical or chemical factors influencing stream selection. Correlative tests have been carried out on 13 such parameters, but a strong positive correlation ($r = 0.77$) was found only between electric weir catches and discharge, (Meyer 1984). Marquette Biological Station personnel (USFWS) more recently obtained an even better correlation ($r = 0.90$) 'between portable trap catches and discharge (Unpubl. data).

a) Discharge and Temperature

Stream discharge and water temperature are considered important in attracting spawning runs to streams (Applegate 1950; Wigley 1959; Beamish 1980; and Morman et al. 1980). Applegate suggested that a river plume would be encountered by sea lampreys moving along the shoreline, presumably inducing a positive 'thermotropic' and/or 'rheotropic' response. He thus attributed the erratic nature of the number of lampreys running smaller streams, where temperature alone could not account for the observations, to the disruption of the stream plume by wind. A larger stream (based on mean discharge) would exert a greater temperature influence over a larger adjacent area of the lake, and with greater consistency.

According to Hardisty and Potter (1971), the general literature on lamprey species shows that high water levels are of key importance in attracting spawning runs. However, Lanzing (1959) notes these conclusions can be misleading due to a 'build up' of spawning run animals during periods of low water levels. It seems realistic to assume these two parameters are totally interdependent.

Skidmore (1959) attempted to test Applegate's assumption that sea lamprey follow the lakeshore in order to locate tributary entrances. While not conclusive, his investigation did suggest the occurrence of such activity. While his results showed specimens released off one side of the stream more readily located the mouth than did those released from the opposite side, he sought no answer in the potential influence of longshore currents.

b) Pheromone Communication

The attractiveness of streams containing sea lamprey larvae for spawning phase adults has been observed by sea lamprey management personnel. The possibility that this attraction may influence the size of the spawning runs is a concern to interpretation of catches. Moore and Schleen (1980) provided convincing evidence that a temporary decline in the size of spawning runs generally occurs in the year following lampricide TFM treatments. They discussed a number of factors that could control this, including homing, temperature, stream flow, water quality, the reduction of flora and fauna, and the effects of ammocoete populations; further stating: "It is likely that the removal of a larval sea lamprey population from a stream by a lampricide treatment is a major factor that explains the decline in the adult run of sea lamprey in many streams the following year". Teeter (1980), stated that initial preference tests indicated "...both male and female landlocked sea lampreys, after reaching a specific stage of sexual maturation, release pheromones which attract conspecifics of the opposite sex. In addition, sexually immature males, captured at the beginning of a spawning migration, exhibit a preference for water in which sea lamprey larvae have been held, suggesting that chemical signals, originating from populations of sea lamprey in a river, may aid migrating adults in selecting a suitable spawning stream."

Further investigations were conducted to isolate the active compounds (Teeter et al. 198 a, 198 b). Therefore, this mechanism may explain stream selection, although-little-is known about threshold levels nor the number of pheromone-releasing specimens needed to achieve the reaction.

c) Spatial Distribution

Another mechanism by which sea lampreys may choose a stream for spawning is the distribution of lampreys in relation to prey. Johnson and Anderson (1980) noted that "predatory phase sea lampreys remained concentrated near the mouths of their parent streams if sufficient numbers of prey were present." More recently, Heinrich et al. (1985) demonstrated that tagged sea lamprey captured from one or the other of two designated areas of northern Lake Huron generally were recaptured from nearby lake waters or tributaries of their respective area. While this evidence is circumstantial, there remains a simple logic to the concept. It follows that large numbers of spawners would probably enter those tributaries at spawning time nearest a region of the lake with a large associated prey population. This effect could arise either if the host population remained in the area throughout the entire period in the lake, or if a more mobile host population moved into the same area at the same critical time each year. This hypothesis probably accounts in some measure for stream selection.

d) Homing

The homing theory in sea lampreys generally has been rejected. Applegate (1950) noted that sea lampreys entering Milligan Creek, Lake Huron (estimated as 600 to 1,000 each year between 1947 and 1949) ultimately abandoned the stream without spawning. A tagging study in 1949 resulted in six marked lampreys (7% of total released) recaptured in the two nearest lamprey producing streams (up to 14 km away), and one from the Mackinac Straits (40 km distant). Applegate and Smith (1951[b]) reported sea lampreys from a blocked migratory run in the Cheboygan River, Lake Huron, contributed significantly to the runs in streams up to 64 km distant, while making minor contributions to streams as far distant as 240 km to the west and south. A number of other streams occur in the Great Lakes basin with significant spawning runs but no larval populations.

In a variation of these studies, Skidmore (1959) examined homing of spawning lamprey to the stream from which they were initially captured. The release of tagged specimens at a number of sites in adjacent waters of the lake provided little evidence of any preference for the stream of capture over others. In 1974 a similar study was conducted in Lake Ontario using specimens from the Humber River, a stream with a major spawning migration but no resident larval population. Tagged lampreys were released at sites ranging from just downstream of the point of capture to 128 km into the lake (alongshore). Johnson (1975) concluded, based on the subsequent pattern of movement (Figure C-3), that "There was no evident tendency for sea lamprey released elsewhere than in the Humber or immediately off its mouth, to return to the point of capture."

Johnson (1976) repeated the study in 1975 but used only four release sites (Figure C-4). The only release associated with the Humber River this time was 0.8 km offshore and although 44 were recaptured at the original site from this group, another five were taken from as far away as 48 km to the southwest and 168 km to the west. Johnson (1976) made no comment similar to that of 1975 but stated "There is however an indication that a significant proportion of the spawning phase sea lamprey in the northwest quadrant of Lake Ontario may enter the Humber River during their migrations. Unfortunately this study sheds no light on the mystery of where these animals would eventually spawn since they apparently do not do so in the Humber River."

If there is a tendency for spawning phase sea lampreys to return to their natal stream, it is unlikely to be true homing. Skidmore (1959) suggests no such tendency was demonstrated, and while Johnson may have modified his earlier statement because of the-1975 results, the idea that a fairly large percentage of marked animals may return to a stream without a resident larval population is contrary to the homing concept in aquatic species. The fact that sea lampreys do not appear to home is highly important in relation to mark and recapture proposals.

e) Water Quality

Little definitive work relates to the effect of water quality on the distribution of sea lampreys, although for example, pollution has been hypothesized as the principal factor responsible for the lack of sea lamprey in southwestern Lake Ontario, and southwestern Lake Michigan (the Chicago area).

Applegate (1950) was unable to find any observable correlations between turbidity, oxygen or carbon dioxide levels and the incidence or magnitude of spawning runs. Further, he described the use by migrating lamprey of a sewage wastepipe from a paper mill on the Manistique River to reach a small upstream tributary. However, Whitefield (1948) stated (apparently without corroborative evidence) that sea lampreys used as a cue the colloidal clay suspension in a turbid stream outflow.

More recently, Morman et al. (1980) discussed the possible effects of chemical factors and pollution on all life stages, and suggested that "Adult spawners may be more tolerant of some pollutants than embryonic or larval lampreys since they run polluted streams in which larvae have never been detected". They cite unsuccessful spawning in a heavily polluted section of the Saginaw River system, but also discuss several instances of migration through heavily polluted main streams to spawn in cleaner tributaries. The recent use of new streams or stream sections in different areas of the Great Lakes coincident with pollution abatement is also mentioned. Thomas (1962) found no correlation between conductivity, or pH, and larval abundance, while Wilson (1955) attributed the disappearance of some larval populations to the formation of marsh gas (CH_4) in bottom habitats. Such findings may provide indirect evidence of certain chemical parameters capable of influencing spawning runs.

The Great Lakes Fisheries Research Branch of DFO has also begun testing sets of coupled streams (two streams closely associated both geographically and in physical appearance), one a regular or previous sea lamprey producer, the other not. The chemical characteristics of these streams are to be compared using mass spectrophotometry.

2. Preliminary activity off the stream mouth

Little has been written about the activity of sea lampreys immediately prior to ascending a stream. Observations by Applegate (1950) off the mouth of Carp Creek, Lake Huron in 1947, note that "Prior to the beginning of the run, sea lampreys congregate off the mouths of the streams. Before any enter a watercourse, they may appear for a number of nights on the alluvial fan off the mouth of a stream...and then drop back into the lake each day rather than enter the stream". He attributes this behaviour to colder water in the river than the lake. After a few days, the river water warmed for a few hours each day above that of the bay, and a few lampreys moved upstream. Other possibilities such as the effects of light could explain this behaviour.

3. Timing of the run

a) Latitudinal Effect

Sea lamprey spawning runs begin in early April in the southern portion of the Great Lakes and occur progressively later to the north. The latest known migratory runs in the Great Lakes are in the St. Marys River, the outflow of Lake Superior, where the annual peak is in early July.

A number of authors and sources have reported the first captures 'of specimens for the season. These vary greatly and are subject to the amount of collecting effort (complicated by weather conditions) or the time trapping devices were placed (date of first trapped in many cases may not be the same as date of commencement of the run). This is even more true at present than during the earlier electric barrier operations, because trapping efforts now concentrate on the major portion of the run and increase the likelihood of missing early or late specimens.

Spawning phase specimens have been reported to occur in streams for an extensive portion of the year. Records exist of captures as early as February 24 on Lake Ontario (Humber River), and March 22 on Lake Superior (McLain et al. 1965). Electric barrier operations on Lake Superior captured specimens into mid-September (McLain et al. 1965; Price 1956b). Applegate (1950) reported a specimen taken from the Ocqueoc River on September 24, 1949.

The peaks of the spawning run occur annually with great regularity and provide more appropriate indications of stability than do the extremes. Applegate and Smith (1951a) studied the peaks in runs observed at four streams on Lake Michigan, one on Lake Superior, and the U.S. mechanical trapping network of Lake Huron. Their results showed differences of more than one month from south to north in 1950. Combined catches from the present assessment network support Applegate's contention, although Lake Superior counts are rather small to show peaks in runs. However data from the Lake Superior electric barriers, when catches were much larger, suggest an average peak somewhere in early to mid-June. Investigations by Price (1956b) and Lamsa (1957a) on large runs in the Batchawana Bay area substantiate this time-frame, while a graph developed from Canadian electric barrier catches by Carter and Lamsa (1958) essentially completes the profile.

b) Potential factors regulating in-stream movement

As shown in the previous section, differences in latitude influence the timing of the runs, but other factors must be found to account for local differences in their movements. The same mechanisms that affect stream selection may apply to in-stream movement, so it is important to look at the potential factors operating within individual streams. The factors being considered, while essentially those discussed under stream selection, may elicit different levels of response once the individual streams have been entered (i.e., their roles are reprioritized).

Through his work at trapping sites within streams, Applegate (1950) demonstrated a positive correlation between temperature and numbers in the spawning run, but could not obtain a correlation with stream discharge (other than a negative response of the run to increased discharge due to cold rains or snowmelt - resulting in lower stream temperatures). Apparently while in-stream migrants move independently of stream discharge, yet discharge serves as a critical factor by creating in the adjacent lake area the cue necessary for initial attraction of the spawners to the stream. He found that migratory runs of northern Lake Huron generally would not commence at mean daily water temperatures below 4.4°C, and that the magnitude of the run remained small until temperatures of 10°C were attained. Below this, the run was highly responsive to any change in water temperature. Greatest migratory activity occurred as the water warmed between 10°C and 18.3°C, while temperatures above this tended to be inhibitory. As a result migrations are predictably erratic during the early weeks of a run, building to a peak (which may last from 35 to 50 days) then becoming sporadic again. Since streams with smaller discharges generally reacted to temperature changes more readily, the runs were correspondingly less consistent. Varying climatic conditions may serve to accelerate or delay migratory runs and make predictions of run commencements only approximate from year to year.

Price (1956b) and Lamsa (1957a) were unable to correlate the runs with fluctuations in temperature in eastern Lake Superior streams. Price indicated that "Probably the peak run is timed by conditions in the lake off the mouth of the particular stream". Lamsa noted that of two streams, one (Pancake River) experienced a peak run before the other (Chippewa River) at a time when the latter was actually warmer by 3°C. However, Applegate (1950) did point out that while a curvilinear relationship could be derived between stream temperature and the movement of spawners, there were deviations which became more pronounced later in the run.

c) Effect of diurnal changes in light intensity

Most spawning-run sea lampreys appear to migrate upstream at night. Applegate (1950) reported that, for a 3-year period (1947 to 1949), 98.1 to 99.6% of the annual run entered a trap in Carp Creek (Presque Isle County, Michigan) after dark. Of these, a majority were caught after midnight. He found similar results for the Ocqueoc River in 1949, and noted that earlier work on this stream by Shetter (1949) generally agreed. At a Canadian electric barrier on Lake Superior, Lamsa (1957b) observed that lampreys first appeared immediately after dark, with the peak between 2200 hours and shortly after midnight. McCauley (1958) concluded that the peak of the run in the Pancake River occurred between 2000 and 2400 hours. As to diurnal movement, Applegate (1950) could attribute no significant difference between sexes.

The foregoing observations do not imply that sea lampreys exhibit a totally negative response to light. Applegate (1950) described the response as increasingly less pronounced among later arrivals as the season progressed. Observations by Wigley (1959), Skidmore (1959), and Manion and Hanson (1980) support his contention that this change in behaviour is apparently associated with the gradual onset of blindness and an intensifying need to spawn.

In a 1982 study on the Cheboygan River lighted assessment traps captured about five times as many lamprey as dark traps did (GLFC 1983), but the reasons for the differences are not clear (Purvis et al. 1985). In 1984, an array of 500 watt quartz lights was placed diagonally across a section of the Ocqueoc River to study this phenomenon further. A series of night-time observations, in conjunction with results obtained from traps within and upstream of the site, were inconclusive. The investigators state that "as currently installed, the high intensity light array was ineffective in halting migration, directing movement, or increasing trapping efficiency of sea lamprey spawners.", although some form of course alteration was noted in 55% of the 91 lampreys observed (Meyer 1984).

d) Changes during the run of sex ratio and size

Surface (1898, 1899) reported that males predominate in the early part of the run, and females in the latter part. Applegate (1950) however observed that males predominated throughout the run and, while the sex ratio gradually closed with time, a sudden influx of males occurred near the end. He did note however that the failure of females to dominate in the latter part could have been due to the overall sex ratio which so strongly favoured males in his study area of northern 'Lake Huron. Present assessment trap results do not demonstrate any decided trends, and many examples occur of situations the reverse of those observed by Surface.

Decrease in the average size of the sea lamprey (both male and female) as the season progresses is often observed. A number of authors, among them Applegate (1950) and Price (1956b) have used length as the principal measure to demonstrate this observation. Portable trap collections support these findings over the entire Great Lakes basin. Manion and McLain (1971) showed that shrinkage of spawning lampreys differed by sex, and was based on time spent in the river before spawning. Studies of two species of lampreys in Scotland suggest that both shrinkage and actual small size are factors in the decrease of mean size during the spawning run (unpubl. data).

4. Habits and behaviour during the run

a) Distances travelled

Sea lamprey migrants may travel considerable distances upstream to reach suitable spawning grounds. Applegate (1950) listed known migrations of up to 77 km from the mouths of selected streams. However, the treated lengths of some Upper Peninsula streams are routinely much greater than those reported by Applegate. For example, the Ford River (Delta County, Michigan) has a sea lamprey distribution of over 113 km on the mainstream alone. Hardisty and Potter (1971) suggested that mortality of adult lampreys prior to spawning increased with the distance travelled.

b) In-stream sustained swimming speeds

Wigley (1959) found that sea lamprey moved upstream in Cayuga Inlet two to three km per day in the slow moving portions of the lower river, and only one-half km per day in the faster moving upper reaches. Skidmore (1959) determined rates of upstream migration of between 0.027 and 0.53 km per day in the Pancake River. Skidmore and McCauley (1958) using a special apparatus, measured cruising speeds of spawning adults at 14 m per minute at 2°C, and 21 m per minute at 15°C. A later study measured the uninhibited swimming activity of spawners in a test tank at 0.39 m per second, or 23 m per minute (Thomas and McCauley 1960). If one assumes a rate of 21 m per minute (or about 1.3 km/h), then over a single night-time period of swimming activity of some six hours the distance travelled would be about 8 km. According to Hardisty and Potter (1971), anadromous sea lampreys are able to travel 320 km in a few weeks (a rate of about 16 km per day).

Beamish (1974) found that at equivalent temperatures and for specimens of a similar size, the swimming rates of the parasitic phase sea lamprey exceeded those of the spawners by a factor of 15 to 19. He presumed that some of this difference was due to the effect of food deprivation and the gradual loss of energy reserves during the spawning migration.

c) Nature of movement and the reaction on encountering a physical barrier

In general, sea lampreys migrate along stream banks in shallow water when proceeding upriver against a strong current. Following brief periods of intense swimming activity the lamprey rests by attaching to rocks or other objects.

The sea lamprey is tireless in its efforts to reach suitable spawning grounds and this is most evident in its response to obstacles in its path. The sea lamprey's ability to surmount many natural falls and man-made dams of low or irregular construction is well known. Negotiating these obstacles is accomplished by a short forward lunge, which may have a vertical component seldom in excess of 0.6 m (Hardisty and Potter 1971), accompanied by a wriggling motion and a re-securing of the oral disc in the new location. In this fashion, sea lampreys slowly progress up and over low irregular obstacles. Attempts to negotiate steeper barriers consist of searching for leads and openings in the barrier itself. Thus they often find some small aperture by which to pass upstream. Observations by Davis and Shera (1971) at the Saugeen river dam showed lamprey were capable of swimming up a steep-sloped spillway up to 2.4 or 3 m against a velocity of 3.7 m/s. Six lamprey maintained this speed for periods of 1.1 to 6.1 seconds. Tests at Hammond Bay showed lampreys had burst swimming speeds of 3.6 m/s but failed at 3.9 m/s (GLFC Annual Rep. 1980). However, solid faced obstructions (natural or man-made) with a vertical height of over 30 cm are generally considered to be effective barriers to upstream migrations of sea lampreys (Hunn and Youngs 1980).

When spawning run lampreys are blocked by barriers near the stream mouth, significant numbers disperse to other nearby streams (Applegate and Smith 1951[b]). Where the barrier is located some distance upstream however, the nature of the dispersal is not well understood. Most of the blocked specimens eventually appear to abandon their attempts to surmount the barrier and drop back downstream, rather than completely exhausting themselves and dying without spawning. How far downstream they move can only be conjectured, and likely depends on a number of factors pertaining to the nature of the individual stream and the time of season. Such behaviour can be studied by techniques involving individual numbered tags or telemetry.

THE SPAWNING ACT

1. Maturation of Gametes

Larsen (1980) defined sexual maturation as the period from the appearance of secondary sex characteristics until death. The occurrence of these secondary characters coincides with the time of follicle differentiation, rapid vitellogenesis, and spermiogenesis. Applegate (1950) demonstrated that early female migrants carried ova less than fully developed (based on measurements of egg diameter) with 68% of the ova development yet to occur in females found in a stream in mid-April. By late June, development was essentially complete, but in only a few of the Late migrants had the eggs burst into the coelom. Larsen (1980) noted that the testes of male sea lamprey reach maximum size (about 7% of initial body weight) at the time when spermiogenesis commences. Spermatogonia or primary spermatocytes are the only sexual products to be found prior to this time. Hardisty (1971) suggested that mitotic division is still occurring in early upstream migrants of Lampetra fluviatilis, a species considered by Larsen to be very similar to the *sea* lamprey. Thus, lampreys of both sexes that arrive at the spawning sites early are less sexually mature than later arrivals.

2. Fecundity

A general overview of investigations on fecundity in the lampreys is provided by Hardisty (1971). Fecundity studies of Great Lakes sea lampreys have been conducted on an irregular basis by several researchers, including Surface (1899), Gage (1928), Applegate (1950), Vladykov (1951), Wigley (1959) and Manion (1972). More recently, Morse (Pers. Comm.) has been comparing fecundity estimates among the lakes. The Larval Phase Group of WESLP provides a summary of the more relevant works.

3. Habitat requirements for successful spawning

Applegate (1950) concluded' that at least three essential physical conditions must be fulfilled before sea lampreys may spawn with any degree of success. First, suitable substrates of sand and gravel (0.9 to 5.1 cm diameter) must be present for nest construction and egg adhesion to the nest. Sand (or a similar fine material) is needed as a surface for egg adherence, to increase the level of egg retention in the nest. Second, a steady unidirectional flow of water (0.5 to 1.5 m/s) must pass over the spawning grounds. And third, water temperatures must be adequate *for* spawning. He reported that major spawning activity occurred at 14.5 to 15.5°C, and coincided with those temperatures associated with peak migration. Manion and Hanson (1980) reported the requirement for temperatures in the range of 10.0 to 18.5°C, although some spawning occurred at temperatures as high as 26.1°C. They also listed water depths ranging from 13 to 170 cm and uniform flows of 0.5 to 1.5 m/s as necessary for spawning success. Piavis (1961) observed that burrowing larvae were produced only at temperatures of 15.6 to 21.1°C with an optimum of 18.3°C.

A lingering controversy continues to involve the reported requirement for a unidirectional current to achieve spawning success. Manion and Hanson (1980) noted that lamprey attempting to spawn in waters of changing direction or velocity become disoriented and frequently abandon the nest, while McLain et al. (1965) felt that changing water flows would not permit successful spawning along shorelines of the Great Lakes.

Some studies generally support the contention that sea lampreys may be able to spawn successfully in lentic environments. Two field investigations were able to obtain development of eggs to the two-cell stage (Scott 1957) and to larvae (Skidmore 1960) from still water situations within streams. Also, Skidmore (1959) observed successful spawning in still waters of the Pancake River. More recently Lamsa and Westman (1972) and Johnson (1973) reported that a SCUBA diver observed lampreys constructing nests along the shoreline of Lake Huron at Point Edward and in the entrance to the St. Clair River. The diver observed a few hundred animals on the nests, all apparently silver lampreys with the exception of one captured sea lamprey.

Other investigations contradict these indirect observations. All attempts to get penned animals to spawn in lake environments failed (Pahapill and Lamsa 1955; Lawrie 1956; and Skidmore 1960). Field observations to study potential areas (Lawrie 1956; Hogg 1956; Thomas 1961[b], among others) as well as years of general field observations by personnel of Great Lakes fisheries agencies were also unable to discover a single -instance of spawning activity occurring in a lentic environment.

In 1982, SCUBA work in conjunction with a sea lamprey telemetry study led to the discovery of nest construction and spawning activity within the St. Marys River system at depths as great as 7 m in the rapidly moving waters of the power canals. While this situation may simulate a few sites in the Great Lakes, it is not known if larvae were produced in these deepwater nests.

Smith et al. (1974) noted that even where the conditions for spawning are satisfied it is not necessarily true that such sites will be used, even if visited.

4. Nest construction

The first evidence of spawning activity on the part of either sex is the construction of a nest. Generally, nest construction is initiated by the male, who excavates a small depression about 20 cm in diameter in the gravel (Manion and Hanson 1980). Following the arrival of a female, more active nest construction then occurs. By moving rocks from the upstream to the downstream portion of the nest, an 8 cm deep depression with a crescentic downstream margin is created. Normally, one to three days are required to build the typical 45 cm wide by 40 cm long nest (Manion and Hanson 1980). Frequent spawning acts occur throughout the nest construction.

In the Ocqueoc River, 1948, the first observed nest construction was on May 22 and the last spawning was observed on July 28 (Applegate 1950). In the Big Garlic River, 1960, spawning was observed from June 27 to July 20 (Manion and McLain 1971). However, Skidmore (1959) observed spawning that produced larvae without any apparent nest construction.

5. Mate selection

Sea lampreys are predominately monogamous spawners (Manion and Hanson 1980) although the proportion of monogamy varies. Applegate (1950) observed that 77% of the nesting in the Ocqueoc River was monogamous, that the pairs remained mated for the entire spawning venture, and that polygamous matings (i.e., one male, multiple females) occurred 16% of the time, Hanson and Manion (1978, 1980) observed during studies on the Big Garlic River (Lake Superior), monogamous matings accounted for 56% of the spawning activity in 1974 and 87% in 1976. They attributed the lower percentage in 1974 to a higher percentage of females and suggested that sex ratios determine the number of females in each nest. Promiscuous spawning (more than one pair of lamprey per nest) was reported by Applegate (1950) to occur in only 2% of the nests observed on the Ocqueoc River. However, in the St. Marys River where there is a large number of spawners and a limited amount of spawning habitat, promiscuous spawning is common.

INVENTORY OF SPAWNING HABITAT

Some participants in WESLP have suggested that an inventory of spawning habitat by stream is needed. Development of a comprehensive system might provide the means to categorize Great Lakes streams by their quantity and quality of spawning habitat.

Most of the documented information comes from early attempts to assess streams (particularly on Lake Superior) for spawning potential, primarily by a subjective ranking scheme. Loeb and Hall (1952) and Loeb (1953) examined 1,293 U.S. streams from 1950 to 1952 and rated 267 as meeting requirements for lamprey spawning. Lawrie (1955b) reported that 157 of the 622 Canadian streams visited in 1954 fitted this category. Further work on this subject is rarely mentioned.

No concerted effort has been made to map the spawning habitat of Great Lakes streams. It may be possible with the many years' of survey and treatment records on sea lamprey control unit files to develop a rough approximation for a number of streams. The control unit of the USFWS at Marquette has recently been involved in utilizing a computer program known as the "River Reach" information system to attempt this. Data from the Ontonagon and Brule Rivers have been coded into this system.

THE QUESTIONNAIRE

INTRODUCTORY REMARKS

The WESLP Steering Committee prepared a questionnaire seeking comment on the current methods of evaluating sea lamprey populations, and asking for suggestions for improvement. The questionnaire was sent to 99 fishery investigators in the Great Lakes area, and responses were received from 45 of them. In this report we address those responses relating to the spawning phase of the sea lamprey. Regrettably this process excluded from consideration some generalized comments or overviews made by a number of the respondents. Accordingly the participants were asked to consider some of these general remarks in addition to the rather simplified synopses provided by the three working groups. Additionally, certain responses were, at least insofar as their relevance to the spawning phase, more applicable to another topic, while others did not follow the scheme of the questionnaire in their response, some respondents noting that the questions were not mutually exclusive. Thus it was necessary to interpret these remarks in the light of the present context,' hopefully with objectivity,

While a few respondents refrained from directed comment, none questioned the need for sea lamprey assessment. Of the responses bearing on the spawning phase, a number were somewhat general, while a few provided more detailed analysis, or included more in-depth discussion.

We have not commented on the validity or practicality of the responses, but simply list them to illustrate the variation in opinions.

SUMMARY OF RESPONSES

Question #1:

> What measures of [spawning phase] sea lamprey populations are wanted? At what level of detail (precision, spatial or temporal resolution) should the measures be provided?

Responses:

- Present measures must be inadequate, otherwise why the need for WESLP.
- Measures required are determined by the information needs that must be satisfied, namely:
  - .. a quantitative basis for treatment decisions,
  - .. a quantitative measure of control effectiveness in relation to incremental changes in management effort,
  - .. continuity in collecting methods for the sake of obtaining more precise abundance trends,
  - .. measures of precision (assignment of confidence intervals) obtained through the design of experiments permitting replication.

Recognizing these needs, the spawning phase measures required are:

.. time trends of population abundance indices with appropriate studies to tie them to control-efforts;

.. estimates of reliability (precision, bias, reproducibility) for sampling methods,

.. knowledge of sea lamprey dynamics to permit the formulation of numerical relationships between life stages,

.. understanding the *causes* or changes in biological characteristics (sex. ratio, length-weight). Why are the changes correlated with abundance indices for Lake Superior but not for *the* other lakes?

- While several indicated *a* need to study all phases to understand better their interrelationships, others tended to disagree. One person noted that the spawning phase (and parasitic) should be measured in absolute terms, while relative measures were probably adequate for larvae. Another suggested there was no obvious need for the spawning phase (or larval) to be measured quantitatively-- only the parasitic. A third commented that the only life stage necessary for quantification was the spawning phase. In agreeing, a fourth said that reasonable estimates were needed if a sterilization program was to be implemented, and suggested first efforts be aimed at one lake basin (such as Lake Superior).

- It was suggested that while the basic need is for parasitic phase numbers, it may only be possible to derive this from an index such as the number of spawners. One person carried this one step further by suggesting the use of this derivation for stable stocks of feeding lamprey, which can then serve as references for others.

- While one individual commented that present measures are adequate except in specific problem areas, especially where lake trout stocking is intensified (e.g., Peshtigo River situation), others saw the need for a much expanded sampling network.

- Where one mentioned the need for better trend series for several biological variables, through improved precision by the use of new or refined techiques, another noted that mean length of spawners was the most reliable and consistently collected statistic, and by itself served as a direct measure of the level of fish stock rehabilitation achieved. Information already available is adequate for a thorough analysis of this one characteristic. Most avoided a discussion of biological parameters.

- It was noted that the relative effects of variance due to both natural fluctuations and observer "error" must be recognized and limited. Such variation was reported as arising from changes in the size of the population from one sampling time to the next, behavioural changes with time, variations in sampling gear efficiency, variations in lamprey distribution, and clerical or counting errors.

- One respondent commented that the spatial resolution of population estimates should be considered on a lake-by-lake basis, as within-lake resolution would be unrealistic because of the observed large-scale movement of lamprey. Another considered-that sea lamprey assessment should be tied to the 'lake trout management units' presently being established by the individual Lake Committees (essentially the former 'Statistical Districts').

- Also it was mentioned that year-to-year resolution need not be high, other than in select situations, with bi- or triennial sampling likely more accurate than annual. Logistically this would permit an increased concentration of effort on each lake.

- Based *on* personal experience in allied fields of study, two respondents recommended as acceptable and possibly realistic, a level of precision of the population estimate on the order of 10 to 25%.

Question *#2:*

Should present [spawning phase] data collection practices be changed in order to satisfy the stated needs in terms of precision, reliability, and detail?

Responses:

- Two respondents indicated that present collection practices are probably adequate, but one noted that it is always possible to enhance them with additional techniques, while the other indicated that an understanding of the meaning of the results was inadequate.

- The remainder who responded to this question saw a definite need for change, first by improving methods of capture (such as by the use of artificial light), then by expansion of the network with concurrent studies (tag-recapture) directed at obtaining absolute estimates. It was further noted that because of inconsistent sampling methods, estimates to date have been of questionable precision and reliability.

- The effect of blocking spawning runs (such as by barrier dams) needs thorough investigation.

Question #3:

Are there any techniques or approaches that could improve the quality of [spawning phase] sea lamprey evaluation?

Responses:

From those discussing the need for absolute estimates of spawning populations:

- A first need, suggested by several, was that the sampling effort be intensified, i.e., expand the present sampling network either by concentrating on one lake, or by alternating intensified efforts among' the lakes so that each lake is looked at every two or three years).

- It was noted by one respondent that this intensification would compensate for the fact that sea lamprey are not randomly distributed, while another recommended that an understanding of homing (or its lack) and of distribution be developed so that allocation of the spawning runs are predictable.

- Systematic tag-recapture studies were recommended by *several,* although the approaches varied to some degree.

- One commented that the Schaefer Method (Schaefer 1951; Ricker 1958) should be used to obtain absolute numbers of spawners within streams.

- Another suggested that the upstream migrants be marked in some simple manner (e.g., fin punching) and released back into the lake of origin (either randomly throughout or, more realistically, randomly spread along the nearshore waters).

- Two mentioned that if absolute estimates were derived for both spawning and parasitic phases, then a comparison would be possible.

- Another suggested using by spawning phase males in mark/recapture experiments if it proves necessary to import specimens from other lake basins (to reduce the risk of improving the spawning potential in the study area).

- It was pointed out that statistical confidence was needed for such estimates, using replicate tests, and that the units of effort should be standardized.

- Expanding any river-by-river estimates to a lakes-wide estimate would' require some form of stream classification system.

- Develop a detailed map of the spawning areas within each stream with some measure of relative product .ty or use.

Other comments relating to this question included:

- use impartial analysis by outside experts (research labs, universities, private business) for data interpretation.

- Look to case studies for detailed analysis. One respondent indicated that the Finger/Oneida Lakes situations would be ideal for establishing well designed studies, while a second suggested freeing one or more streams from control. The latter respondent felt that the ability to estimate transformer/spawner ratios from such case studies would lead to transformer/spawner mortality data which would likely permit modelling of control effectiveness in terms of reproductive value.

- Look to new methods (e.g., light-as-attractant, remote sensing) wherever possible.

- Assess any new techniques, but evaluate their worth versus the costs in effort and resources.

- Develop increased cooperation among involved agencies for collecting lamprey data.

- Continue to develop computer technology with emphasis on standardization in reporting observations.

Question #4:

Is there a problem in interpreting sea lamprey evaluation data with regard to measuring the impact of sea lamprey predation on fish populations?

Responses:

All but a few of the respondents took this question in its most rigid sense (i.e., relevant only to the parasitic phase). Those remarks relating to the spawning phase were essentially as follows:

- One respondent implied that no real problems exist in interpretation for any of the life stages.

- Another suggested that, while present relative measures of abundance of the spawning phase populations are (within limits) reasonable, the problem exists in relating these measures to the lake feeding populations.

- Correlation between different indices of abundance from the historical record have been demonstrated without any explanation for or understanding of the causes. One example would be the strong correlation between trends in relative spawning population abundance and fish stock restoration with only imprecise, vague notions of the interactions involved. Another would be the apparent relationship between changes in sex ratio and mean size of lamprey with changes in their abundance (well demonstrated on Lake Superior with runs at the electric barriers, but not very well repeated in other lakes). Controlled experiments are needed to address these concerns,

Additional Comments

Remarks which do not fit the four questions are listed below.

- Assessment of the control programme is the responsibility 'of the various fish management agencies who are in the only position to answer whether or not, from the standpoint of rehabilitation, present control levels are acceptable.

- Evaluation must not remain subordinate to other aspects of the control programme, for after 27 years, control is still measured on the basis of the "number of streams treated" rather than "defined reductions in the population".

- The perceived purposes for collecting population data should be addressed early in the WESLP process.

- The cost/effectiveness of all proposed methods must be assessed in relation to programme requirements (especially as to degree of accuracy, and geographic and temporal measures).

- Control agents. should concentrate their efforts on "damage reduction" rather than on, say, killing the most lamprey.

- It was suggested that four criteria are useful for deciding on sampling methods: availability, cost, feasibility, and reliability.

- A paradox exists in which we praise our success and yet lament about evidence of major problems with sea lamprey.

- The decision-analysis used to determine the need for certain treatments (e.g., the 1983 Nipigon River treatment) should be written up as case histories for discussion.

- The numbers of sea lamprey should serve as an excellent indicator of the level of rehabilitation achieved.

- There is a need to look more closely at the effects of land use practices on sea lamprey populations.

- R. Pycha has volunteered to provide his data from the early 1970's which showed a correlation of r = 0.93 between Michigan-Wisconsin spring wounding rates and the spawning runs at 16 barriers, including those assumptions and adjustments made to achieve it.

- The comment was made that, since man has been so successful at overharvesting other species, why not sea lamprey?

LIST OF QUESTIONS NEEDING ANSWERS
(A SUBJECTIVE INTERPRETATION BASED ON THE RESPONSES)

GENERAL TYPES:

1) Where does the ultimate responsibility reside for deciding the acceptability of a given population size of sea lamprey, and should it be there?

2) Do we require some quantitative measure of control effectiveness, capable of recognizing responses to incremental changes in management effort?

3) Should continuity in assessment practices be of greater concern than continually seeking new methodologies?

4) Are more intensive studies of sea lamprey dynamics needed in order to link trends in population numbers to control efforts while accounting for natural fluctuations, and to permit the development of numerical relationships between life stages?

5) Should the role of evaluation be recognized as equal to other aspects of the control program, so that effectiveness can be more appropriately stated in terms of "defined reductions in the population" or "damage reduction" in the fish stocks, rather than "numbers of streams treated" or "numbers of lamprey killed"?

6) Are measures of precision required? To achieve this, should not experimental design permit replication?

7) Should analysis of the data be conducted by (impartial) outside expertise?

8) Should sea lamprey control case histories be described to demonstrate the role of assessment in the decision-making process (e.g., 1983 treatment of the lower Nipigon River)? Should specific case studies be instituted to permit quantification of control effectiveness under experimental conditions (e.g., a detailed look at the Finger Lakes; freeing a stream, lake basin, or an entire lake from control)?

9) Should increased cooperation among all fisheries agencies be deliberately imposed or developed? Should further standardization of reporting and computer technology be pursued?

SPECIFICALLY DIRECTED AT THE SPAWNING PHASE:

1) Are absolute population measures necessary for the spawning phase?

2) With respect to spatial resolution, at what geographic level would spawning phase assessment prove realistic? Practical?

3) With respect to temporal resolution, might bi- or triennial sampling prove more accurate than annual, and would this not free resources to permit more intensive efforts to be instituted?

4) Should the spawning phase sampling effort be intensified?

5) What is the effect on spawning runs of physical blockages such as barrier dams? Is there justification for the fear that modifications to spawning patterns could be imposed, leading to misinterpretation of assessment data?

6) Is a better understanding of the causes of measured changes in spawning phase biological characteristics required? For instance, why was the correlation with between abundance and lamprey size possible on Lake Superior but not the other lakes?

ADDITIONAL STUDIES AND INFORMATIONAL NEEDS

This section consists of a list of issues, concerns or questions which have been identified 'by members of the Spawning Phase Sea Lamprey Group over many years of assessment work, or in the development of this paper. Some of these items are similar to those expressed by participants who contributed to Section V (The Questionnaire), but the fact that they have been identified by both the corresponding participants and the group members may serve to emphasize their importance. The following needs are not prioritized.

- a standard working definition of a spawning phase lamprey;
- to develop new, and standardize existing, assessment policies, and better protect assessment budgets to ensure long-term consistency;
- to acknowledge the possibility that spawning phase assessment may itself serve as a form of control (potentially problematic for any sterile male control program);
- to alter treatment schedules so they do not conflict with assessment operations (a problem particularly acute on streams of Lake Ontario);
- detailed investigations into the underlying physical/chemical/biological factors that cause lampreys to select streams for spawning;
- increased emphasis on the collection of physical and chemical data on streams currently assessed for spawning phase lampreys. Presently this information is deficient , particularly during the period in which active spawning occurs;
- to develop the means to account for the influence of changing methods on measures of abundance (e.g., electric weirs to mechanical weirs to dam traps) not only to meet future requirements, but to interpret existing data sets;
- further validation of nest counts as an approach to estimating populations of spawners;
- an inventory of spawning habitat by stream. Development of a comprehensive system might provide the means to categorize all Great Lakes tributaries by their spawning-run loading capacity, and may be one attribute required to derive realistic estimates;
- to define the relations of spawning habitat to larval habitat to total production of larvae;
- to define the relation of use of spawning habitat to the total number of spawning adults;
- a thorough investigation of the effect (in terms of numbers of lamprey) of blocking spawning runs, both on the affected stream and its adjacent areas;
- an understanding of the mortality factors from the parasitic- to spawning-phases;
- to know the effect of concentrations of host fish species on the distribution of spawning runs;

- the study of design criteria for assessment devices so as to maximize collecting effectiveness, including:

  1. size of trap-or weir - is uniformity preferrable to designing devices to suit individual sites?

  2. materials - are solid sides preferrable to open mesh in mechanical traps?

  3. what is the optimum funnel configuration and entrance size, etc.;

- development of techniques to effectively sample populations from streams where present methods cannot be utilized;

- knowledge of the minimum number of sea lamprey specimens required for a reliable estimate of relative numbers, or to provide representative samples for length/weight and sex ratio data. Some of the specific questions relating to this are:

  1. how many sites are needed on a lakewide or regional basis (includes geographical spread needed for adequate coverage)?

  2. the importance of negative or marginal catches in terms of objectives;

  3. how best to sample on a daily basis to maximize and standardize results;

- to determine the most reliable, cost-effective procedure to estimate spawning runs in individual tributaries, taking into account many of the above considerations. At present a stratified tagging and recovery system is a popular approach. Are there modifications to this which would enhance its accuracy or simplify its application?

- further analysis of the relationship between sampling efficiency and estimated run size from the historical record and any future studies. Can significant correlations be drawn that will allow predictions of run size by sampling procedures alone?

- to understand the representativeness of in-stream collections in relation to the stream run. Possible concerns include:

  1. the number and types of tributaries to a stream, located below the collecting site, which attract portions of the run;

  2. the distance to the collecting site and the amount of spawning habitat available below the site that could result in a progressive thinning of the numbers moving upstream;

  3. are there other biases, such as: one sex tending to move further upstream than the other, one size range of lamprey more willing (or forced) to move further upstream than others, relative physical strengths between sexes or among size groups to overcome obstacles, the effect of the time of season on the desire to spawn versus migrate, etc.?

We believe that the foregoing concerns should be considered on their own merits, regardless of the support that may, or may not, be accorded the research proposals (Detailed Description of Proposals) that embody some of the same ideas, and evolved from a similar process of reasoning.

DETAILED DESCRIPTION OF PROPOSALS

PROPOSAL C-1 - Relative abundance based on counts from index streams

PROPOSAL C-2 - Relative abundance based on changes in biological characteristics

PROPOSAL C-3 - Absolute population estimates based on the mass release of marked spawners into the lake environment

PROPOSAL C-4 - Lakewide expansion of absolute population estimates from index streams

PROPOSAL C-1

An approach to monitoring the abundance of sea lampreys in the Great Lakes: The measurement of annual changes in the relative abundance of spawning phase sea lampreys at index rivers.

BACKGROUND

All present methods used to monitor the populations of spawning phase sea lampreys in Great Lakes waters of the United States and Canada are measures of relative abundance. The theory is that annual catches of lampreys taken consistently from the same sites during the same time, will show long-term changes in the population. Such trend data are shown in Table C-I.

Sea lamprey are captured with several types of traps, the designs and modifications of which are discussed in another section of the report. Barrier dam traps were first constructed in 1971 and portable traps, the primary collection tool, were first operated in 1975. Thereafter, they were extensively tested for several years in more than 110 streams in the U.S. and Canada and, by 1980, had displaced the electric barriers. More recently, traps built into barrier dams have become increasingly important in Canada. In 1984, 48 tributaries were monitored in the Great Lakes, 32 in the U.S. and 16 in Canada.

Another present measure of relative abundance of sea lampreys in the Great Lakes is the count of nests in standardized sections of selected streams. In 1984, nest counts were conducted on four tributaries of Lake Erie and seven tributaries of Lake Ontario by personnel of the New York Department of Environmental Conservation.

The following summary outlines the assessment of spawning phase sea lampreys in 1984.

OBJECTIVES

1. To monitor the relative abundance of spawning phase sea lampreys at barriers on index tributaries of the Great Lakes.

2. To establish a trend-through-time series of catches on index streams and to correlate this data series with the intensity of the control program.

3. To establish trends in the biological characteristics (length, weight, and sex ratio) of sea lampreys captured in index streams.

4. To monitor the annual abundance of sea lamprey nests in standardized index sections of selected tributaries of Lakes Erie and Ontario.

5. To provide live sea lampreys for use in experimental control measures and other scientific investigations.

6. To reduce the overall reproductive potential of the lamprey population by removing a portion of the spawning run.

PROCEDURE

The current assessment program for spawning phase sea lampreys is well defined in procedural manuals and annual reports to the GLFC. With respect to assessment trapping, the U.S. and Canada take slightly different approaches to collection of the data. For 1984; the USFWS contracted the field work on 20 of the 32 streams through universities or consulting companies. The other 12 were serviced by USFWS employees. In Canada, all devices were checked by DFO employees. Nest counts were conducted immediately after the completion of the peak of lamprey spawning which varies slightly from year to year.

The timing of the spawning run varies geographically. Traps are set first in southern Lake Michigan and Lake Erie (April 1-10), next in Lake Ontario and central Lakes Michigan and Huron (April 11-May 5), and then in Lake Superior (May 1-10). Traps are set last in the St. Marys River (June 1o-20).

The trapping season is 8 to 10 weeks. The peak of the run lasts about 2-3 weeks and generally occurs about three weeks after the traps are first set. Traps are removed in the same order in which they were set, first in the south and then gradually working north. All routine trapping is finished by August 10, the last being in the St. Marys River.

Nest count surveys require about one week for all streams. Also, about two days are needed for the training and testing of personnel.

SCHEDULE

The following are the highlights of the schedule for 1984:

JANUARY - MARCH

Plan steps and sequence of work
Prepare field schedule for personnel
Repair damaged traps, construct replacements as needed
Prepare equipment associated with trap runs

APRIL - AUGUST

Conduct trapping operations and nest counts on index streams

SEPTEMBER

Conduct inventory on trap equipment
Draft and submit to Regional Office (U.S.) contract proposals for the next season

OCTOBER - DECEMBER

Compile and analyze data
Prepare reports on data
Make repairs to trap sites; prepare new trap sites as needed

B U D G E T - ONE YEAR

		Estimated Cost in U.S. $	
UNITED STATES FWS			
PERSONNEL -			
Biologists - 1 for 1/3 time	$40,000 x .33	13,200	
Technicians- 4.25	20,000 x 4.25	85,000	
	Total personnel		98,200
COST COMPONENTS			
Travel		12,500	
Transportation of things		900	
Communications		1,300	
Rent and Utilities		8,600	
Printing and Reproduction		200	
Other Contractual Services		67,800	
Equipment		15,000	
	Total Cost Components		106,300
ADMINISTRATIVE SERVICES			
WO		3,300	
RO		13,100	
	Total Administration		16,400
	T O T A L - USFWS		$220,900
NEW YORK DEC			
PERSONNEL			
Biologist - 1 for 1/20 time	$40,000 x .05	2,000	
Technicians - 4 for 1/20 time	20,000 x .05	4,000	
	T O T A L - N Y D E C		$ 6,000
CANADA DFO			
PERSONNEL			
Biologist -	$40,000 x .33	13,200	
Technicians/casuals	20,000 x 2.6	52,000	
	Total Personnel		55,200
COST COMPONENTS			
Travel		11,000	
Transportation of things		4,200	
Communications		400	
Rent & Utilities		700	
Printing and Reproduction		300	
Other Contractual Services-(Incl. EDP)		3,900	
Equipment		10,300	
	Total Cost Components		30,800
ADMINISTRATIVE SERVICES		5,000	
	Total Administration		5,000
	T O T A L - D F O		$101,000

It is important to recognize that the previous discussion, and especially the outlined budget, are based on the 1984 assessment program. While the budget indicates present assessment strategies through measures of relative abundance, it neglects to show that funding constraints have imposed some limitations on the coverage of the Great Lakes. A more thorough and adequate assessment system, based on present techniques, would necessitate a budget increase of about 50% over the 1984 level.

PROPOSAL C-2

An approach to monitoring the abundance of sea lampreys in the Great Lakes: The measurement of annual changes in the biological characteristics of lampreys.

BACKGROUND

The sea lamprey has been native to Lake Ontario for over a century, and its biological characteristics have changed in adaptation to the freshwater habitat. Mature adult sea lampreys from the marine environment have an average length of 830 mm and an average weight of 925 g (Beamish 1979), but those from the Great Lakes are smaller. Lampreys captured in Carp Creek, Lake Huron, in 1947 (one of the first years in which a significant number of lampreys were sampled from a Great Lakes tributary) averaged 442 mm in length and 184 g in weight, but as conditions changed, the length, weight, and sex ratio varied.

Factors that influence changes in length, weight, and sex ratios of lampreys have been stated in previous sections. Heinrich et al. (1980) reported changes in length and weight in the Great Lakes as a result of chemical control, lamprey abundance, and prey abundance. The annual mean lengths and weights were relatively low when lampreys were abundant and increased as the numbers were reduced by the control efforts. Sea lamprey lengths and weights were low when prey fish stocks in the Great Lakes were near depletion. As salmonids again became abundant through natural resurgence or stocking, lampreys grew larger. In U.S. waters of Lake Superior, where detailed records on lake trout abundance have been available since 1959, a significant relation exists between changes in the estimated weight of sea lampreys at the arbitrary length of 410 mm and in abundance of lake trout greater than 432 mm in length (1959-78). Male sea lampreys were the dominant sex when populations of the parasite were high, but a shift to a preponderance of females occurred in the upper Great Lakes as lamprey abundance declined. This phenomenon has not appeared in Lake Ontario where the population has maintained a slight predominance toward males in spite of lampricide treatments.

As an alternative to monitoring the abundance of sea lampreys directly, we shall describe the changes that would be needed to use variation in biological characteristics as the sole measure of assessment. This method provides an indirect indicator and its use probably would be appropriate during times of significantly reduced funding. The information is presently collected as a part of the assessment trapping program. An example of the data collected by the Control Agents in 1983 is presented in Table C-II.

OBJECTIVES

1. To monitor the condition of the populations of spawning phase sea lampreys through the collection of data on biological characteristics (length, weight, and sex ratio) from key index tributary rivers.

2. To correlate the biological characteristics of sea lampreys with the relative abundance of the lamprey population.

3. To correlate the biological characteristics of sea lampreys with the population of lake trout or other host species.

PROCEDURE

Although past data have shown a significant co-relation between population abundance and biological characteristics of sea lampreys (particularly Lake Superior), in other areas of the lakes the relationship is not as apparent. Several questions need to be answered before an assessment scheme based solely on biological characteristics can be adopted.

A statistically sound sampling design would need to be defined. To achieve the same reliability in data presently collected, what streams need to be sampled and during what time period? Data from the last 40 years would need to be reviewed and analysed statistically to determine total number of lampreys required, which streams to sample, and for what duration of time collections would be needed from a basin.

A clearer definition is needed of the factors involved in changes in lamprey length and weight. Are they a reflection of lamprey abundance, prey abundance or both? To define the causes would require review of past data from all lakes, laboratory experiments, and possibly a field experiment. With the exception of Lake Superior data, lampreys in the other lakes are now considerably larger than they were 15 to 20 years ago. Analyses of data on lamprey size, the timing of control techniques, and the varying abundance of prey (when these combinations of data are available) need a close examination. Still, we believe a comprehensive, long-term laboratory experiment using varying combinations of prey and parasites in large ponds will be necessary to draw further conclusions.

The mechanism causing the changes in the ratio of males to females is not well understood. The reduction in the percentage of males in the populations of lampreys is evident after control in the upper lakes, but the change was not as great in Lakes Michigan and Huron as in Lake Superior. The trend in Lake Ontario was always toward a dominance of males. Are these simply a factor of undetected recruitment of larvae? Possibly the answer lies in a careful examination of the sex of larvae from all or most of the streams in a lake basin to determine the relation between sex of larvae and adults. Much of this information is now available, but where it is not, new collections would need to be made.

While a correlation between the sea lamprey length/weight rates and lake trout abundance has been shown in Lake Superior, no such relations have been demonstrated in the other lakes. An examination of the data for evidence of such a correlation can be attempted for the other lakes where a sufficiently large number of years of information is available. Lake trout have not been sampled on the consistent, long-term basis in the other lakes as in Lake Superior, but possibly the same type of correlation could be demonstrated for another species of fish (e.g., chinook salmon).

The development of an acceptable assessment scheme based on the collection of data on the biological characteristics of sea lampreys will progress through three steps:

1. The annual collection of data on biological characteristics. This can be obtained in a minimum amount of time and needs only the development of the most reliable sampling design.

2. Generating information on fish abundance and species composition for developing correlations between these variables and the lamprey length/weight relationship, and sex ratio. This will require considerable interagency cooperation.

3. Determining the relation between changes in lamprey biological characteristics and the control effort. This will be difficult to address reliably. Heinrich et al. (1980) showed length/weight, and sex ratio, in some instances, are correlated with relative abundance of sea lampreys. The solution may become evident with the successful completion of step 2.

SCHEDULE

YEAR1

.. Determine sampling design

.. Set specific number of lampreys that need to be collected

.. Determine specific streams to take collections from

YEAR 2-5

.. Design and conduct long-term study to clearly define relation **of** biological characteristics of lampreys to fish abundance

.. Review relation of sex ratio in larvae to sex ratio in adult lampreys

.. Continue as in Year 1

B U D G E T - ONE YEAR

UNITED STATES FWS

		Estimated Cost in U.S. $	
PERSONNEL -			
Biologists -	$40,000 x 1.5	60,000	
Technicians -	20,000 x 2.5	50,000	
	Total personnel		110,000
COST COMPONENTS			
Travel		5,000	
Transportation of things		900	
Communications		1,300	
Rent and Utilities		8,600	
Printing and Reproduction		200	
Other Contractual Services		30,000	
Equipment		15,000	
	Total Cost Components		61,000
ADMINISTRATIVE SERVICES			
WO		3,300	
RO		13,100	
	Total Administration		16,400
	T O T A L - U S F W S		$187,400

CANADA DFO

PERSONNEL			
Biologists -	$40,000 x .5	20,000	
Technicians/casuals	20,000 x 4.0	80,000	
	Total Personnel		100,000
COST COMPONENTS			
Travel		18,300	
Transportation of things		7,000	
Communications		700	
Rent & Utilities		700	
Printing and Reproduction		400	
Other Contractual Services	(Incl. EDP)	7,000	
Equipment		15,000	
	Total Cost Components		49,100
ADMINISTRATIVE SERVICES		8,300	
	Total Administration		8,300
	T O T A L - D F O		$157,400

PROPOSAL C-3

The absolute estimate of a population of spawning phase sea lamprey based on the mass release of marked members of the population into open lake waters.

BACKGROUND

As a possible option to estimate populations of sea lamprey, we propose the marking and release of a statistically valid number of spawning phase adults, into the body of water that is the source of the spawning runs under investigation. The subsequent capture of representative samples of both marked and unmarked specimens will yield the variables of marked to unmarked members to be entered into an appropriate estimate model.

Although the method appears simple, certain assumptions are required and a number of practical difficulties would occur. The assistance of other Great Lakes agencies would be needed (for handling and transport, etc.), while other concerns could only be clarified through additional study.

For the purpose of the following exercise, we define a lake as one of the Great Lakes, and a lake basin as some smaller portion of a lake. While there is some evidence to suggest that populations of sea lamprey in each lake are essentially isolated from one another, and that within-lake populations may be segregated into discrete regions (Heinrich et al. 1985), the evidence remains circumstantial. Also, realistic geographical boundaries are not rigorously defined.

The few studies that have addressed the movement of adult spawners in open lake waters were cited in the sub-section on homing tendencies. Of these, the work by Johnson (1975, 1976) offers the most appropriate background for the present proposal. Intended to test homing, and provide an incidental measure of the effectiveness of the Humber River dip-net operation, this study also demonstrated a surprisingly high per cent of return in an area where there was no organized in-stream collecting network (Figures C-3 and C-4). With the addition of the trapping network that now exists on Lake Ontario, we presume the per cent, return in a similar study today would be higher. Some of the spawners in Johnson's studies travelled long distances after they were released. While such movement may reflect disorientation, we do not believe this to be a significant factor. It does suggest that, for at least smaller water bodies such as a Lake Ontario, the release of sea lamprey in some randomized fashion over its surface- is a realistic concept.

OBJECTIVES

1. To make precise estimates of the total spawning phase sea lamprey population entering tributary streams of a Great Lake

2. To test the validity of data sets based on relative numbers as evidence of trends in abundance

3. To provide additional observations on the distribution and movement of pre-spawning adults in the lake

4. To test the effectiveness of spawning phase collecting methods

5. To test the concept of discrete sea lamprey stocks

PROCEDURE

We must first decide in what geographic areas the approach would be practical. Then we must consider several interrelated factors, as discussed below.

A. Methods of Initial Capture.

Presently, the only effective ways of collecting sea lampreys from a lake environment are through the commercial and sport fisheries. Trawling was effective in the St. Marys River in years past, but the lamprey concentration needs to be very high before the method is practical. We do not know of any areas in the Great Lakes where trawling would work. Furthermore, these methods are labour intensive and, for the most part, deal with feeding phase lamprey. Therefore, we view in-stream collections of spawning phase adults as the only practical approach to capturing lampreys.

Several techniques used to capture lampreys in streams include mechanical traps, dip or impounding nets, and hand capture off the spawning redds. A chief concern with in-stream collections is the need to wait for the specimens to arrive at the collecting sites. When the specimens are returned to the lake after marking, they must reorient themselves, traverse the distance to the same or another stream, and ascend that stream (i.e., in effect roughly doubling their migration). Because sea lampreys deteriorate physically as the season progresses causing a possible bias, we believe that collection off the spawning grounds holds little promise for capturing lampreys to mark. This limits collection methods to in-stream traps and nets. Further, we need to develop a cut-off date to limit the duration of the collection season.

If the numbers of sea lamprey available from the lake or basin under study are insufficient, then supplementary or even primary sources might be sought elsewhere. It may be possible to import lampreys from exotic sources such as the Finger Lakes, Lake Champlain, or the East Coast for marking and release in the Great Lakes.

B. The Number of Spawners Required

The estimate model would begin with a preliminary survey to determine the possible numbers of lampreys in the population. This could be based on a combination of historical information and subjective observations, but the more acceptable approach is to run an initial mark-recapture effort for the preliminary value. This initial survey is less rigid from a statistical sense (Robson and Regier 1964 suggest for the Petersen Estimator a value of $p= .5$, with a $p= .25$ or better for the ultimate study).

C. Modes of Transport

Transportation requirements will depend on the scheme used to select release sites. Trailered boats can be used if releases are close to shore and reasonably accessible. However, if a central point or randomly scattered pattern is chosen, something larger would be needed (government agency research or management vessels, fishing tugs, charterboats or aircraft). Various state and provincial fish stocking agencies have experience in the use of tugs and aircraft for stocking procedures, and cost breakdowns and travel times are available.

D. Design for Release Sites

This is the major consideration in the proposal. A near-shore release will minimize the hardships imposed on the lampreys. However, if the spawning phase animals are normally scattered throughout the lake, then a scatter release may be preferred to maximize the admixing of the marked and unmarked members.

The options are:

- a release in the central portion of the lake or lake area;
- a randomized release over the surface of the lake area;
- a release weighted by known or perceived natural densities within the area;
- a randomized release along the shoreline;
- a release off the mouths of the streams of capture (if they occur in the lake area under study).

We view the shoreline releases (whether randomized or concentrated) to be most feasible because past evidence suggests most spawning phase lampreys would normally be inshore prior to entering streams.

E. Methods of Retrieval

The preferred technique for the recovery of marked lampreys is to use the same traps initially used to capture lampreys to mark. A problem exists here in that from the time of first release of marked specimens into the unmarked population, some time must be allowed for complete mixing to occur. Therefore, the commencement time of the retrieval count must be carefully chosen.

The use of manual capture of specimens off the spawning grounds also could play a significant, if not major, role in the retrieval count. Again, it is necessary to determine a realistic time to initiate the retrieval, as the earliest spawners may not be represented by marked members. Reaches of spawning gravel on known spawning streams could be traversed daily during the critical period.

F. Type of Estimator

If the lake-tributary complex could be considered as a closed system with no immigration and the only loss of significance being mortality, then a modified Petersen estimate is reasonable. Otherwise if a stratified sampling method is used it will be difficult to decide on an appropriate model for the estimate. The Schnabel Method is used to compute a population of constant size by repeated sampling and marking, while the Overton modification of the Schnabel Method is intended to account for known reduction or removal of individuals from the population. This aspect requires further examination.

SCHEDULE

The following assumes that for the first effort, a geographical setting (be it a lake basin, lake, or 'lake group) has already been designated. If a trial run is required, it would likely be limited to a single lake basin or lake (to permit a concentration of resources, and avoid an overly ambitious effort).

YEAR 1: PILOT STUDY

Jan. - Mar.- Plan steps and sequence of work.

- Design and obtain equipment for capture, tagging, transport, release and recapture purposes as necessary.
- Arrange for personnel resources.
- Prepare field schedules.
- Contract or otherwise arrange for modes of transportation to be used (vehicles, commercial tugs, fishery agency vessels, aircraft, etc.).

Apr. - Aug. - Conduct field investigations.

- Maintain control over the information being generated and problems arising.

Sept. - Dec. - Compile and analyze data.

- Prepare reports.
- Inventory, maintain, and repair equipment - replacing as necessary.

NOTE: If the pilot study were successful, and of adequate intensity, it might subsequently become an acceptable model for the definitive estimate.

YEAR2 (to YEAR?):

A more intensive schedule similar to YEAR 1.

<u>ONE YEAR BUDGET</u>
(U. S. Dollars)

A budget for the present proposal would be about 1.75 times the dollar base for Proposal C-l. We base this on a 50% increase over the 1984 costs (needed to satisfactorily upgrade that method of relative abundance), plus a further 25% for other costs incurred by the present proposal (additional personnel to mark and release lampreys, greater need for supervisory control, aircraft or other transport costs, etc.).

PROPOSAL C-4

An approach to monitoring the abundance of sea lampreys in the Great Lakes: Estimating absolute numbers of spawning phase sea lampreys in index tributaries and transforming the estimates into a lakewide estimate;

BACKGROUND

The methods used to estimate the population size of spawning phase sea lampreys entering Great Lakes tributaries are complex. At present, estimates of run size are determined only in selected tributaries where assessment traps operate efficiently (Section C: page 2 - Introduction, and page 12 - Mark-Recapture Studies to Date). The primary estimator is a stratified tagging and recovery system developed to estimate the number of fish in spawning runs of Pacific salmon (Schaefer 1951; Ricker 1975) that appears reliable for sea lampreys as well. To relate the estimates in monitored streams to non-monitored streams for a lake-wide estimate complicates the process. As a result, methods to estimate spawning populations of sea lampreys must address two areas. First is the ability to reliably estimate the number of spawners entering a particular river. Second, the design must relate an appropriate selection of monitored streams (all or a subsample) where run sizes are estimated to the total number of spawning phase lampreys entering non-monitored tributaries. The latter presents the major difficulty in the estimation process.

Determination of the estimated population size of spawning phase lampreys occurs after completion of the spawning run. More precise estimates could guide program resource allocations in future years. Estimates from other life stage sources (particularly the parasitic phase) may enable prediction of future run sizes thereby providing numbers of sea lampreys available for programs such as a sterile male release.

OBJECTIVES

1. To make annual estimates of the spawning phase sea lamprey population in a select group of tributaries of the Great Lakes.

2. To relate the estimates of spawning run strength in monitored streams to populations of lampreys in non-monitored streams.

3. To correlate the estimates for streams into basinwide estimates.

PROCEDURE

Estimates of run size require a sequential set of observed catches at a fixed sampling site. The usual procedure is to sum these catches over the duration of the run with each catch weighted by the efficiency of the trap.

$$N = \Sigma_t \alpha C_t \qquad (1)$$

where C_t is the catch at time t and α is the efficiency of the assessment trap. Mark and recapture studies at each trapping site will provide a measure of trap efficiency.

If it is impossible to use traps at barrier dams, an alternative would be a survey of nest density. To estimate the size of a run from nest counts requires information on total spawning habitat area and average nest density or information on nest density by- habitat type (i.e., substrate composition or suitable surrogate) and the area of stream in each habitat category. Without spawning habitat area, nest density can only be used as a relative measure of run size for a particular stream over time.

To extrapolate from a subsample of runs (i.e., those tributaries that can be readily sampled) to the abundance of spawning phase lampreys requires' a prediction of the relationship between the subsample streams and all other streams. One approach would be to assume that the run size estimates of equation (1) are a function of a linear combination of stream attributes:

$$N_i = B_o + B_1X_1 + . . . + B_pX_p \qquad (2)$$

where Ni is the run in stream i, X_j (j = 1 to p) are attributes of stream i, and Bj are coefficients. Attributes o2 each stream could include physical, chemical, or biological characteristics.

Estimation of the Bj coefficients in equation 2 is possible by multiple regression, using runs and a specified subset of stream attributes (e.g., flow, temperature, chlorides, length, ammocoete density, etc.) from monitored streams. Estimates of runs in non-monitored streams are then made from known attributes and coefficients. To be reliable, however, this protocol requires that the range of attributes used in the estimation of coefficients in equation 2 be representative of those for all non-monitored streams. Because presence of adults has been the primary criterion for monitoring a stream, the selection of rivers for trapping serves the control program and not an explicitly designed scheme to estimate total abundance of spawning phase sea lampreys. As a result, the requirement for the' protocol may not be met unless assessment effort is redirected to include monitoring some streams not currently assessed which possess attributes more closely oriented to other non-monitored streams.

As a check on estimation protocol it might be worthwhile to explore the common characteristics of streams known to produce ammocoetes. For example, Seelye and Scholefield, as reported in Meyer (1984), have shown a correlation between electric barrier catches on eight Lake Superior tributaries and mean spring discharge of the streams. Similarly, we found high correlation (r = 0.90) between average spring flows and the estimated total spawning runs of seven Great Lakes tributaries where assessment traps were placed during 1977 to 1980. Further, multivariate statistical techniques (cluster analysis, ordination, discriminant function analysis, etc.) could be applied to all streams entering a lake. These analyses may show for example that ammocoete density is a good indicator of the spawning run, or that the subset of monitored streams does not account for the majority of spawning runs in the lake, rather only the successful ones. In either case, these preliminary analyses must be guided by various hypotheses of the behaviour of spawning run sea lampreys and what stream attributes influence lampreys selection of a stream. Furthermore, data must be obtained on attributes of as many streams for the basin as is feasible.

SCHEDULE

Year

1 ____ Spawning phase assessment is carried out on the selected Great Lakes streams (number scheduled for FY85; United States 38 and Canada 13).

____ Detailed physical and chemical data are collected during the spawning season on each of these streams.

____ Population estimates using stratified tagging and recovery are performed on each stream.

____ Data are analyzed to determine stream attributes exhibiting correlation with run size.

2 ____ As above plus

____ Physical and chemical data are collected during spawning season on non-monitored sea lamprey streams.

____ Data are examined to reveal if attributes found in year 1 are representative of those examined in non-monitored streams of year 2.

____ Population estimates for representative non-monitored sea lamprey streams are extrapolated.

3 ____ As above for year 1 and 2 plus

____ Research historically negative streams as to the fate of lampreys that may ascend them during the spawning season.

____ Assessment activities are realigned if necessary, based on results from year 1 and 2 to ensure that monitored streams are representative of non-monitored streams.

4-6 ____ As in year 1, 2, 3

7 and beyond--Annual estimation of the spawning runs in the monitored streams and extrapolation to non-monitored positive (and negative if necessary) streams.

MANPOWER AND RESOURCES

Budget is based on a best guess for the required number of personnel and on a percentage of the FY86 budget for the cost components. For the initial 3 years of implementation add 15% each year to cover additional contracting services and other costs, for years 4-6 5% is added for growth as the proposal's activities stabilize. Year 7 should allow for reduction in costs when only trapping/estimating of "index" streams occurs. We estimate this at 20%.

B U D G E T - FIRST YEAR

UNITED STATES FWS

		Estimated Cost in U.S. $	
PERSONNEL - .			
Biologists -	$40,000 x 1.5	60,000	
Technicians -	20,000 x 5	100,000	
	Total personnel		160,000
COST COMPONENTS			
Travel		15,000	
Transportation of things		1,000	
Communications		1,500	
Rent and Utilities		8,600	
Printing and Reproduction		200	
Other Contractual Services		67,800	
Equipment		20,000	
	Total Cost Components		114,100
ADMINISTRATIVE SERVICES		26,400	
	Total Administration		26,400
	T O T A L - U S F W S		$300,500

CANADA DFO

PERSONNEL			
Biologists -	$40,000 x .75	30,000	
Technicians/casuals	20,000 x 7.0	140,000	
	Total Personnel		170,000
COST COMPONENTS			
Travel		32,000	
Transportation of things		12,200	
Communications		1,200	
Rent & Utilities		700	
Printing and Reproduction		600	
Other Contractual Services	(Incl. EDP)	10,000	
Equipment		22,500	
	Total Cost Components .		79,200
ADMINISTRATIVE SERVICES		14,500	
	Total Administration		14,500
	T O T A L - D F O		$263,700

IMPLEMENTING YEAR	COST	% CHANGE
1	$563,700	
2	648,300	15
3	745,500	15
4	782,800	5
5	821,900	5
6	863,000	5
7	690,400	-20

LAKE HURON

25. St. Marys R.
26. Kaskawong R.
27. Thessalon R.
28. Mindemoya R.
29. Manitou R.
30. Blue Jay Cr.
31. Ocqueoc R.
32. Cheboygan R.

LAKE ERIE

33. Chagrin A.
34. Grand R.
35. Cattaraugus Cr.

LAKE ONTARIO

36. Humber R.
37. Don R.
38. Duffin Cr.
39. Bowmanville Cr.
40. Wilmot cr.
41. Graham Cr.
42. Shelter Valley Br.
43. Little Salmon R.
44. Grindstone Cr.
45. Catfish Cr.
46. Sterling Valley Cr.
47. Sterling Cr.

LAKE SUPERIOR

1. Pancake R.
2. Sable R.
3. Stokely Cr.
4. Tahquamenon R.
5. Betsy R.
6. Sucker R.
7. Miners A.
8. Rock R.
9. Dig Garlic R.
10. Iron R.
11. Middle R.

LAKE MICHIGAN

12. Fox R.
13. Peshtigo R.
14. t&nominee A.
15. ford R.
16. Days R.
Whitefish R. (W.Br.)
18. Manistique R.
19. Carp Lake R.
20. Jordan R. (Deer Cr.)
21. Boardman R.
22. Betsie R.
23. Muskegon R.
24. St. Joseph R.

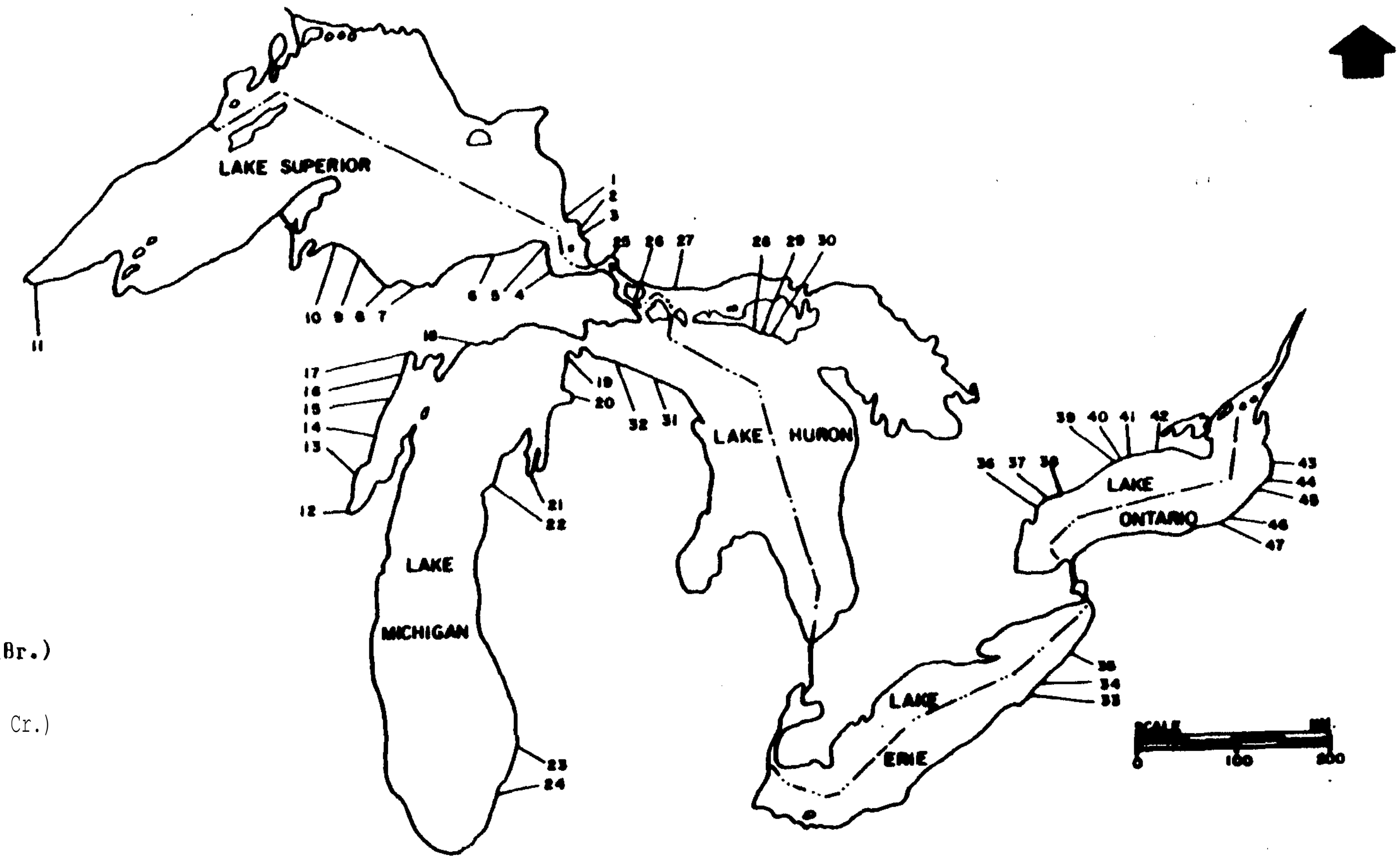
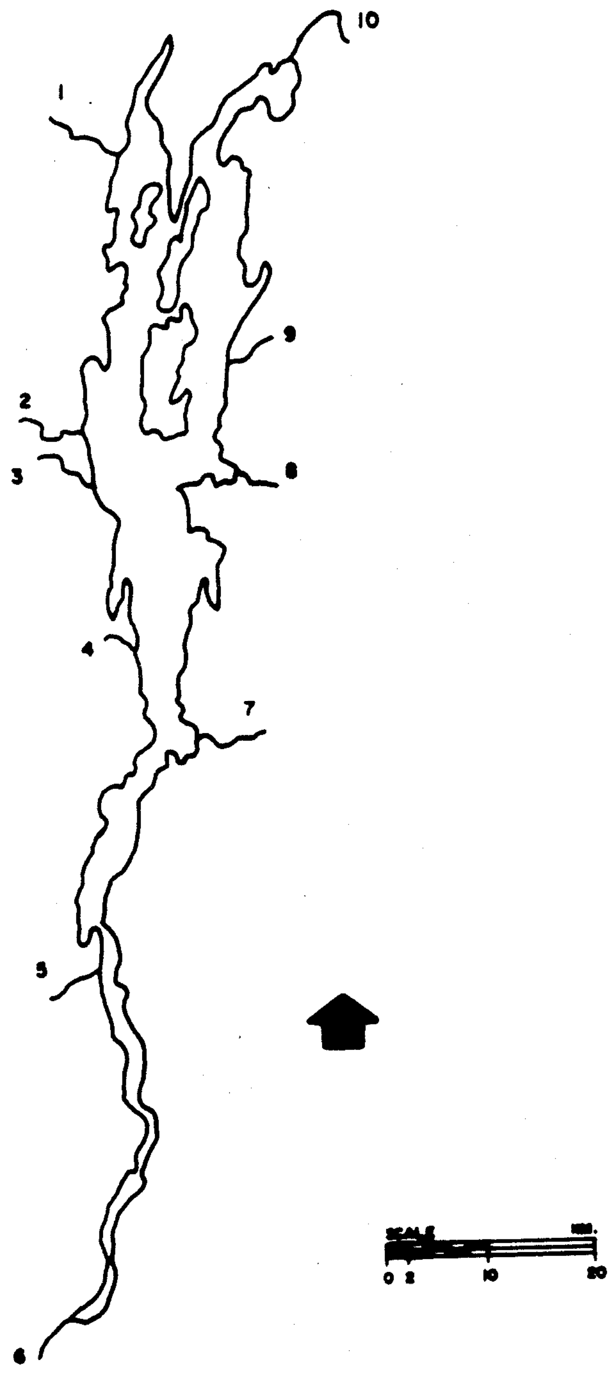


Figure C-1. 1984 Collection sites of spawning phase sea lamprey from tributaries of the Great Lakes.



1. Great Chazy River
2. Salmon River
3. Little Ausable River
4. Boquet River
5. Putnam Creek
6. Mt. Hope Brook
7. Lewis Creek
8. Indian Brook
9. Stonebridge Brook
10. Pike River

Figure C-2. Lake Champlain tributary streams in which spawning phase sea lamprey runs are monitored.

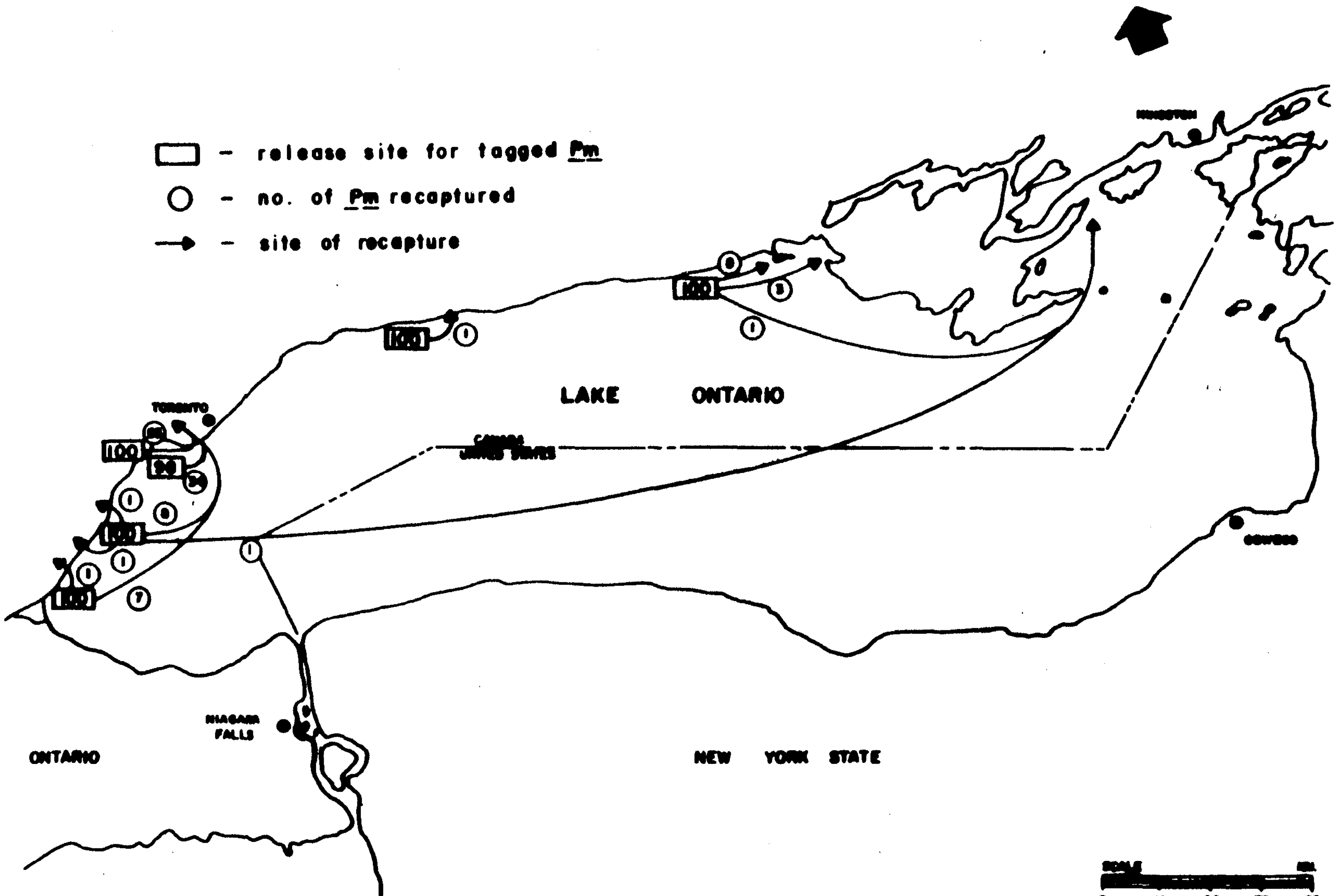


Figure C-3. A sea lamprey tag-recapture study, based on the release of spawning phase adults along the Canadian shoreline of Lake Ontario - 1974.

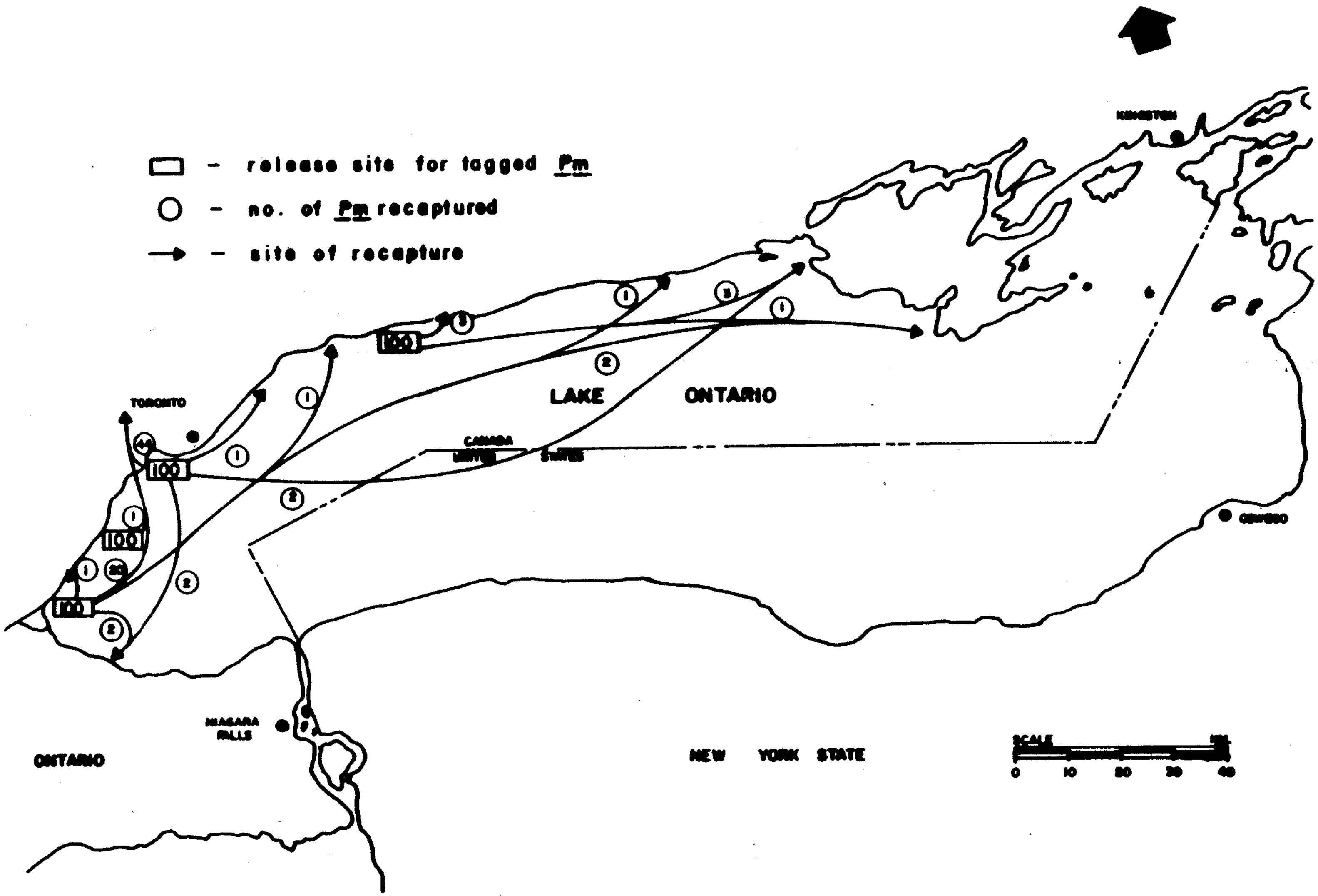


Figure C-4. A sea lamprey tag-recapture study, based on the release of spawning phase adults along the Canadian shoreline of Lake Ontario - 1975.

Table C-I. Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57
							YEAR OF OPERATION								
							LAKE SUPERIOR								
CANADA															
S-1 E. Davignon Cr.	EB												1	3	
s-2 W. Davignon Cr.															
- Main	EB												0	1	
- Bennets Cr. (dam)												0	0	0	0
S-4 L. Carp Cr.	EB												20	24	26
s-5 Big Carp Cr.	EB												5	27	28
S-23 Cranberry Cr.	EB												6	11	18
S-24 Goulais R.															
- Main	EB												46	61	820
- Robertson Cr.	LW														
S-25	MW												0		
S-26	MW												0		
S-27 Bostons Cr.	MW												0		
S-33 Horseshoe Cr.	MW												1		
S-34 Haviland Cr.	EB												0	3	
S-36 Stokely Cr.	EB											49	11	58	5
"	MW														
"	DT														
S-39 Harmony R.	EB											20	29	29	16
S-41 Sawmill Cr. (dam)													0	0	
S-42 Jones Landing Cr.	EB												0	0	
S-43 Downey Cr.	E8												0	0	
s-48 Chippewa R.	EB												807	838	359
S-52 Batchawana R.	EB												608	421	427
S-54 Carp (Sable) R.	MW							72	28	49	31				
"	EB											39	43	65	76
"	PT														
"	DT														

Note: Key to Table C-I on Page 102

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION '58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71
LAKE SUPERIOR															
CANADA															
s-1 E. Davignon Cr.	El3														
S-2 W. Davignon Cr.															
- Main	EB														
- Bennets Cr.(dam)		0													
S-4 L. Carp Cr.	EB	5	5												
s-5 Big Carp R.	EB	19	15	20	6	5	2	1	15	3	2				
S-23 Cranberry Cr.	EB	6													
s-24 Goulais R.															
- Main	El3	682	395	760											
- Robbertson Jr.	LW														
S-25	MW														
S-26	MW														
S-27 Bostons Cr.	MW														
S-33 Horseshoe Cr.	MW														
S-34 Haviland Cr.	El3														
S-36 Stokely Cr.	EB	2	0												
"	MW														
"	DT														
S-39 Harmony R.	EB	6	8	19	14	3	1	4	5	0	0				
S-41 Sawmill Cr.(dam)															
S-42 Jones Landing Cr.	EB														
S-43 Downey Cr.	EB														
S-48 Chippewa R.	EB	220	2.96	1,051	453	124	222	274	114	78	92				
s-52 Batchawana A.	EB	358	482	629	561	136	336	216	140	119	119				
S-54 Carp (Sable) A.	MW														
"	EB	47	142	246	100	10	36	5	17	14	8				
"	PT														
"	DT														

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

			YEAR OF OPERATION													
	STREAM NAME	METHOD	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
								LAKE SUPERIOR								
CANADA																
S-1	E. Davignon Cr.	EB														
S-2	W. Davignon Cr.															
	- Main	EB														
	- Bennets Cr.(dam)															
S-4	L. carp cr.	EB														
s-5	Big Carp Cr.	EB														
S-23	Cranberry Cr.	EB														
S-24	Goulais R.															
	-Main	EB														
	- Robertson. Cr.	LW														
S-25		lw														
s-26		Mw														
S-27	Bostons cr.	MW														
s-33	Horseshoe Cr.	Mw														
s-34	Haviland Cr.	EB														
s-36	Stokely Cr.	EB														
	"	MW											11			
	"	DT										12	3	5	1	4
s-39	Harmony R.	EB														
S-41	Sawmill Cr.(dam)															
S-42	Jones Landing Cr.	EB														
S-43	Downey Cr.	EB														
S-48	Chippewa R.	EB														
s-52	Batchawana R.	EB														
s-54	Carp (Sable) R.	MW				14	44	15	3	11	18	17				
	"	EB														
	"	PT					6									
	"	DT													45	129

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944-54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67
							YEAR OF OPERATION								
							LAKE SUPERIOR								
CANADA															
S-56 Pancake R.															
-Main	EB		555	715	1,073	802	816	1,306	931	187	389	257	94	64	138
- Gimlet Cr.	PT														
- "	MW														
S-75 Queminico Cr.	lw		0	0											
s-89 Speckled Trout Cr.	MW		0												
S-93 Agawa R.	MW		2												
"	EB			0	26	19	18								
S-98 Barrett R.	lw		0	0											
S-103 Coldwater R.	MW		0	0											
"	EB				0										
s-105 Baldhead R.	MW		0												
"	EB				0										
S-114 Gargantua Harbour Cr.	Mw		0	0											
S-116 Gargantua R.	lw		0	0											
"	EB				0										
S-125 Newman Bay Cr.	MW			0											
s-127 Red Rock Cr.	MW		0												
s-138 Old Woman R.	MW		0	0											
"	EB				0										
s-1643 Mission Cr.	Ew		0	0											
S-167 Michipicoten' R.															
- Trib. to "	MW		0												
- Main	EB			53	372	641	371	143							
S-180 Michipicoten Cr.	MW		0	0											
S-183 Dore R.	MW		0	0											
S-184 Dore Pt. Cr.	MW		0	0											
s-186	MW		0	0											
S-191 Bear Cr.	MW		0	0											

Table C-I (Continued). Spawning phase sea lamprey counts fran systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	68-79	'80	'81	'82	'83	'84	'85
					YEAR OF OPERATION			
				LAKE SUPERIOR				
CANADA								
S-56 Pancake R.								
-Main	EB							
- Gimlet Cr.	PT		20	9	30	29	5	0
- "	MW				60			
S-75 Queminico Cr.	MW							
S-89 Speckled Trout Cr.	MW							
S-93 Agawa R.	MW							
"	EB							
S-98 Barrett R.	MW							
S-103 Coldwater R.	MW							
"	EB							
S-105 Baldhead R.	MW							
"	EB							
S-114 Gargantua Harbour Cr.	MW							
S-116 Gargantua R.	MW							
"	EB							
S-125 Newman Bay Cr.	MW							
S-127 Red Rock Cr.	MW							
S-138 Old Woman R.	MW							
"	EB							
S-166 Mission Cr.	MW							
S-167 Michipicoten R.								
- Trib. to "	MW							
- Main	EB							
S-180 Michipicoten Cr.	MW							
S-183 Dore R.	MW							
S-184 Dore Pt. Cr.	MW							
S-186	MW							
S-191 Bear Cr.	MW							

Table C-I (Continued). Spawning phase sea lamprey **counts from** systematic collections carried out by fishery agencies in tributaries of the Great **Lakes** - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944-54	'55	'56	'57	'58	'59	'60-85
				YEAR OF OPERATION				
								LAKE SUPERIOR
CANADA								
S-202 Dog (University) R.	MW		1					
"	EB				9	0	10	
S-211 Eagle R.	MW		0	0				
S-215 Ghost. R.	MW		0	0				
S-217	MW		0	0				
s-222	MW			0				
S-225 Campbell R.	MW			0				
S-224	MW			0				
S-228	Mw			0				
S-229	MW			0				
S-232 Pipe R.	MW		0	0				
S-233 Red Sucker Cr.	MW		0	0				
S-240 Julia R.	MW			0				
S-243 Imogen R.	MW		0	0				
S-255 Otter Cove Cr.	MW		0	0	1			
S-259 Sand Bay Cr.	Mw		0	0				
S-261 Swallow R.	EB				0			
S-264 N. Swallow R.	Mw		0	0				
S-278 White Gravel R.	MW		0	0				
"	EB				0			
s-284	Ew		0	0				
S-285 Three Fingers Bay Cr.	Mw		0					
S-287 Oiseau Cr.	lw		0	0				
S-294	MW			0				
s-295	MW			0				
S-297 Willow R.	EB				0			
S-306 Duncan Cr.	MW		0	0				
S-308 Hare (Big Munro) Cr.	Mw		0	0				

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAM	METHOD	1944-53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68-85
									LAKE SUPERIOR								
CANADA																	
s-313 L. Munro Cr.	MW			0	0												
S-315 Mink Cr.	MW			0	0												
S-321 Neys Farm Cr.	MW			0	0												
S-322 Little Pic R.	Mw			7													
"	EB				0	0											
S-323 Dead Horse Cr.	MW			0	0												
S-324 McKellar Cr.	MW			0	0												
S-326 Ripple Cr.	MW			0	0												
S-327 Prairie A.	MW		17														
"	EB			0	0	13	0										
S-328	MW			0	0												
S-335 Steel R.	EB			0	1	0											
S-337 Sawmill Cr.	MW			0	0												
S-338	MW			0	0												
S-339 Fishnet Cr.	Mw			0	0												
s-340	MW			0	0												
S-347 Worthington Cr.	Mw			0	0												
S-348 Crooks Lake Cr.	Mw			0	0												
S-351 Hewitson Cr.	EB			0	0	1	1										
S-353 McLeans Cr.	MW			0													
"	EB				0	0											
S-358 Bear Trap Cr.	MW			0													
s-359	MW			0	0												
S-360 Pays Plat R.	MW		0	0													
"	EB				6	3	4	32	10	31	9	9	5	0	2	1	
s-361 Little Pays Plat R.	MW				0	0											
S-364 Nishin Cr.	MW			0	0												

Column heads '54 to '68-85 are printed under the heading YEAR OF OPERATION.

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944-53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65
						YEAR OF OPERATION								
							LAKE SUPERIOR							
CANADA														
S-368 Gravel R.	EB				7	99	154	541	626	799	315	64	52	191
S-369 Little Gravel R.	EB				0	2	0	0						
"	MW													
S-374 Cypress R.	EB				1	3	5	1						
"	MW													
S-375 McInnes Cr.	MW				0									
S-377 Dublin Cr.	MW				0									
S-379 Jackpine R.	MW				0									
s-380	MW				0									
S-381	MW				0									
i-382	MW				0									
S-384 Little Ozone Cr.	MW				0									
S-385 Jackfish R.	EB				0	0	64	240						
S-387 Firehill Cr.	MW				0									
s-391	MW													
5-392 Nipigon R.														
- Clayhill Cr.	MW													
S-410 Cash Cr.	MW													
S-455 Stillwater Cr.	MW				0									
S-457 Trout Cr.	MW				0									
s-461	MW				0									
s-462	MW				D									
s-468	MW				0									
S-470	MW				0									
s-471	MW				0									
s-473	MW				0									
s-475	MW				0									
s-477	MW				0									

Table C-I (Continued). **Spawning** phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great **Lakes** - 1944 to 1985 inclusive.

STREAM NAME	METHOD	'66	'67	'68-76	'77	'78	'79	'80	'81	'82-85
							YEAR OF OPERATION			
							LAKE SUPERIOR			
CANADA										
S-368 Gravel R.	EB	101	23							
S-369 Little Gravel R.	EB									
"	MW							2	13	
S-374 Cypress R.	EB									
"	MW				23	44	9	9	30	
S-375 McInnes Cr.	MW									
S-377 Dublin Cr.	MW									
S-379 Jackpine R.	MW									
S-380	MW									
S-381	MW									
S-382	MW									
S-384 Little Ozone Cr.	MW									
S-385 Jackfish R.	EB									
S-3137 Firehill Cr.	MW									
S-391	MW									
S-392 Nipigon R.										
- Clayhill Cr.	MW									
S-410 Cash Cr.	MW									
S-455 Stillwater Cr.	MW									
S-457 Trout Cr.	MW									
S-461	MW									
S-462	MW									
S-468	MW									
S-470	MW									
S-471	MW									
S-473	MW									
S-475	MW									
S-477	MW									

Table C-I (Continued), Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION 1944-53	'54	'55	'56	'57	'58	'59	'60-79	'80	'81	'82-85
LAKE SUPERIOR												
CANADA												
S-482	MW			0	0							
S-483	MW				0							
s-485	MW			0	0							
s-506	MW				0							
s-506A	MW				0							
S-510 Big Squaw Cr.	MW			0	0							
S-511 Little Squaw Cr.	MW			0	0							
S-517 Wolf R.	PT										1	
S-518 Coldwater Cr.	MW			0	0							
S-527 Welsh Cr.	MW			0	0							
S-528 Pearl R.	MW			0	0							
S-530 Portage Cr.	MW			0	0							
S-531 Squaw Bay Cr.	MW			0	0							
S-533 *Joe Bay Cr.*	MW			0	0							
s-535	MW				0							
S-536 Findlay Cr;	MW				0							
S-537 Sibley Cr.	MW			0	0							
S-538 Sawbill Cr.	MW			0	0							
S-545 Blende Cr.	MW			0								
S-548 Birchbeach Cr.	MW			0	0							
S-552 Amethyst Cr.	MW			0	0							
S-554 Mackenzie R.	PT											
S-559 Blind Cr.	MW			0	0							
S-560 Wild Goose Cr.	MW			0	0							
S-569 McVicars Cr.	MW				0							
S-570 McIntyre R.	MW		0	0								
"	EB					0	2	2				

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION 1944-53	'54	'55	'56	'57	'58	'59	'60-85
						LAKE SUPERIOR			
CANADA									
S-571 Neebing R.	MW			0	0				
"	EB					1	0	0	
S-572 Kaministiquia R.									
- Mosquito Cr.	MW			0	0				
- Slate Cr.	MW			0	0				
S-585 Jarvis R.	MW			0					
S-587 Clod R.	MW		0	0					
S-589 Pine R.	MW			0					
S-590 Lenore Cr.	MW			0					
S-592 Pigeon R.	MW			11					
S-593 Perch Cr.	MW			0					
S-608	MW				0				
S-609	MW				0				
s-610	MW				0				
S-611	MW				0				
s-612	MW				0				
S-613 Iron Lake Cr.	MW				0				
s-614	MW				0				
S-615 Brook Cr.	MW				0				
S-616 Rainbow Cr.	MW				0				
S-617 Tedesco Cr.	MW				0				
S-618 St. Ignace Cr.	MW				0				
S-621	MW				0				
S-622	MW				0				
S-627	MW				0				

N.B. The early "Annual Reports" only note MW's for the years 1954 (5), 1955 (105), 19% (114) and 1957 (4) [Except those run as part of EB operations]. To date, file records (thus stm nos.) have not been found for all.

Table C-I (Continued). Spawning phase sea lamprey **counts** from systematic collections carried out by fishery agencies in tributaries of the Great **Lakes** - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57
							YEAR OF OPERATION								
							LAKE SUPERIOR								
UNITED STATES															
Waiska R.	EB											32	47	71	55
Pendills Cr.	MW							38	20						
"	EB										23	40	45	42	47
"	PT														
Halfaday Cr.	EB											12	3	14	4
Ankodosh Cr.	EB											0			
Tahquamenon R.	PT														
Betsy R.	EB										221	567	569	1,577	786
"	PT														
Little Two Hearted R.	EB														739
Two Hearted R.	EB										371	638	600	1,766	7,899
Dead Sucker R.	EB										0	0			
Sucker R.	EB .										750	1,309	1,713	4,400	3,597
"	PT														
Hurricane R.	EB											8	25	99	188
Beaver Lake Outlet	EB										8	19	19	20	49
Miners R.	EB										64	53	148	%	427
"	PT														
Furnace Cr.	EB										18	47	66	209	274
Autrain R.	EB										204	350	486	434	739
"	PT														
Joels Cr.	EB													179	
Rock R.	EB												1,633	3,407	3,102
"	PT														
Laughing Whitefish A.	EB										9	25	16	19	37
Sand R.	EB											0			
Chocolay R.	MW								301	360	3 %	1,227			
"	EB												3,350	6,888	8,096

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71
							YEAR OF OPERATION								
								LAKE SUPERIOR							
UNITED STATES															
Waiska R.	EB	70	43	127	87	10	34	47							
Pendills Cr.	MW														
"	EB	17	40	33	74	10	11	3							
"	PT														
Halfday Cr.	EB	2													
Ankodosh Cr.	EB														
Tahquamenon R.	PT														
Betsy R.	EB	1,092	1,006	705	1,365	316	444	272	187	65	57	78	120	87	104
"	PT														
Little Two Hearted R.	EB	460	461	715	558	68									
Two Hearted R.	EB	3,577	4,141	4,508	7,498	1,757	2,447	1,425	1,265	878	796	2,132	1,104	1,132	1,035
Dead Sucker R.	EB														
Sucker R.	EB	1,842	2,522	4,980	3.209	474	698	386	532	223	166	658	494	337	485
"	PT														
Hurricane R.	EB	29	65	80	96	6	36	31							
Beaver L&e Outlet	EB	18													
Miners R.	EB	97	159	411	220	64	107	74	23	85	75	158	57	90	
"	PT														
Furnace Cr.	EB	41	396	2,293	1,012	132	142	93	199	118	119	126	178	83	
Autrain R.	EB	348	168	80	181	179	130	84							
"	PT														
Joels Cr.	EB														
Rock R.	EB	1,488	1,250	2,646	3.660	399	353	229	237	158	439	498	138	667	
"	PT														
Laughing Whitefish R.	EB	11	28	42	267	8									
sand R.	EB														
Chocolay R.	MW														
"	EB	6,221	3,500	4,216	4,201	423	358	445	563	260	65	122	142	291	53

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
							YEAR OF OPERATION								
							LAKE SUPERIOR								
UNITED STATES															
Waiska R.	EB														
Per-dills Cr.	MW														
"	EB														
"	PT					0	0								
Halfaday Cr.	EB														
Ankodosh Cr.	EB														
Tahquamenon R.	PT						170	310	433	337	594	229	182	1523	360
Betsy R.	EB	146	294	201	197	148	162	185	104						
"	PT									188	211	232	58	67	43
Little Two Hearted R.	EB														
Two Hearted R.	EB	1,507	894	489	683	229	654	355	450						
Dead Sucker R.	EB														
Sucker R.	EB	642	468	249	478	314	533	974	367						
"	PT										168	58	183	73	23
Hurricane R.	EB														
Beaver Lake Outlet	EB														
Miners R.	EB														
"	PT								12	82	22	1	1	20	20
Furnace Cr.	EB														
Autrain R.	EB														
"	PT						0								
Joels Cr.	EB														
Rack R.	EB														
"	PT				377	498	477	508	677	329	581	530	608	561	938
Laughing Whitefish R.	EB														
Sand R.	EB														
Chocolay R.	lw														
"	EB	294	270	17	24	IO	4	6	63						

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57
		YEAR OF OPERATION													
		LAKE SUPERIOR													
UNITED STATES															
Carp R.	EB											0	2	1	4
Harlow R.	EB											1	1	0	3
Little Garlic R.	EB											0	0		
Big Garlic R.	EB											54	89	154	270
"	PT														
Iron R.	EB											67	206	335	737
"	PI														
Salmon Trout R.	EB											1	0	0	
Pine R.	EB											10	12	18	34
Little Huron R.	EB											0			
Huron R.	EB											147	472	1,628	2,868
Ravine R.	EB											1	4	2	10
Slate R.	EB											0			
Silver R.	EB											247	786	963	2,810
Sturgeon R.	EB											1	1	4	31
Otter R.	EB											0	0	1	0
"	PT														
Pilgrim R.	EB											0			
Traprock R.	EB											0	0		
Traverse R.	EB											3	4	37	45
Tobacco R.	EB											0			
Little Gratiot R.	EB											0	1	4	9
Gratiot R.	EB											1	0	4	2
Boston & Lilly Cr.	EB											0			
Scholtz Cr.	EB											0			
Salmon Trout R.	PT														
Graveraet R.	EB											0			
Elm R.	EB											0	7	7	7

Table C-I **(Continued).** Spawning phase sea **lamprey** counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71
							YEAR OF OPERATION								
								LAKE SUPERIOR							
UNITED STATES															
Carp R.	EB	0	5	5											
Harlow R.	EB	3	31	14	22	89	28	38							
Little Garlic R.	EB														
Big Garlic R.	EB	262	247	87											
"	PT														
Iron R.	EB	428	266	342	2,430	1,161	110	178	283	491	643	82	556	713	1,518
"	PT														
Salmon Trout R.	EB		68	5	12	1									
Pine R.	EB	22	43	28	70	2	20	0							
Little Huron A.	EB														
Huron R.	EB	3,526	1,492	1,377	4,825	70	201	363	637	8	2	14	280	4	
Ravine R.	EB	5	23	8	6	2	3								
Slate R.	EB														
Silver R.	EB	2,152	878	1,386	5,052	267	760	593	847	1,010	339	1,032	1,147	321	342
Sturgeon R.	EB	28	544	161	427	397	1,445	375	135	259	43	132	46	26	
Otter R.	EB	0													
"	PT														
Pilgrim R.	EB														
Traprock R.	EB														
Traverse R.	EB	76	598												
Tobacco R.	EB														
Little Gratiot 'R.	EB	1	11												
Gratiot R.	EB	31	11												
Boston & Lilly Cr.	EB														
Scholtz Cr.	EB														
Salmon Trout R.	PT														
Graveraet R.	EB														
Elm R.	EB	2	8	12	9	0	0								

Table C-I **(Continued).** Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
								LAKE SUPERIOR							
UNITED STATES															
Carp R.	EB														
- Harlow R.	EB														
Little Garlic R.	EB														
Big Garlic R.	EB														
"	PT					90	30	135	191	122	182	170	361	26	17
Iron R.	EB	280	16	1	8	3 3	a	2 6	21						
"	PT									3	6	1	37	3	20
Salmon Trout R.	EB														
Pine R.	EB														
Little Huron R.	EB														
Huron R.	EB														
Ravine R.	EB														
Slate R.	EB														
Silver R.	EB	2,574	495	117	206	199	312	162	145						
Sturgeon R.	EB														
Otter R.	EB														
"	PT					18	33	5							
Pilgrim R.	EB														
Traprock R.	EB														
Traverse R.	EB														
Tobacco R.	EB														
Little Gratiot R.	EB														
Gratiot A.	EB														
Boston & Lilly Cr.	EB														
Scholtz Cr.	EB														
Salmon Trout R.	PT					0	0								
Graveraet R.	EB														
Elm R.	EB														

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944-53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67
								YEAR OF OPERATION								
								LAKE SUPERIOR								
UNITED STATES																
S. Br. Elm R.	EB		0	0												
Misery R.	EB			183	571	868	896	2,581	761	962	80	24	12	3	IO	26
Firesteel R.	EB		60	150	229	1,039	1,546	2,084	276	1,118	70	178	327	11	15	9
Flintsteel R.	EB		2	1	1	2	2	0	0							
Union R.	EB		0	0												
E. Br. Ontongon R.	PT															
Montreal R.	PT															
Bad R.	EB				685	2,652	6,203	4,468								
White R.	EB				219	412	231	552	233							
"	PT															
Fish Cr.	EB					520	251	428	354							
Cranberry R.	EB						0	14	50	12	1	3				
Irm R.	EB						0									
"	PT															
Fish Cr. (Orienta)	EB						0									
Reefer Cr.	EB						1									
Brule R.	EB					3,988	22,842	19,389	9,755	22,478	2,026	3,418	6,718	6,163	226	364
Poplar R.	EB					126	580	8	58	103	2	0				
"	PT															
Middle R.	EB					4,289	4,853	3,645	2,839	3,502	311	48	45	52	17	19
"	PT															
Amnicon R.	EB					11,055	7,670	986	1,165	4,741	879	131	232	700	938	200
Black R.	EB						4	13	21							
Nemadji R.	EB						3	1	IO							
St. Louis R.	PT															

Table C-I (Continued). Spawning phase sea lamprey counts Fran systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION '68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80-83	'84	'85
								LAKE SUPERIOR								
UNITED STATES																
S. Br. Elm R.	EB															
Misery R.	EB	52	90	12												
Firesteel R.	EB	25	14	11												
Flintsteel R.	EB															
Union R.	EB															
E. Br. Ontongon R.	PT															
Montreal R.	PT															
Bad R.	EB															
White R.	EB															
"	PT															
Fish Cr.	EB															
Cranberry R.	EB															
Iron R.	EB															
"	PT											0				
Fish Cr. (Orienta)	EB															
Reefer Cr.	EB															
Brule R.	EB	2,657	3,574	167	1,754	4,121	261	568	285	1,085	2,572	794	1,217			
Poplar R.	EB															
"	PT										0					
Middle R.	EB	22	8	16												
"	PT														19	215
Amnicon R.	EB	148	1,576	1,733	4,324	132	149	270	2,606	80	493	2,310	46			
Black R.	EB															
Nemadji R.	EB															
St. Louis R.	PT															0

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57	'58
								YEAR OF OPERATION								
									LAKE MICHIGAN							
UNITED STATES																
Sheboygan R.	EB															1
"	PT															
Fischer Cr.	MW							847	3,455							
"	EB															59
Pine Cr.	EB															2
Manitowac R.	PT															
West Twin R.	PT															
East Twin R.	MW		28	7				7,712	21,080	12,357	16,091					
"	EB											6,960	7,558	12,131	10,313	3,474
"	PT															
Kewaunee R.	MW						411	1,353	3,270	2,324	4,008					
"	EB											4,159	5,127	2,286	3,134	766
Casco Cr.	PT															
Three Mile Cr.	MW						84	1,051	2,407	1,246						
"	EB												1,945	1,473	839	237
Ahnapee R.	EB															57
"	PT															
Stoney Cr.	EB															1
Bear Cr.	EB														66	25
Lilly Bay Cr.	MW							16	123	205						
"	EB												66	40	68	18
Shivering Sand Cr.	EB													2	325	15
Whitefish Bay Cr.	EB														245	14
Hibbards Cr.	MW		61	125	596	989	1,579	5,431	12,640	3,302	9,247					
"	EB											7,279	6,389	5,325	6,625	2,563
Ephraim Cr.	EB												13	6	14	6
Fox R.	PT															

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	'59	'60	'61	'62	'63	64-76	'77	'78	'79	'80	'81	'82	'83	'84	'85
								LAKE MICHIGAN								
UNITED STATES																
Sheboygan R.	EB															
"	PT							0								
Fischer Cr.	MW															
"	EB	694														
Pins Cr.	EB															
Manitowac R.	PT							0								
West Twin R.	PT							0								
East Twin R.	MW															
"	EB	3,708	1,799													
"	PT							21								
Kewaunee R.	MW															
"	EB	484	323													
Casco Cr.	PT							0								
Three Mile Cr.	MW															
"	EB	241	211													
Ahnapee R.	EB	31														
"	PT							1								
Stoney Cr.	EB															
Bear Cr.	EB															
Lilly Bay Cr.	MW															
"	EB	153														
Shivering sand Cr.	EB	3														
Whitefish Bay Cr.	EB	16														
Hibbards Cr.	MW															
"	al	2,287	989	966	1,320	783										
Ephraim Cr.	EB	16														
Fox R.	PT									0	0	0	0	0	0	0

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944-47	'48	'49	'50-51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62
										LAKE MICHIGAN						
UNITED STATES																
Suanim R.	lw					91										
"	EB											15	18	12		
Little Suamico R.	EB											0				
Pensaukee R.	EB								893	1,099	520	789	681	283		
Oconto R.	Pi															
Little R.	EB								128	412	142	160	195	26		
Peshtigo R.	PT															
Menominee R.	MW		116	680												
"	PT															
Beattie Cr.	EB										39	44	66	38′		
Johnson Cr.	EB											0				
Cedar R.	EB								13,324	16,331	12,188	8,134	6,856	4,676	9,423	5,729
"	PT -															
Walton R.	EB										162	8	30	38		
"	PT															
Bark R.	EW								2,420	1,712	2,484	1,255	1,047	1,065	1,085	710
Ford R.	EW									7,946	10,289	5,920	3,525	3,133		
"	PT															
Portage Cr.	EB										35					
Escanaba R.	PT															
Days R.	EB							205	264	192	272	120	111	39		
"	PT															
Tacoosh R.	EB							11	15	8	31	4	4	4		
Rapid R.	EB							574	1,377	937	1,396	546	311	401		
Whitefish R.	Ew							1,489	3,408	2,638	5,263	1,681	2,293	2,419		
W.Br Whitefish R.	PT															
Squaw Cr.	Ew					146										
"	EB							283	348	284	179	82	35	23		
Oqmtz R.	EB											529	463			

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAM	METHOD	YEAR OF OPERATION '63	'64	'65	'66	' 67-76	'77	'78	'79	'80	'81	'82	'83	'84	'85
							LAKE MICHIGAN								
UNITED STATES															
Suanica R.	MW														
"	EB														
Little Suamico R.	EB														
Pensaukee R.	EB														
Oconto R.	Pi						7	-	3	2					
Little R.	EB														
Peshticp R.	PT						2,360	644	265	305	294	475	590	240	- 332
Menominee R.	MW														
"	PT						714	1,840	131	194	77	62	73	126	500
Beattie Cr.	EB														
Johnson Cr.	EB														
Cedar R.	EB	6,412	3,568	2,576	661										
"	PT														13
Walton R.	EB														
"	PT						0								
Bark R.	Ew	298	202	189	113										
Ford R.	Ew														
"	PT													2	1
Portage Cr.	EB														
Escanaba A.	PT						0	-	-	0					
Days R.	EB														
"	PT													0	0
Tacoosh R.	EB														
Rapid R.	EB														
Whitefish R.	EW														
W.Br.Whitefish A.	PT										0	15	_18	1	
Squaw Cr.	MW														
"	EB														
Ogontz R.	EB														

Table C-I (Co&hued). Spawning pháse sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944-49	'50	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62
LAKE MICHIGAN															
UNITED STATES															
Sturgeon R.	EB						4,113	2,534	1,610	3,503	1,280	733	910	2,370	1,650
Big Fishdam R.	EB						692	459	500	835	375	409	315		
Poodle Pete Cr.	EB										9				
Bursaw Cr.	EB										737	877			
Manistique R.	PT														
Weston cr.	PT														
Marblehead Cr.	EB										40				
Bulldog cr.	EB										330	452			
Milakokia R.	EB										610	637			
Point Patterson Cr.	EB										10				
Cataract R.	EB										59	101			
Crow R.	EB										63	67			
Millecoquins R.	EB									955	447	389			
Black R.	MW		2,144	-	707	1,578	915	712	36						
"	EB										218	302			
E.Br. Black R.	EB										99	109			
Hog Island cr.	EB									77	16	93			
Davenport Cr.	EB										6	37			
Brevort R.	EB									497	85	238			
"	PT														
Carp L&e R.	MW		3,821	4,918	857										
"	EB						2,653	2,828							
"	PT														
Wycamp Lake Outlet	EB										55				
Bear R.	PT														
McGeach Cr.	EB									257	82				
Boyne R .	EB									225	40				
"	PT														
Monroe Cr.	EB									1	0				

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION '63	'64	'65	'66	'67-76	'77	'78	'79	'80	'81	'82	'83	'84	'85
								LAKE MICHIGAN							
UNITED STATES															
Sturgeon R.	EB	751	823	512	394										
Big Fishdam R.	EB														
Poodle Pete Cr.	EB														
Bursaw Cr.	EB														
Manistique R.	PT						3,273	5,408	4,948	7,895	0,226	11,417	10,480	9,085	13,291
Weston cr.	PT								146	61	30	4	0	-	
Marblehead Cr.	EB														
Bulldog Cr.	EB														
Milakokia R.	EB														
Point Patterson Cr.	EB														
Cataract R.	EB														
Crow R.	EB														
Millecoquins R.	EB														
Black R.	MW														
"	EB														
E.Br. Black R.	EB														
Hog Island cr.	EB														
Davenport Cr.	EB														
Brevort R.	EB														
"	PT														7
Carp Lake R.	MW														
"	EB														
"	PT								68	293	608	575	241	655	208
Wycamp Lake Outlet	EB														
Bear R.	PT							4							
McGeach Cr.	EB														
Boyne R.	EB														
"	PT							29	-	-	13				
Monroe Cr.	EB														

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried Out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

		YEAR OF OPERATION														
STREAM NM	METHOD	1944-56	'57	'58	' 59-64	'65	'66	'67-77	'78	'79	'80	'81	'82	'83	'84	'85
									LAKE MICHIGAN							
UNITED STATES																
Jordan R.	EB		579	457												
-Deer Cr.	PT								40		67	52	129	6	12	115
Elk R.	PT								16							
Yuba Cr.	EB		214	93												
Mitchell Cr.	EB		71	27												
Boardman R.	PT								62		163	62	172	88	91	124
Crystal R.	PT								0							
Platte R.	PT								0							
Betsie R.	EB		1,704	712												
0	PT								451	_	317	187	255	235	269	474
Manistee R.	PT											9	12	-		
Bear R.	PT								7							
Little Manistee R.	EB			176												
Lincoln R.	EB		800	223			204									
sable R.	PT															
Pere Marquette A.	EB			2,006		678	311									
N.Br.Pentwater R.	EB		108	208			197									
S.Br.Pentwater R.	EB		0	0												
"	PT								1							
White R.	PT								11							
Muskegon R.	PT								67	_	13	55	34	a6	27	
Grand R.	PT								28							
Kalamazoo R.	PT								6							
Rabbit R.	PT								9							
Swan Cr.	PT								2							
S.Br.Black R.	PT								7							
St. Joseph R.	PT								879	-	176	137	355	341	261	406

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION								
		1944-49	'50	'51	'52	'5357	'58	'59-77	'78	'79-85
								LAKE MICHIGAN		
UNITED STATES										
Pan Paw R.	EB						10			
"	P T								13	
Blue Cr.	EB						226			
Pipestone Cr.	EB						1,068			
Galien R.	EB						41			
Trail Cr.	Mw		896	260						
"	EB						288			
Dunes Park Cr.	MW				160					

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

	STREAM NAME	METHOD	YEAR OF OPERATION 1944	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57
	LAKE HURON															
CANADA																
H-S	St. Marys R.	PT														
H-3	Root R.															
	- main	MW						141								
	- "	LW											102			
	- "	EB														
	- Silver(Crystal) Cr.	MW						20								
	- "	LW											66			
H-4	Gar&n R.	EB														
H-ID	Echo R.	EB														
	"	PT														
H-33	Desbarats R.	HN			12											
	"	MW				D										
H-34	Stoby (Portlock) Cr.	HN			0											
H-39	Sucker (Gawas) Cr.	MW					243									
	"	PT														
H-50	Two Tree R.	EB														
H-58	Gordon's Cr.	PT														
H-59	Brown's Cr.	PT														
H-62	Kaskawong (Milford	MW				273	760	1,620	469	865	405	017	665			
	" Haven) R.	LW												375	491	
	"	EB														
	"	DT														
H-87	MacBeth (MacBess) Cr.	HN			22											
	"	MW				52										

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

	STREAM NAME	METHOD	YEAR OF OPERATION '58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71
	LAKE HURON															
CANADA																
H-S	St. Marys R.	PT														
H-3	Root R.															
	- main	MW														
	- "	LW														
	- "	EB								16	10					
	- Silver(Crystal) Cr.	MW														
	- "	LW														
H-4	Garden R.	EB								35	107					
H-10	Echo R.	EB									526	458	195	337	161	
	"	PT														
Ii-33	Desbarats R.	HN														
	"	MW														
H-34	Stoby (Portlock) Cr.	HN														
H-39	Sucker (Gawas) Cr.	MW														
	"	PT														
H-50	Two Tree R.	EB									m	22	6	7	0	
H-58	Gordon's Cr.	PT														
H-59	Brow's Cr.	PT														
H-62	Kaskawong (Milford	MW														
	" Haven) R.	LW														
	"	EB										83	239	478	482	271
	"	DT														
H-B7	MacBeth (MacBess) Cr.	HN														
	"	MW														

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried Out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

	STREAM NAME	METHOD	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
								YEAR OF OPERATION								
								LAKE HURON								
CANADA																
H-S	St. Marys R.	PT					115	44	25	12	2	8		2,409	3,624	7,763
H-3	Root R.															
	- main	MW														
	- "	LW														
	- "	EB														
	- Silver(Crystal) Cr.	MW														
	- "	LW														
H-4	Garden R.	EB														
H-10	Echo R.	EB														
	"	PT								15	4		16	0		
H-33	Desbarats R.	HN														
	"	MW														
H-34	Stoby (Portlock) Cr.	HN														
H-39	Sucker (Gawas) Cr.	MW														
	"	PT									7	5				
H-50	Two Tree R.	EB														
H-58	Gordon's Cr.	PT										0				
H-59	Brown's Cr.	PT										0				
H-62	Kaskawong (Milford	MW											95			
	" Haven) R.	LW														
	"	EB	207	135	146	169	187	182	209	302	263					
	"	DT										155	351	170	115	648
H-B7	MacBeth (MacBess) Cr.	HN														
	"	MW														

Table C-I **(Continued).** Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great **Lakes** - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION													
		1944	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57
								LAKE HURON							
CANADA															
H-88 Thessalon R.															
-main															
-at Sherwood	EB												?	?	?
- at Ansonia	LW							1,401	2,168	1,414	2,485	935			
- at Rydal Bank	PT														
- at Poplardale	Mw						765								
"	LW										300	610			
- Bridgeland(L.Thess.)															
- below L.Rapids	MW			11,286	5,442	5,701	4,883	3,010	0	0					
"	LW								2,119	715	1,157	1,087			
"	EB[1]														
- at L.Rapids	PT														
H-92 Livingstons Cr.	MW			99	107										
H-110 Blind R.	PT														
"	DN														
H-112 Lauzon cr.	MW			42	157	0									
H-116 Serpent R.															
- Grassy Cr.	MW				212	286									
H-305 Mindemoya R.	PT														
H-313 Manitou R.	EB														
"	PT														
H-314 Blue Jay Cr.	MW				2										
"	EB														
H-331 Kaboni (Trudeau) Cr.	?														
H-726 Still R.	EB														
H-832 Naiscoot R.															
- main	EB														
- Harris R.	EB														

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71
							YEAR OF OPERATION								
							LAKE HURON								
CANADA															
H-88 Thessalon R.															
- min															
- at Sherwood	EB														
- at Ansonia	LW														
-at Rydal Bank	PT														
- at Poplardale	MW														
"	LW														
- Bridgeland(L.Thess.)															
- below L.Rapids	MW														
"	LW														
"	EB[1]		?												
- at L. Rapids	PT														
H-92 Livingstone Cr.	MW														
H-110 Blind R.	PT														
"	DN														
H-112 Lauzon cr.	MW														
H-116 Serpent R.															
- Grassy Cr.	MW														
H-305 Mindemoya R.	PT														
H-313 Manitou R.	EB										637	597	144	3	12
"	PT														
H-314 Blue Jay Cr.	Mw														
"	EB										957	1,807	1,130	236	332
H-331 Ksboni (Trudeau) Cr.	?														
H-726 Still R.	EB								344	1,820	1,839	6,154	1,621	558	960
H-832 Naiscoot R.															
-main	EB								38	64	103	202	68	0	1
- Harris R.	EB								555	904	1,532	1,054	717	173	445

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION '72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
							LAKE HURON								
CANADA															
H-88 Thessalon R.															
- min															
- at Sherwood	EB														
- at Ansonia	LW														
- at Rydal Bank	PT								2	0				622	677
- at Poplardale	MW														
"	LW														
- Bridqeland(L.Thess.)															
- below L.Rapids	Ew														
"	LW														
"	EB[1]														
- at L. Rapids	PT								459	272	230	453	734	998	3,889
H-92 Living&me Cr.	MW														
H-110 Blind R.	PT								0						
"	DN										0				
H-112 Lauzon Cr.	lw														
H-116 Serpent R.															
- Grassy Cr.	Mw														
H-305 Mindemoya R.	PT									3				37	
H-313 Manitou R.	EB	11	14	4	8										
"	PT													1	
H-314 Blue Jay Cr.	MW							20	77	91	103			33	
"	EB	380	22	65	127	213	804								
H-331 Kaboni (Trudeau) Cr.	?														
H-726 Still R.	EB	426	14	10	28	48	1	0							
H-832 Naiscoot R.															
-main	EB	2	D	0	0	0	0	0							
- Harris R.	EB	472	8	1	8	13	31	13							

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery sgsncies in tributaries of the Great **Lakes** - 1944 to 1985 inclusive.

STREAM **NAME**	METHOD	YEAR OF OPERATION 1944-49	'50	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60-65	'66	'67
LAKE HURON															
CANADA															
H-1343 Sturgeon R.	LW								473	533					
"	PT														
H-1360 Nottawasaga R.															
- Mad R.	EB													324	333
H-1376 Silver Creek	MW										789	485			
"	PT														
H-1385 Beaver R.	LW			848	1,439	664		1,464	1,526						
"	PT														
H-1422 Sydenham R.	PT														
H-1477 Sauble R.	LW			*166*											
H-1492 Saugeen R.															
- Dennys Bridge (Dam)	LW		11,488	9,040	6,195	5,027	4,349	4,687	6,466	8,062					
	DN?						4,519	3,630							
	DT														
	PT														
H-1589 Lucknow (NineMile) R.	LW			276											
	PT														
H-1614 Maitland R.	LW			29											
H-1681 Bayfield R.	EB													443	789

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82-85
							YEAR OF OPERATION									
							LAKE HURON									
CANADA																
H-1343 Sturgeon R.	LW															
"	PT												0	0	2	
H-1360 Nottawasaga R.																
- Mad R.	EB	413	42	8	15	1	D	1	0							
H-1376 Silver Creek	MW												52	8	7	
"	PT													0		
H-1385 Beaver R.	LW															
"	PT												0	1	25	
H-1422 Sydenham R.	PT												0			
H-1477 Sauble A.	LW															
H-1492 Saugeen R.																
- Demys Bridge (Dam)	LW															
	DN?															
	DT				436	21	9	1							2	
	PT										0	30	11	1	0	
H-1589 Lucknow (NineMile) R.	LW															
	PT											2	?	1		
H-1614 Maitland R.	LW															
H-1681 Bayfield R.	EB	191	582	128	7	7	4	2	4							

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57
							YEAR OF OPERATION								
							LAKE HURON								
UNITED STATES															
St. Marys R.	PT														
- N.Br. Pine R.	PT														
Martins Cr.	MW							3							
Little Black R.	MW							953	909						
Cheboygan R.	lw								2,368						
"	PT														
Sturgson R.	PT														
Black R.	PT														
Elliott Cr.	MW							266	70						
Greene Cr.	MW							1,945	785						
Milligan Cr.	MW							700	527						
Cedar Cr.	MW							0	0						
Grace Harbor Cr.	MW							52	32						
Carp Cr.	MW				1,617	2,939	2,763	1,161	1,266	286	721				
Ocqueoc R.	Ew	"3,025	"3,660				24,643	18,822	19,393	9,437	11,676				
"	EB											10,183	13,683	-	8,163
"	PT														
Trout R.	lw							1,702	1,903						
"	PT														
Thunder Bay R.	PT														
AuSable R.	PT														
East AuGres R.	PT														
Tittabawassee R.	PT														
Chippewa R.	PT														

Table C-I (Continued). Spawning phase sea lamprey cods from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION '58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71
								LAKE HURON							
UNITED STATES															
St. Marys R.	PT														
- N.Br. Pins R.	P T														
Martins Cr.	MW														
Little Black R.	MW														
Cheboygan R.	lw														
"	PT														
Sturgeon R.	PT														
Black R.	PT														
Elliott Cr.	MW														
Greene Cr.	MW														
Milligan Cr.	Ew														
Cedar Cr.	MW														
Grace Harbor Cr.	MW														
Carp Cr.	Mw														
Ocqueoc R.	MW														
"	EB	-	2,766	7,560	4,715	5,205	4,674	2,677	1,390	3,273	674	3,418	3,291	736	2,997
"	PT														
Trout R.	MW														
"	PT														
Thunder Bay R.	PT														
AuSable R.	PT														
East AuGres R.	PT														
Tittabawassee R.	PT														
Chippewa R.	PT														

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
									LAKE HURON						
UNITED STATES															
St. Marys R.	PT				429	627	1,419	1,148	1,213	1,995	1,946	3,848	1,590	1,687	3,420
N.Br. Pine R.	PT										0				
Martins Cr.	MW														
Little Black A.	MW														
Cheboygan R.	MW														
"	PT						3,360	6,489	0,327	7,469	7,720	14,584	14,711	17,616	9,972
Sturgeon R.	PT								2	0					
Black R.	PT								2						
Elliott Cr.	Ew														
Greene Cr.	MW														
Milligan Cr.	MW														
cedar cr.	MW														
Grace Harbor Cr.	MW														
Carp Cr.	MW														
Ocqueoc R.	MW														
"	EB	2,847	639	910	1,901	6,937	503	2,121	2,240	473					
"	PT										583	1,794	1,010	1,444	4,693
Trout R.	MW														
"	PT						39	40	2	1	22	56	4	-	
Thunder Bay R.	PT								2						
AuSable R. .	PT								0						
East AuGres R.	PT														680
Tittabawassee R.	PT														IO.
Chippewa R.	PT														0

Table C-I (Continued). Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERA1 ION 1944-49	'50	'51-55	'56	'57	'58	' 59-79	'80	'81	'82	'83	'84	'85
LAKE ST. CLAIR														
CANADA														
C-20 Little R.	PT		0											
LAKE ERIE														
CANADA														
E-99 Big Otter Cr.														
-main	PT								0					
-Stony Cr.	PT								0					
i-104 Big Cr.	LW				1,086									
"	EB[1]					0	16							
"	PT								92	58				
-Stony Cr.	MW						n40							
E-112 Cranes (Potters) Cr.	PT								0					
E-113 Fishers Cr.	PT								1	14				
E-121 Young Cr.	PT								115	8 %				
E-149 Grand R.														
-at Dunnville	PT									18				
-at Caledonia	PT									5				
UNITED STATES														
Grand R.	PT												280	495
Chagrin R.	PT												105	1 %
Cattaraugus Cr.	PT								1,181	1,400	954	1,671	625	1,732

Table C-I **(Continued).** Spawning phase sea lamprey counts from systematic collections carried out by fishery agencies in tributaries of the Great L&es - 1944 to 1985 inclusive.

STREAM NAME	METHOD	1944-51	'52	'53	'54	'55	'56	'57	'58-67	'68	'69	'70	'71
									YEAR OF OPERATION				
LAKE ONTARIO													
CANADA													
0-76 Bronte Cr.	LW		1,460	2,057	1,229	3,153	674	830					
(Twelve Mile)	PT												
O-79 Oakville Cr.	LW						221						
(Sixteen Mile)													
O-92 Credit R.	PT												
"	DT												
O-100 Humber R.	DN									1,240	1,464	2,185	2,450
"	PT												
"	DT												
O-101 Don R.	PT												
O-117 Duffin Cr.	PT												
"	DT												
0-121 Lynde Cr.	PT												
O-124 Oshawa Cr.	DT												
O-131 Bowmanville Cr.	PT												
O-132 Wilmot Cr.	PT												
O-133 Graham Cr.	MW												
"	PT												
"	DT												
O-144 Ganaraska R.	DT												
"	PT												
O-148 Cobourg Br.	PT												
O-154 Grafton Cr.	PT												
O-157 Shelter Valley Br.	PT												
O-161 Lakeport Cr.	DT												
O-163 Salem Cr.	PT												
O-242 Salmon R.	PT												

Table C-I (Continued). Spawning phase sea lamprey counts fran systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NM	METHOD	YEAR OF OPERATION '72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
LAKE ONTARIO															
CANADA															
D-76 Bronte Cr.	LW														
(Twelve Mile)	PT									2					
O-79 Oskville Cr.	LW														
(Sixteen Mile)															
O-92 Credit R.	PT									3	0	0			
"	DT											0			
O-100 Humber R.	IN	4,609	6,308	3,350	6,848	4,030	1,601	2,453			608				
"	PT									104					
"	DT											876	4,626	1,366	2,828
O-101 Don R.	PT													0	
O-117 Duffin Cr.	PT					0	0			0					
"	DT										293	149	606	520	1,059
O-121 Lynde Cr.	PT									4					
O-124 Oshawa Cr.	PT											0			
O-131 Bowmanville Cr.	PT					75	65	109	62	28	182	309	100	242	466
O-132 Wilmot Cr.	PT							14	15	67	107	80	566	9	58
O-133 Graham Cr.	MW					88	84	65	168	160	32	67			
"	PT					0									
"	DT													26	672
O-144 Ganaraska R.	DT			0	0										
"	PT						0								
O-148 Cobourg Br.	PT					31	0								
D-154 Grafton Cr.	PT										2				
O-157 Shelter Valley Br.	PT							6	152	12	14	144		14	123
D-161 Lakeport Cr.	DT														47
O-163 Salem Cr.	PT										3				
O-242 Salmon R.	PT					23	260	223	IO	4					

Table C-I (Continued). Spawning phase sea lamprey counts fram systematic collections carried out by fishery agencies in tributaries of the Great Lakes - 1944 to 1985 inclusive.

STREAM NAME	METHOD	YEAR OF OPERATION 1944-50	'51	'52	53-74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
LAKE ONTARIO																
UNITED STATES																
Sodus Cr.	PT										0					
Wolcott Cr.	PT										0					
Sterling Cr.																
-Main	PT										28	125	361	174	43	85
- Sterling Valley Cr.	Pi										324	218	422	461	427	258
Rice Cr.	PT										0					
Oswego R.																
- Main																
- Lock 7 Dan	PT								81						51	
- Lock 6 Dam	PT														0	
- Black Cr.	PT														0	
-Lock 2 Dam	PT														0	
-Seneca R.																
- Carpenter Br.	PT														1	
- Cayuga Lake Inlet	MW		?													
- Cayuga L&e Inlet	PT		?	?												
- Cayuga L&e Inlet	DT					3,128	3,055	3,135	2,244	3,429	3,752	2,709	2,897	1,431	1,605	
- Oneida R.																
- Caughdenoy Dam	PT														0	
- Big Bay Cr.	PT														0	
- Fish Cr.																
- W.Br.	PT								9	51					0	
- E.Br.	PT														0	
Catfish Cr.	PT								65	360	29	11	IO	11	2	0
Little Salmm R.	PT								242	673	47	113	316	7	2	52
Grindstone Cr.	PT								315	623	311	210	255	678	128	70
Salmm R.																
- Beaverdam Br.	PT										54					
Skimer Cr.	PT										0					
South sandy Cr.	PT										ii					1
Stony Cr.	PT										0					

KEY TO TABLE C-I
(pages 60 to 101 inclusive)

EB - electric barrier (alternating current)
[For varying periods, a number were augmented by direct current fish guiders placed immediately downstream]

EB[1] - electric barrier (direct current)

Mw - mechanical weir (includes devices designated as check weirs or standard weirs)

LW - Lipsberg weir (while a subgroup of the mechanical weir, sufficiently unusual for special notation)

HN - Hoop net

DN - Dip net

PT - Portable trap

DT - Dam trap

___ - year in which a TFM treatment was conducted

^{n}N - N is only approximated

NOTE: While Table C-I attempts to report all organized efforts made by government fishery agencies to collect spawning phase sea lamprey in the Great Lakes basin, too many historical records are vague or incomplete to suggest this list to be all inclusive. Indeed, a few examples of missing information are presently known (e.g., Canadian records for 9 mechanical weirs in 1955, 6 in 1956 and 2 in 1957 are apparently missing). Further, other systematic collections carried out on Great Lakes tributaries by private interest groups, universities and other institutions, commencing in the mid- to late 1800's, are not reported here. Collections taken from Cayuga Lake Inlet by staff of Cornell University in 1898, and again in 1970 to 1974 inclusive, are examples of these.

Table C-II. Number and biological characteristics of adult sea lampreys captured in assessment traps in tributaries of the Great Lakes, 1983.

STREAM	Number Captured	Number Sampled	Percent Males	Mean Length (mm) Males	Mean Length (mm) Females	Mean Weight (g) Males	Mean Weight (g) Females
LAKE SUPERIOR							
CANADA							
Pancake R.							
- Gimlet Cr.	29	28	25	434	426	176	175
Stokely Cr.	5	5	60	485	425	253	188
TOTAL/AVERAGE	34	33	30	449	426	199	176
UNITED STATES							
Tahquamenon R.	182	182	50	430	431	174	180
Betsy R.	58	56	21	394	395	135	150
Sucker R.	183	32	38	408	388	154	147
Miners R.	1	1	0		362		101
Rock R.	608	581	28	412	407	154	153
Big Garlic R.	361	361	23	407	402	160	154
Iron R.	37	37	27	423	397	181	150
TOTAL/AVERAGE	1,430	1,250	30	415	407	161	156
COMBINED TOTAL/AVERAGE	1,464	1,283	30	416	407	162	157
LAKE MICHIGAN							
UNITED STATES							
Fox R.	0	0					
Peshtigo R.	590	590	44	480	481	235	247
Menominee R.	73	73	41	449	461	188	215
W. Br. Whitefish R.	18	17	47	471	440	232	210
Manistique R.							
- Main	10,480	2,835	39	484	483	218	233
- Weston Cr.	0	0					
Carp Lake R.	241	241	39	424	427	165	171
Jordan R.							
- Deer Cr.	6	6	38	480	442	251	206
Boardman R.	88	88	40	455	455	216	221
Betsie R.	235	225	41	453	460	217	230
Muskegon R.	86	86	43	474	485	223	255
St. Josephs R.	341	340	39	474	486	227	245
TOTAL/AVERAGE	12,158	4,501	40	476	478	218	232

(continued on next page)

Table C-II. (Continued) Number and biological characteristics of adult sea lampreys captured in assessment traps in tributaries of the Great Lakes, 1983.

STREAM	Number Captured	Number Sampled	Percent Males	Mean Length (mm) Males	Mean Length (mm) Females	Mean Weight (g) Males	Mean Weight (g) Females
			LAKE HURON				
CANADA							
St. Marys R.	2,409	1,663	56	465	475	223	240
Echo R.	0						
Kaskawong R.	170'	170	35	439	455	187	211
Thessalon R.							
- Bridgeland Cr.	734	662	48	475	483	230	251
TOTAL/AVERAGE	3,313	2,495	53	466	475	223	241
UNITED STATES							
St. Marys R.	1,590	682	44	486	484	239	249
Trout R.	4	0					
Ocqueoc R.	1,010	0					
Cheboygan R.	14,712	1,003	41	445	451	196	204
TOTAL/AVERAGE	17,316	1,685	42	463	466	214	225
COMBINED TOTAL/AVERAGE	20,629	4,180	49	465	471	220	234
			LAKE ERIE				
UNITED STATES							
Cattaraugus Cr.	1,671	1,544	53	498	492	275	278
			LAKE ONTARIO				
CANADA							
Humber R.	4,626	1,670	59	457	452	212	224
Duffin Cr.	606	428	62	450	450	214	226
Bowmanville Cr.	100	100	60	470	482	216	240
Wilmot Cr.	566	542	61	465	460	235	239
TOTAL/AVERAGE	5,898	2,740	60	458	455	217	227
UNITED STATES							
Grindstone Cr.	678	2	50	455	447	192	274
Little Salmon R.	7	6	67	472	495	250	308
Catfish Cr.	11	10	50	512	481	274	243
Sterling Cr.							
-Main	174	1	100	447	-	195	-
- Sterling Valley Cr.	461	461	63	487	483	243	247
TOTAL/AVERAGE	1,331	480	63	487	483	243	248
COMBINED TOTAL/AVERAGE	7,229	3,220	60	463	459	221	230

Table C-III. The number of sea lanprey nests counted in standardized sections of tributaries of Lake Chtario, Oneida Lake, Lake Champlain, Cayuga Lake, Seneca Lake, and Lake Erie, 1971 - 1984.

	Sectim Length (mi)	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
LAKE ONTARIO															
South Sandy Cr.	1.3										CT	84	154	836	
Skinner Cr.	4.2	411	CT	CT	49	226	HW	272	392	133[1]/	CT	HW	76	CT	122
Lindsey Cr.	2.1	158	CT	CT	24	26	HW	81	42	36[1]/	CT	HW	36	CT	68
Little sandy Cr.	1.6	223	CT	CT	9	33	HW	89	106	CT	44	42	CT	139	136
Orwell Br.	2.2	162	CT	CT	3	CT	Hw	25	CT	31	82	CT	15	CT	12
Grindstone Cr.	2.0	97	CT	CT	11	CT	HW	43	107	210[2]/	168	377	CT	493	427
Sterling Cr.	1.2	73	CT	CT	49	CT	HW	49	82	CT	95	233	CT	206	198
ONEIDA LAKE															
W. Br. Fish Cr.	4.5										45	30	21	24	CT
LAKE CHAMPLAIN															
Lewis Cr.	1.8						588	854	560	182[1]/	573	779	1,170	1,326	1,062
LaPlatte R.	0.5						85	87			42			57	48
Poultnay R.	0.2													–	57
Mt. Hope Br.	0.6													121	72
Putnam Cr.	2.9								861	621	803	1,096	541	4 %	466
Boquet R.	0.2											374		124	177
Little Ausable R.	0.8							126	67[1]/					172	66
Salmon R.															
- Lower	0.8						96	281	77[1]/			395	263	260	147
- Upper	0.4						17		34			54		66	51
Great Chazy R.															
-Lower	0.1							43	27			85			
- Middle	0.2													114	163
- Upper	0.5												278	245	196
Pike R.	0.2												87	198	175
CAYUGA LAKE															
Cayuga Inlet[3]/															
- Lower	1.7									117	0	0	0	638	0
- Upper	0.9									15	1	0	0	302	0
Fall Cr.	0.2									110	128		17	97	4
Cascadilla Cr.	0.4									43	72	37	6	91	33
Sixmile Cr.	0.6									152	89	66	177	97	157
Salmon Cr. .	0.4									105	12	11	0	12	8
Yawger Cr.	1.4									141	127	82	56	34	68

Table C-III (Continued). The **number** of sea **lamprey** nests counted in standardized sections of tributaries of lake **Ontario,** Oneida Lake, **Lake Champlain,** Cayuga Lake, Seneca La&e, **and Lake** Erie, 1971 - 1984.

	Section Length (mi)	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
SENECA LAKE															
Catherine Cr.4/															
- Section 1	0.7	-	-	-	-	-	-	-	-	-	503	94		144	187
- Section 2	1.0	-	-	-	-	-	-	-	-	-	272	189		286	232
- Section 3	1.2	-	-	-	-	-	-	-	-	-	462	172		500	324
- Section 45/	0.9	-	-	-	-	-	-	-	-	-	3	2		0	0
Keuka Outlet6/															
- Section 1	0.2	-	-	-	-	-	-	-	-	-	209	100		62	-
- Section	0.8	-	-	-	-	-	-	-	-	-	5	0		0	-
LAKE ERIE7/															
Delaware Cr.		-	-	-	-	-	-	-	-	-		28 (1.7)	5 (1.1)	11 (0.8)	119 (0.7)
Cattaragus Cr.															
- Clear Cr.		-	-	-	-	-	-	-	-	-		32 (4.3)	78 (4.4)	192 (5.1)	594 (5.0)
- N.Br.Clear Cr.		-	-	-	-	-	-	-	-	-		9 (0.6)	6 (0.6)	9 (0.6)	46 (0.6)
Canadaway Cr.		-	-	-	-	-	-	-	-	-		3 (3.4)	1 (0.3)	5 (0.8)	24 (0.8)

CT - Chemical treatment during that year; counts not attempted
HW - High stream flows resulted in erosim of nests during that year; counts not attempted
1/ - Some nests may not have been visible due to him water during survey period
2/ - Some lampreys removed from river before nest count survey (captured in assessnent traps and sacrificed); counts may be biased downward
3/ - Partial barrier is present in lower river; lampreys present in survey sections only during some years
4/ - Stream treated with TFM in 1983
5/ - A partial barrier is present in this section of stream
6/ - Stream treated with TFM in 1982
7/ - Table for Lake Erie originally represented as number of nests per mile surveyed. A different number of miles were surveyed for each stream and year. Data was transposed to conform to information from the other lakes. The number of miles of stream surveyed is listed (in parenthesis) under the number of nests counted in each year.

Table C-IV. Number of nests constructed by a known or estimated number of sea lampreys.

	Numbers of Sea Lamprey Males	(%)	Total	Year	Number of Nests	Number of Lampreys/Nest	Number Nests Constructed/Male
1/	300	50	600	1974	95	6.3	.32
2/	1,020	60	1,700	1983	1,240	1.4	.80
3/	5,728	61	9,390	1951	1,468	6.6	.26
4/	440	61	722	1960	206	3.5	.52
5/	200	67	300	1984	107	2.8	.53
6/	390	81	370	1976	213	1.7	.71
TOTAL	6,968		11,382		2,089		

1/ Hanson and Manion (1978)
2/ T. Chiotti (NYDEC Pers. Comm. 1983)
3/ Wigley (1959)
4/ Manion and McLain (1971)
5/ Manion et al. (1987)
6/ Hanson and Manion (1980)

Table C-V. Comparison of sea lamprey nests counts in standardized sections with catches of adults in Portable Assessment Traps (PATs) in two Lake Ontario streams, New York.

Year	Grindstone Creek Nest Counts	Grindstone Creek PATs	Sterling Creek Nest Counts	Sterling Creek PATs
1978	107	315	82	
1979	210	623	CT	
1980	168	311	95	28
1981	377	210	233	125
1982	CT	255*	CT	361*
1983	493	678	206	175
1984	427	128	198	43

CT or * denotes lampricide treatment during spawning run.

Table C-VI. Numbers of sea lamprey nests counted in a 0.3 km indexed section of the Bad River, Lake Superior - 1964 to 1974. [from P. Rugen, (USFWS, Marquette, MI) pers. comm.]

Year	Nest Count
1964	146*
1965	41
1966	34
1967	51
1968	107*
1969	61*
1970	44
1971	51*
1972	86
1973	98*
1974	43

* a TFM lampricide treatment was conducted some time between August and October of the year shown

Note: These nest counts to be compared, for the same period, with sea lamprey catches made at the final eight index barriers operated on Lake Superior - see Table C-I.

Table C-VII. Estimation, by Schaefer's Method, of the population of spawning phase sea lamprey in the Cheboygan River, Lake Huron - 1984.

A. Recoveries from spawning phase sea lampreys tagged in successive weeks divided according to week of recovery upstream; together with the total number tagged each week **(M_i)**, and the number recovered and examined for tags **(C_j)**. [from Schaefer 1.9511

	Week of tagging (i)									Tagged Lamprey Recovered	Total Lamprey Recovered	Cj/Rj
	1	2	3	4	5	6	7	8	9			
Week of Recovery **(j)**										R_j	C_j	
2										0	8	0
3										0	0 610	00
											1,598	
4		1								1	10,499	10,499
5				1						1	2,229	2,229
6						1				1	1,916	1,916
7						4	2			6	406	67.7
8							2	-2		4	158	39.5
9								1		1	29	29
Tagged Lamprey Recovered (Ri)	0	1	0	1	0	5	4	3	0	14	17,453	
Total Lamprey Tagged **(m_i)**	0	1	0	1	0	24	26	36	8	96		
Mi/Ri	0	1	0	1	0	4.8	6.5	12	0			

B. Computed estimates of spawning phase sea lampreys using Schaefer's Method. [from Schaefer 1951]

	Week of tagging (i)									
	1	2	3	4	5	6	7	8	9	Total
Week of Recovery (j)										
1										0
2										0
3										0
4		10,499								10,499
5				2,229						2,229
6						9,197				9,197
7						1,299	880			2,179
8							513	948		1,461
9								348		348
TOTAL	0	10,499	0	2,229	0	10,496	1,393	1,296	0	25,913

Table VIII. Estimation, by Schaefer's Method, of the population of spawning phase sea lamprey in the Manistique River, Lake Michigan - 1984.

A. Recoveries from spawning phase sea lampreys tagged in successive weeks divided according to week of recovery upstream; together with the total number tagged each week (Mi), and the number recovered and examined for tags (Cj). [from Schaefer 1951]

	Week of tagging (i)								Tagged Lamprey Recovered	Total Lamprey Recovered	Cj /Rj
	12345			6		7		89			
Week of Recovery (j)									R_j	C_j	
1									0	2	0
2									0	34	0
3									0	527	0
4			6						6	1,716	286
5			3						3	1,657	552.3
6				1					1	2,741	2,741
7									0	1,058	0
8			1				'7		8	1,083	135.4
9								1	1	129	129
Tagged Lamprey Recovered (R_i)	0	0	010	1	0	0	7	1	19	8,947	
Total Lamprey Tagged (m_i)	0	0	127	2	1	4	52	25	112		
Mi/Ri	0	0	0 2 . 7	2	0	0	7.4	25			

B. Computed estimates of spawning phase sea lampreys using Schaefer's Method. [from Schaefer 1951]

	Week of tagging (i)									
	1	2	3	4	5	6	7	8	9	Total
Week of Recovery (j)										
1										0
2										0
3										0
4				4,633						4,633
5				4,474						4,474
6					5,482					5,482
7										0
8				366				7,041		7,407
9									3,225	3,225
TOTAL	0	0	0	9,473	5,482	0	0	7,041	3,225	25,221

Table C-IX. Estimation, by a modification to Schaefer's Method, of the population of spawning phase sea lamprey in the Cheboygan River, Lake Huron - 1984.

A. Recoveries from spawning phase sea lampreys tagged in successive weeks divided according to week of recovery upstream; together with the total number tagged each week (M_i), and the number recovered and examined for tags (C_j). [from Schaefer 19511

	Week of tagging (i)									Tagged Lamprey Recovered	Total Lamprey Recovered	Cj /Rj
	1	2	3	4	5	6	7	8	9			
Week of Recovery (j)										R_j	C_j	
1										0	8	0
2		11								11	610	55.5
3		13	8							21	1,598	76.1
4		61	71	41						173	10,499	60.7
5		8	11	26	36					81	2,229	27.5
6	3	4	3	24	40	20				94	1,916	20.4
7		2		3	11	17				33	406	12.3
8					1	2		6		9	158	17.6
9								4		4	29	7.3
Tagged Lamprey Recovered (Ri)	3	99	93	94	88	39	0	10	0	426	17,453	
Total Lamprey Tagged (m_i)	8	124	125	125	125	124	0	102	26	759		
Mi/Ri	2.7	1.3	1.3	1.3	1.4	3.2	0	10.2	0			

B. Computed estimates of spawning phase sea lampreys using Schaefer's Method. [from Schaefer 19511

	Week of tagging (i)									Total
	1	2	3	4	5	6	7	8	9	
Week of Recovery (j)										
1										0
2		762								762
3		1,237	816							2,053
4		4,628	5,774	3,309						13,711
5		275	406	952.	1,407					3,040
6	163	102	82	651	1,158	1,296				3,452
7		31		49	192	665				937
8					25	112		1,075		1,212
9								296		296
TOTAL	163	7,035	7,078	4,961	2,782	2,073	0	1,371	0	25,463

Table C-X. Estimation, by a modification to Schaefer's Method, of the population of spawning phase sea lamprey in the Manistique River, Lake Michigan - 1984.

A. Recoveries from spawning phase sea lampreys tagged in successive weeks divided according to week of recovery upstream; together with the total number tagged each week (M_i), and the number recovered and examined for tags (C_j). [from Schaefer 19511

	Week of tagging (i)									Tagged Lamprey Recovered	Total Lamprey Recovered	Cj/Rj
	1	2.3		4	5	6	7	8	9			
Week of Recovery (j)										R_j	C_j	
1										0	2	0
2		'4								4	34	8.5
3		3	17							20	527	26.4
4		18	17	2						37	1,716	46.4
5		2	5	11	21					39	1,657	42.5
6	13		8	8	25	26				71	2,741	38.6
7		2	3	4	7	10	21			47	1,058	22.5
8			5		4	2	13	35		59	1,083	18.4
9			1			1	1	5	4	12	129	10.8
Tagged Lamprey Recovered (Ri)	1	32	56	25	57	39	35	40	4	289	8,947	
Total Lamprey Tagged (m_i)	1	34	126	125	126	125	117	125	86	865		
Mi/Ri	1	1.1	2.3	5	2.2	3.2	3.3	3.1	21.5			

B. Computed estimates of spawning phase sea lampreys using Schaefer's Method. [from Schaefer 1951]

	Week of tagging (i)									Total
	1	2	3	4	5	6	7	8	9	
Week of Recovery (j)										
1										0
2		3	6							36
3		84	1,008							1,092
4		885	1,774	464						3,123
5		90	478	2,337,	1,972					4,877
6	39	123	695	1,544	2,133	3,222				7,756
7		48	152	450	348	723	1,579			3,300
8			206		162	118	797	2,004		3,287
9			24			35	36	168	925	1,188
TOTAL	39	1,266	4,337	4,795	4,615	4,098	2,412	2,172	925	24,659

SECTION D

PROCEEDINGS OF THE WORKSHOP TO EVALUATE SEA LAMPREY POPULATIONS (WESLP) IN THE GREAT LAKES, AUGUST 1985

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INTRODUCTION

Populations of sea lampreys (*Petromyzon marinus*) in the Great Lakes are monitored primarily to measure the effectiveness of the lamprey management program. Relative abundance of spawning phase sea lampreys is measured by annual catches in traps at index sites in streams and abundance of parasitic phase lampreys by recording incidental catches of lampreys attached to fish in the commercial and sport fisheries at index ports. An indirect measure of the population of parasitic phase lampreys is the systematic recording of lamprey-induced marks on certain stocks of fish. Streams, deltas, and offshore areas are surveyed periodically with backpack shockers and granular 2',5-dichloro-4-nitro-salicylanilide (Bayer 73) to determine distribution, relative abundance, and growth of sea lamprey larvae.

Although the methods to measure the relative abundance of sea lampreys in the various life stages were adequate in the past, present needs for assessment of sea lampreys have become more demanding. Increasingly, the program managers have been asked to define the relation of the catches of spawning phase sea lampreys in streams to lakewide abundances, predict the size of spawning runs, interpret year-to-year variations in populations of spawning and parasitic phase lampreys, estimate annual production of transformed lampreys, measure accurately the abundance and age of larvae before scheduling of treatments, and define the cost-benefit analysis of the stream treatment selection process. These questions resulted from recommendations made at the Sea Lamprey International Symposium (Smith 1980), the Report of the Audit of the Great Lakes Fishery Commission's Program of Sea Lamprey Control and Research (Chamut 1980), the Committee for the Review of Commonality in Sea Lamprey Control Report (Johnson et al, 1981), the Workshop Concerning the Application of Integrated Pest Management (IPM) to Sea Lamprey Control in the Great Lakes (Spangler and Jacobson 1985), and the Application of Decision Analysis to Sea Lamprey Control (Heimbuch and Youngs 1982). Also, integration of future control methods (e.g., sterile-male release technique) and long-term fishery management goals will require quantitative measures of lamprey abundance in each lake basin.

The problems with present assessment of sea lampreys have often been discussed by the sea lamprey agents (Department of Fisheries and Oceans Canada and U.S. Fish and Wildlife Service) and other fishery agencies. Each has suggested ways or taken steps to remedy specific situations, but a structured and coordinated approach based on established priorities would provide solutions more effectively.

As a result of a recommendation from the Committee for the Review of Commonality in Sea Lamprey Control, a motion was passed to fund the Workshop to Evaluate Sea Lamprey Populations (WESLP) at the 1983 Annual Meeting of the Great Lakes Fishery Commission (GLFC). The purpose of the workshop was as follows: review past and present methods and practices used to assess populations of sea lampreys in the spawning, parasitic, and larval life stages; investigate needs to improve or expand present assessment strategies; and recommend alternate ways to collect, interpret, and present the data. Emphasis was placed on the need to provide quantitative rather than qualitative measures of sea lamprey abundance and to establish criteria for the reliability, precision, and detail of the data. The goals were to develop an improved measure of the effectiveness of sea lamprey control and to determine how the intensity of control measures affects lamprey populations and other fish stocks.

A steering committee, appointed in July 1983, held nine meetings between August 1983 and August 1985. Originally, the committee consisted of 4 members, but was expanded to 11 over the 2 years as additional expertise was needed to thoroughly develop the foundation and format of the workshop. The committee polled members of the GLFC and its control agents and other fishery agencies for their views on the needs of sea lamprey assessment. The questionnaire sent to 99 people asked four basic questions:

1. What measures of sea lamprey populations are wanted and at what level of detail should the measures be provided?

2. Should present data collection practices be changed in order to satisfy the stated needs in terms of precision, reliability, and detail?

3. Are there any techniques or approaches that could improve the quality of sea lamprey evaluation?

4. Is there a problem in interpreting data with regard to measuring the impact of sea lamprey predation on fish populations?

Responses were received from 45 individuals and tended to be divided- with respect to the occupation of each. Fishery management personnel were generally concerned with measures to assess the damage to the fishery by sea lampreys, whereas sea lamprey control agents wanted better assessments of the effects of various control techniques. Most respondents agreed that present data collection practices needed improvement, but differed in what or how changes should be carried out. They stressed the need for reliable measures of lamprey abundance and lamprey-induced mortality on fish, but did not reach a concensus as to satisfactory levels.

In September 1983, the steering committee appointed chairmen and vice-chairmen of groups to study problems in assessment of sea lampreys in each life stage (spawner, parasitic, and larval). Each group prepared a report that included sections on past and present assessment methods, pertinent life history information, a summary of the responses to the questionnaire, informational needs, recommendations for additional studies, and proposals for future approaches to lamprey assessment. Drafts of the reports were provided to prospective attendees in advance of the workshop and are summarized in this paper.

The integrative session of WESLP was held on august 5-8, 1985, at Marquette, Michigan, and was attended by 36 participants (Appendix D-I) from Canada, Scotland, and the United States. The session had two main sections. In the first section reports of the lamprey life phase groups were presented, assessment proposals from each group were reviewed, and proposals were ranked by priority. Attendees were polled by secret ballot to rank the list of assessment proposals developed by the life phase groups on overall preference, practicality, and cost (Appendix D-II). Each proposal was then presented individually. After these presentations, the groups met to consider comments and make changes in their proposals. The revised assessment proposals were presented and attendees polled a second time (Appendix D-II).

In the second section, attendees were divided into five groups, each representing one of the Great, Lakes; their charge was to develop an assessment plan for that lake. Each group was to consider all assessment proposals and their relative ranking, propose new assessment approaches where appropriate, and prepare a report that included desired fish communities, present sea lamprey control effort, and recommendations for direct and indirect lamprey assessment. The assessment plan for each lake was presented by the group chairman on the final day of the workshop. All attendees were given the opportunity to critique these reports or to propose other assessment alternatives. At the end of the workshop, the lake group reports were distributed and attendees voted a third time to rank the revised set of proposals (Appendix D-II).

The present paper summarizes the sea lamprey assessment reports of the three life history groups and the five Great Lakes groups. These summaries are brief, edited versions of the reports and therefore present only a general direction taken by each group. Almost 2 years went into preparing the life history reports, whereas the lake group reports were developed in less than 2 days. As a result, the lake reports are a review of the informal discussion of each group. The lake reports were not intended to be the final recommendation for lamprey assessment on a lake, but rather to provide further guidance and linkage between the proposals of the life phase groups for the steering committee.

Additional research needs are recommended in the present paper. A final section gives an overview or integration of the recommendations and suggests the possible direction for immediate and long-range assessment of sea lamprey populations.

SPAWNING PHASE GROUP

Summary of Report

The Spawning Phase Group reviewed methods currently used to assess relative abundance of spawning phase sea lampreys, evaluated the need to upgrade assessment strategies, and recommended methods designed to improve the collection and interpretation of assessment data. Their goal was to develop methods that more accurately estimates abundance of spawning phase sea lampreys and methods that more effectively demonstrate the effects of various control strategies.

Spawning phase sea lampreys have been collected from tributaries of the Great Lakes for about 40 years, but methods of collection have undergone several changes. Earliest control methods used mechanical weirs installed in streams to collect spawning phase lampreys, but these were replaced, beginning in 1952, by electrical weirs. In 1960, 3-trifluoromethyl-4-nitrophenol (TFM) was adopted as the principal control method, and only a select group of electrical weirs was operated for assessment purposes. Portable traps were tested in 1975 and, by 1980, they replaced the electrical weirs and became the primary assessment device. Variations in the design and use of assessment traps were described. Information on trap efficiency and lamprey abundance in individual streams was obtained from mark and recapture studies. Counts of lamprey nests have been used as an additional index to lamprey abundance in some streams. Ancillary data compiled from the collections of spawning phase sea lampreys are the average length, weight, and sex ratio of the population.

A comprehensive understanding of the life history of spawning phase sea lampreys is essential to the formulation of sound recommendations for future assessment strategies. The spawning phase group discussed the physiological changes lampreys undergo from the start of their spawning life until death, as well as the mechanisms of pheromone communication, distribution, homing, and stream selection. Knowledge of the influence of physical factors (e.g., water temperature and stream discharge) on the time of spawning runs was reviewed. Information on sustained swimming speeds of the adult was given (lampreys are capable of continuously swimming long distances in a stream) and on their reaction to stream barriers. Another section described the spawning process and included separate segments on the maturation of gametes, fecundity, spawning habitat requirements, nest construction, mate selection, and spawning act. Past and present suggestions to inventory the amount of spawning habitat available to sea lampreys were considered.

The group reviewed the responses to the questionnaire of the steering committee as they related to assessment of spawning phase lamprey populations; most respondents believed that an improvement was needed, but no immediate solutions were available. The group listed the questions that were raised by the respondents, reviewed all recommendations to improve assessment, and then developed a list of needed information and additional studies.

Assessment Proposals

The group developed four proposals for future assessment strategies. Proposal C-l described the present assessment system of index sampling by' counts of spawning phase sea lampreys obtained with assessment and barrier dam traps and nest counts. The group considered the results obtained by these methods to be a reliable index of relative abundance of lampreys for most areas of the lakes. Proposal C-2 presents the collection and tabulation of only the biological characteristics Of lampreys (this information is presently collected in conjunction with the methods outlined in Proposal C-l). The group discussed the merits and drawbacks of Proposal C-2 and showed possible correlations with abundance of fish stocks. Proposal C-2 was suggested as an alternative only during a time of drastically reduced funding. Proposal C-3 suggests estimating the population of lampreys in a lake or region of a lake by the random mass release of marked spawning adults into the lake and their subsequent recapture at index sites in streams. The estimate would be based on the ratio of marked to unmarked lampreys captured at index sites. Proposal C-4 would provide estimates of the total number of spawning adults in a lake and would be carried out in two parts. First, a stratified tag and recapture method would be used to estimate the number of lampreys in the spawning runs of all monitored streams. Next, stream factors (e.g., stream flow, or certain water chemistry characteristics) would be used to estimate the run sizes in unmonitored streams from those in monitored streams. Correlations were demonstrated for stream flow and run size. All estimates for individual streams would be summed to estimate the lake total. Several assumptions are necessary in this proposal and a few unknowns must be answered before the concept can be implemented. The group defined these and suggested ways to meet the needs.

The Spawning Phase Group presented the proposals to participants at the workshop for comments. All comments were considered and the proposals revised as suggested. Proposals C-l and C-2 were combined and Proposal C-3 was modified to include the marking of parasitic phase lampreys. The group ranked the proposals in the following order of priority: C-4, C-3, and C-l - C-2.

Informational Needs

The group developed a comprehensive list of informational needs that at present are unknowns from the standpoint of assessment of spawning phase sea lampreys. The items included short- and long-term studies that could be applied to immediate or long-range goals. The following list indicates significant items of information that are needed for immediate application. For a complete list, see the Report of the Spawning Phase Group.

-- physical/chemical/biological factors that cause lampreys to select certain streams for spawning;

-- relation between use of spawning habitat and the total number of spawning adults;

-- effect of blocked spawning runs on population estimates in adjacent streams;

-- design criteria' for assessment traps and nets so as to maximize capturing effectiveness;

-- biases introduced by the nonrandom selection of index streams; and

-- further validation of nest counts as an approach to estimating populations of spawners.

PARASITIC PEASE GROUP

Summary of Report

The Parasitic Phase Group examined present methods used by fishery management agencies and sea lamprey control agents to assess abundance of parasitic phase sea lampreys. Their goals were to review information on parasitic lampreys and to recommend studies that will increase knowledge of the phase.

The parasitic phase of the sea lamprey is the least understood of the life stages. Once free-swimming in the lakes, lampreys are not easily observed or accessible for population control. Because it is during this stage that the sea lamprey exerts its detrimental effects upon fish stocks, a better understanding of the parasitic stage is essential for further rehabilitation of the Great Lakes fishery.

The impact of parasitic phase lampreys on the fishery has been evaluated by direct and indirect methods. Numbers of parasitic phase lampreys are measured directly through collections of parasitic phase lampreys from commercial and sport fishermen. Indirect methods include counts of wounds on fish, estimates of lamprey-induced mortality to fish, and determination of changes in fish production.

The efficiency of the management program on the impact of parasitic phase lampreys on fish is difficult to evaluate. Problems in assessing parasitic phase populations are related to a lack of coordination in the reporting of data on wounds and insufficient understanding of the relation between marking indices and mortality of lampreys. The GLFC has supported research to standardize methods for the classification of marks (King and Edsall 1979) and the reporting of marks (Eshenroder and' Koonce 1984). King and Edsall (1979) developed a biological method to identify the stages in healing of wounds on lake trout (Salvelinus namaycush). However, Eshenroder and Koonce (1984) found that inconsistencies still existed in classifying stages of wounds and recommended that standards be developed to retain consistency in interpretation of marking data. They also recommended that the diameter of the wound be recorded to distinguish between the two year classes of predatory lampreys present in the Great Lakes in the fall, winter, and spring. Reporting the time of year when wounded fish are found also was advocated because of the seasonal fluctuations observed in wounding rates on fish.

Attempts to estimate lamprey-induced mortality of fish are difficult because little is known about the duration of attacks, survival after attack, and the effect of prey density on attacks. Field and laboratory studies have been conducted to estimate some of these and other factors, but much remains unanswered. Evidence of the level of attack that induces lake trout mortality is difficult to obtain in field studies because lake trout killed by lampreys are seldom found; however, estimates of lamprey-induced mortality of lake trout in Lake Ontario were made from carcasses recovered during trawl surveys in 1982-85. Equations were developed to predict the effect of sea lamprey predation on lake trout mortality (Koonce 1985), and are based on estimates of total mortality of the largest fish in assessment catches, catch per effort by size group, and marks per fish by these same size groups and by age.

Some physical and biological information has been obtained from collections of parasitic phase lampreys. Analysis of data on lampreys collected by commercial fishermen revealed that parasitic sea lampreys are distributed in a nonrandom fashion, have spatial and seasonal variations, and apparently segregate by sex (Johnson and Anderson 1980). More extensive and accurate sampling of the Great Lakes is necessary to acquire additional data that will lead to a thorough understanding of the parasitic phase population. Mark-recapture studies of parasitic phase lampreys have provided important information on the movements of lampreys (Moore et al. 1971; Heinrich et al. 1985). More comprehensive patterns of release based on a density-dependent system of stratification would help reduce the nonrepresentative recapture effort found in these studies. In 1984 a program began to sample incidental captures of lampreys in the sport fishery (in particular, the charterboat industry in the United States) and this sampling should provide additional data. The group identified the need to expand current measures of relative abundance of lampreys as the most crucial step to improve assessments of parasitic phase lampreys.

Effective management of sea lamprey populations must be based on sound knowledge of the biology of lampreys. For example, newly transformed lampreys migrate downstream either in the spring or fall to begin their parasitic phase. It is probable that fall migrants enter the lakes with greater energy reserves and have an earlier opportunity to commence feeding than the spring migrants. It is unknown, however, whether present control practices may favor one of these migration periods.

Other aspects of lamprey biology that may be affected by management practices are body size, sex ratios, and prey selectivity. Lamprey size is negatively related to lamprey abundance and positively related to host abundance (Heinrich et al. 1980). The number of females present in the population also is negatively related to lamprey abundance. These relationships must be taken into account when evaluating management results. Lampreys selectively attack larger fish (Farmer and Beamish 1973; Cochran 1985) and heavily prey on lake trout (Johnson and Anderson 1980). Thus, marking rates on smaller fish and on less preferred species may not be indicative of the effectiveness of management techniques.

Most of the respondents to the questionnaire of the steering committee stressed the need to establish a reliable relation among observed lamprey wounding rates on fish, lamprey-induced mortality, and abundance of parasitic phase sea lampreys. All agreed it presently is difficult to relate lamprey evaluation data to the impact of sea lampreys on fish populations.

Assessment Proposals

The Parasitic Phase Group described six proposals that included several methods to estimate either relative or absolute abundance of parasitic phase lampreys. Within the methods to estimate relative abundance are proposals for sampling through the commercial and sport fisheries, which at present, is the only form of assessment that directly counts parasitic phase sea lampreys. Other proposals suggested the examination of lampricide treatments and subsequent effects on lamprey wounding of lake trout for determination of origins and movements of parasitic phase lampreys, and the use of sea lamprey statolith composition to determine stream of origin. During the workshop a seventh proposal, dealing with the assessment of lake trout carcasses in Lake Ontario, was added.

After presentation of the proposals at the workshop and review of comments of the attendants, the group reordered the proposals in the following priority:

1. Mark and recapture study for population estimates of parasitic phase sea lampreys.

2. Integrated use of gill nets, trawls, and remote sensing to estimate the impact of sea lampreys on the Lake Ontario lake trout population.

3. Estimation of relative abundance of parasitic sea lampreys from lake trout wounding data.

4. Estimation of relative abundance of parasitic phase sea lampreys as determined by lampreys collected from sport fishermen.

5. Examination of the effects of lampricide treatments on. lamprey wounding of lake trout for determination of origins and movements of parasitic sea lampreys.

6. Use of sea lamprey statolith composition to determine stream of origin.

7. Use of commercial large-mesh trap nets to determine relative abundance of parasitic phase sea lampreys.

Proposals B-5 and B-6 were omitted from the list for the third poll because they were funded before the workshop and were in the developmental stage.

Informational Needs

The group developed a comprehensive list of informational needs that at present are unknowns from the standpoint of assessment of parasitic phase sea lampreys. The items include short- and long-term studies that could be applied to immediate or long-range goals. The following list indicates significant items of information needed for immediate application. For a complete list, see the Report of the Parasitic Phase Group.

-- extent of immigration and emigration of marked and unmarked parasitic lampreys in areas where mark and recapture studies are conducted;

-- relation between stream of origin and feeding area or range within the lake;

-- best design for a mark and recapture study of parasitic lampreys;

-- mortality of parasitic lampreys between the time of transformation and first feeding;

-- effect of prey density on attack rates;

-- relation between data on wounds on fish and populations of lampreys; and

-- role of prey size, density, and species preferences in determining wounding rates.

LARVAL PHASE GROUP

Summary of Report

The objective of the Larval Phase Group was to develop recommendations that would improve the ability to quantify populations of larval sea lampreys in the Great Lakes. The reasons for assessing larval populations are twofold: first, systematic surveys provide continuing information on relative abundance, range, instream distribution, length frequency, and predictions of transformation rates to assist management in decisions for stream treatment scheduling; and second, special case estimates of total populations provide information that will assist in the development of predictive capability for management decisions. Although routine surveys for relative abundance were adequate in the past, there now is a need for absolute estimates of numbers to evaluate specific stream treatments or to calibrate new methods of collection. The collection, analysis, and interpretation of data on larval and transforming sea lampreys are standardized within each control agency although approaches are somewhat different between agents. Electronic data processing is used to facilitate retrieval and analysis of data.

The group reviewed the life history of the larval sea lamprey, from fecundity of adults, through egg deposition and survival of embryos, to duration of larval life. The group report included information on larval growth, habitat preference, and transformation rates as well as movement within streams by larvae and transforming lampreys.

The group also reviewed the history of the development of techniques used to capture larval and transforming sea lampreys from 1952 to 1985, beginning with methods involving the sifting of stream sediment, to the use of chemical applications and electric shocking equipment. Nets and traps were designed to capture downstream migrant lampreys, and various marking techniques were developed or modified to conduct population estimates.

Studies of populations of larval sea lampreys began when methods were developed to identify the different species of lampreys and estimate the age of sea lampreys. Age of larvae can be estimated from length-frequency data, but definitive aging techniques for larvae older than 3 years or transforming individuals have not proven reliable. Studies are underway to explore statolith analysis as an aging technique.

The group recommended the following to achieve a goal of improved assessment of sea lamprey larvae: "

1. Canadian and U.S. agents should consider the adoption of common procedures, study programs, and reporting formats. Serious considerations should be given to common data entry and retrieval formats.

2. Sampling equipment and techniques should be improved, especially those used to capture large ammocoetes, transforming larvae, and larvae in deep-water habitats.

3. The many variables and requirements necessary for estimating larval populations dictate that the utmost care must be taken when designing studies and interpreting the data. Population estimates can be improved by the development of marks that are simpler to apply and more recognizable on larval lampreys. Improved methods to collect efficiently or raise large numbers of larval lampreys for marking are necessary.

4. The natural mortality of ammocoetes from hatching to transformation should be determined.

5. The rate of transformation with length and age must be determined for reestablished populations.

6. Present funds and personnel numbers are not adequate for extensive sea lamprey population studies. A significant expansion by the agents to study these populations would require additional resources.

7. The need for population estimates must be evaluated in terms of their contribution to the total lamprey management program. A critical question facing management is allotment of personnel and funds between treatment and assessment strategies.

8. In order to refine the process of decision analysis for stream treatment scheduling, it is necessary, where possible, to replace speculation or educated guesses (where exact quantitative measurements are absent because of incomplete information) with objective definitions and analyses.

Assessment Proposals

The group perceived that the greatest need in larval assessment is to determine where transformed sea lampreys are produced and to estimate the numbers entering the lakes. Toward this end, three proposals were developed and a fourth was added. The first three proposals were (1) use of the removal method (Leslie and Davis 1939; DeLury 1947) to estimate larval and transforming lampreys in streams, (2) an efficiency test of the control agents' present evaluation of larval and transformed populations, by comparing stream rankings for treatment with a judgmental stratification of instream habitat and the expected control benefits from actual treatments, and (3) a study designed to estimate production of transforming lampreys in streams tributary to a lake basin, with Lake Superior as an example. The fourth proposal suggested an integrated approach to larval and spawning **adult assessment, and involves the use of existing assessment** procedures. After review of comments from WESLP participants to the presentation of the proposals, the group combined the four into a single, comprehensive proposal entitled: "To estimate production of transformed lampreys from populations of larval sea lampreys in streams tributary to a lake basin."

Informational Needs

The group developed a comprehensive list of informational needs that at present are unknowns from the standpoint of assessment of larval sea lampreys. The items included short- and long-term studies that could be applied to immediate or long-range goals. The following lists significant information that is needed for immediate application. For a complete list, see the Report of the Larval Phase Group.

-- precise effectiveness of larval sampling tools (shockers, Bayer 73) under various conditions;

-- improved techniques to mark larvae for long-term population studies;

-- natural mortality from hatching through transformation;

-- habitat inventory maps for all sea lamprey-producing waters; and

-- a technique that is more effective and less labor intensive than fyke nets to capture downstream migrant larvae and transforming lampreys.

LAKE SUPERIORGROUP

Fish Community Goals

The present fish **community** of Lake Superior is in a state of transition. Lake trout are considered to have reached 30-50% of the population levels found before invasion of the sea lamprey. Based on commercial harvest, lake whitefish (Coregonus clupeaformis) are at their highest abundance since the turn of the century. Lake herring (C. artedii) and chub (Coregonus spp.) are below historical high abundance, but in **general,** the population is stable. Non-native trout (brown trout, Salmo trutta; rainbow trout, S. gairdneri) and salmon (chinook salmon, Oncorhynchus tshawytscha; coho salmon, O. kisutch; pink salmon, O. gorbusha) have developed self-sustaining populations, with the exception of splake (Salvelinus namaycush X S. fontinalis), in many areas of the lake. Rainbow smelt (Osmerus mordax) are the dominant forage fish, but abundance remains below that established in the mid-1970's. The sea lamprey population appears stable with a probable annual production of about 50,000 adults.

The fish community goals are to establish stable, naturally-reproducing populations of lake trout, lake whitefish, lake herring, and other coregonids. The community also should contain non-native trout, salmon, and rainbow smelt. Management agencies should determine the acceptable abundance for the population of adult sea lampreys.

Present Sea Lamprey Control

The present sea lamprey control practices on Lake Superior are standard procedures and include larval surveys, stream treatments, and population assessments. Surveys provide data on larval distribution and relative abundance before treatments and also determine effectiveness of treatments in terms of the relative numbers of larvae killed and surviving. Streams are selected for treatment based on the following: (1) expected transformation of larvae, (2) abundance of larvae, (3) numbers of residual lampreys after treatment, (4) potential escapement of larvae, (5) interval since previous treatment, (6) number of adult sea lampreys and their impact on fish stocks, and (7) reaction to agencies or public concerns. Assessment is done with traps to measure abundance of spawning adults, and through commercial and sport fishermen to measure numbers of parasitic phase individuals. Barrier dams are used on some streams as a device to block spawning phase lampreys from spawning habitats.

Assessment Plan

The lake was divided into 11 lake management units (LMU), each unit includes the area around one of the 11 major lamprey-producing streams -- Two Hearted (1), Sucker (2), Sturgeon (3), Ontonagon (4), Bad (5), Brule (6), Wolf (7), Nipigon (8), Michipicoten (9), Batchawana (10), and Goulais (11) Rivers (Figure D-l). The group viewed the best approach for direct assessment of lamprey populations to be a combination of the proposals for a lakewide prediction based on the extrapolation of estimates of absolute numbers of spawners in index streams, and of the production of transformed sea lampreys in the 11 streams. The estimates are to be developed for each LMU and then summed for a lakewide total.

The group also recommended use of indirect measures of lamprey abundance. The proposals to estimate relative abundance of parasitic lamprey populations from wounding rates on lake trout 'and to examine effects of lampricide treatments on lake trout wounding rates appeared to have more direct application to Lake Superior than to the other lakes. The group further recommended that wounding data be obtained routinely for chinook salmon, lake whitefish, and lake herring.

The primary justification for the assessment plan is *to* provide an accurate measurement of the effect of sea lamprey control. Other justifications include the following: provide estimates of the number of adult lampreys; determine the origins of transformed lampreys; provide additional data for decision analysis for various control strategies; and provide greater input for calculation of lamprey-induced mortalities and catch quotas for impacted fish populations.

LAKE MICHIGAN GROUP

Fish Community Goals

The fishery of Lake Michigan primarily is managed for cold-water species. Hundreds of thousands of trout and salmon are stocked annually. Walleye (Stizostedion vitrium) and yellow perch (Perca flavescens) are abundant in some areas. Lake whitefish, lake herring, and other coregonids are important commercial species. Rainbow smelt and alewife (Alosa pseudoharengus) are the primary forage fish. Lake whitefish appear to be the dominant prey for lampreys in the Green Bay/Bay de Noc area; lake trout are the dominant prey in the remainder of the lake. The group adopted the policy of the GLFC (1983) on lake trout rehabilitation, but noted that mortality in all areas of the lake appears higher than recommended (Lake Michigan Lake Trout Technical Committee 1985).

Present Sea Lamprey Control

The control program was expanded to include Lake Michigan more than 25 years ago. In general, the first round of treatments was completed by the end of 1965 (Smith and Tibbles 1980). Most lamprey-infested streams are treated every 3 to 4 years; about 20 streams are treated annually.

With the exception of mark and recapture studies of spawning phase lampreys in the Manistique River, all current measures are relative or qualitative rather than total estimates. Surveys for larval lampreys in streams follow routine procedures. Some surveys for larvae are conducted in lentic habitats, but populations in these areas are not considered a problem in Lake Michigan. Assessment of the parasitic phase (which provides indirect information on sea lamprey/fish interactions) is obtained from wounding rates on lake trout in the fall and the collection of parasitic adults from commercial trap net and sport and charterboat fisheries. Spawning phase lampreys are collected with assessment traps in 13 streams.

Assessment Plan

The group divided Lake Michigan into five LMUs (Figure D-2). The Green Bay area (1) includes a number of primary lamprey producing streams (e.g., the Peshtigo and Ford Rivers) and a number of streams where populations of spawning phase lampreys are monitored annually, but the bay does not appear to be major habitat for either lake trout or parasitic phase lampreys. The northern unit (2) includes a major lake whitefish fishery, the Manistique River which receives the largest number of spawning lampreys, and the point of access for any immigrating lampreys from Lake Huron (Straits of Mackinac). The west central (3) and southeastern (4) units include a large sport fishery and some streams that contain larval lampreys. The southwestern unit (5) also includes an excellent sport fishery and parasitic phase lampreys are relatively common, but few larval and spawning phase lampreys are found in tributary streams.

The group viewed the continuation of present measures of relative abundance as important, but also recommended determining absolute numbers in all life stages. The group believed the proposals to estimate numbers of spawners and to provide information on numbers of transforming lampreys were equally critical and shared number one priority. The proposal to mark and release parasitic phase lampreys ranked second.

Assessment of larval and spawning phase lampreys should be carried out for all lake management units. Abundance of parasitic phase lampreys should be calculated on a lakewide basis, although marking should be conducted in such a way that movement among units can be monitored.

The group identified the following information needed to implement the assessment plan:

-- more knowledge is required as to the geographic extent of deep-water lentic populations of ammocoetes in various offshore locations of the lake;

  an accurate assessment of spawning phase lampreys will require an understanding of the extent of immigration of parasitic phase lampreys from Lake Huron;

  increased knowledge of transformation rates of large larvae is necessary to predict production of transformed lampreys from larval populations accurately;

-- the effect of blocked spawning runs on recaptures of marked and unmarked spawning phase animals in adjacent rivers (are lampreys counted more than once?); and

-- an accurate assessment of sea lamprey/fish interactions in Lake Michigan requires that the composition of the fish population must be better defined.

The primary justification for the assessment plan is to obtain an accurate measurement of lamprey control measures. Secondary reasons include: provide an assessment of the cost of lamprey predation to the fishery; provide an assessment of present and economically acceptable levels of lamprey control; calibrate relative abundance indices; and assess the extent of immigration of lampreys into Lake' Michigan from the St. Marys River via northern Lake Huron.

LAKE HURON GROUP

Fish Community Goals

The present fish community of Lake Huron consists primarily of introduced salmonids and native populations of lake whitefish, other coregonids, walleye, and yellow perch. Although some natural reproduction of lake trout occurs, the population is not self-sustaining. Lake whitefish are abundant and are important commercially, but other coregonids are in a recovery phase. In some U.S. waters the salmon fishery is in a developing stage, as is the splake and lake trout fishery in Canadian waters. Walleye and perch are important in some northern and western areas of the lake. Rainbow smelt and alewife are the dominant forage fish.

The desired fish community consists of self-sustaining stocks of lake trout and continued high production of lake whitefish. Goals also include further development in the sport fishery for other salmonids and walleye, continued recovery of other coregonids, and continued development of splake in some Canadian waters.

Present Sea Lamprey Control

Sea lamprey control varies by region of the lake. Although lampricide treatment schedules have been intensified in the north, their effects may be offset by a major untreated source of recruitment in the St. Marys River. Abundance of parasitic and spawning phase lampreys appears to be increasing in the area. Treatments continue at a fairly stable level in the west central part of the lake, but fewer are required in the east central and southern sections and in Georgian Bay where numbers of lampreys have decreased.

Assessment Plan

The lake was divided into five LMUs (Figure D-3) -- the northern part including the St. Marys River (1), the U.S. waters of the western lake from Rogers City south through Saginaw Bay to Grindstone City (2), the Canadian waters of the lake proper east of unit 2 (3), the southern quarter of the lake (4), and Georgian Bay (5).

As a major prerequisite to implementing the proposed assessment plan, the group recommended a stream habitat inventory for each LMU. The group viewed-the inventory as essential to long-term management. The following information could be listed for each stream: length (historical upper limits for sea lampreys), mean width, percentage larval habitat, percentage spawning habitat, minimum age of larvae for transformation, average cost of treatment, potential for production of larval and transforming lampreys, discharge, area of delta, and larval potential in delta.

The group recommended and prioritized four assessment measures. The first is to measure the adult population in each LMU by the *release* of marked transforming lampreys and their recapture in assessment traps and in sport and commercial fisheries. This measure also includes the concurrent estimates of spawners from index streams which then would be expanded into LMU or lakewide estimates. Because large numbers of transforming lampreys are difficult to obtain, consideration should be given to selecting a stream where a nursery for transforming lampreys would be developed and a special trap installed.

The second measure is the development of a quantitative population evaluation through the treatment process. Pretreatment assessment data should be improved and quantitative measurements made of the lamprey kill and the number of residuals. The information gained from this should allow an estimate of the production of transformed lampreys from untreated areas and early stream escapement.

The final two measures include detailed larval population assessments in LMU 1 by using the reduction method, and a population estimate by using marked parasitic phase lampreys recaptured in the sport or commercial fisheries and assessment traps. These also will provide an estimate of mortality of lampreys between the transforming and parasitic stages.

The major justifications for the recommendations are to gain knowledge about numbers in lamprey populations, assess the accuracy of relative estimates, help to evaluate control effectiveness, and determine the origin of transformed lampreys. Lake-wide estimates provide an opportunity to obtain this information. Also management by LMUs allows for a finer resolution to permit the implementation of different levels of control.

The Lake Huron Group gave special consideration to the St. Marys River. The system must be described intensively, although information is being obtained which will give estimates of larval populations (along with the percentage of larvae over 120 mm) and the number of spawning phase adults. The group proposed the following recommendations:

1. Control agents should develop and implement a plan to complete a comprehensive assessment of the lamprey population in LMU 1 by 1990. The plan should include: (a) a detailed habitat inventory (especially substrates within the St. Marys River), (b) further estimates of the number of lamprey in the spawning run, (3) estimates of numbers of parasitic phase individuals, (d) mark-recapture study involving large numbers of transforming lampreys, and (e) estimates of damage to fish stocks.

2. While considerable. percentage of the spawning run is already being trapped, trapping should be intensified to capture a larger proportion of the run. Some consideration should be given to sterilizing the trapped males and releasing them back into the river.

3. Because of the extensive larval habitat (and therefore high cost to treat with TFM) and the apparently limited spawning habitat in the St. Marys River, consideration should be given to control at spawning sites.

LAKE ERIE GROUP

Fish Community Goals

Lake Erie has a diverse fish community. In the shallow western area, cool- and warm-water species predominate, ranging from walleye and yellow perch to freshwater drum (Aplodinotus grunniens), carp (Cyprinus carpio), and channel catfish (Ictalurus punctatus). In the deeper eastern area, salmonids are abundant and are sustained through stocking, but here also walleye and yellow perch are important species.

As a fish community goal, the group concurred with the Strategic Plan for the Rehabilitation of Lake Trout in eastern Lake Erie (Lake Erie Committee Lake Trout Task Group 1985a). The group also recommended implementing management strategies to achieve and maintain optimum sustained yield of native and desirable non-native species, and to maximize recruitment and survival of native species that have declined significantly.

Present Sea Lamprey Control

The streams of Lake Erie have never been treated with TFM for sea lamprey control, but treatment is scheduled for all streams containing sea lampreys, beginning in fall 1986. Most of the sea lamprey-producing streams are tributary to the eastern basin. Assessment traps are operated in three streams and larval surveys have been conducted in all U.S. streams.

The group recommended an experimental approach to the treatment schedule. Consideration should be given to treating all streams containing larval lampreys on a 2-year, back-to-back scheme, with the first treatments in the spring of year 1 and the second in the fall of year 2. This technique may produce the greatest reduction of larvae over a short time by killing some of the lampreys that survived the first treatment plus the subsequent year classes from both years.

Assessment Plan

The group recommended a comprehensive plan covering direct (all the life phases) and indirect methods to evaluate the control strategy for Lake Erie. For the spawning phase, the goal was to estimate the total lakewide number on an annual basis. In 1986, the number of assessment trap sites in the U.S. should be expanded from the three to at least six, and in Canada to five. Instream estimates should be made at least twice for each stream until all index sites are calibrated. Stream estimates then would be expanded lakewide by use of an indicator such as stream discharge.

The proposed goal in larval assessment is to estimate annually the abundance (absolute or relative) of ammocoete populations in streams and to forecast production of transformed lampreys. Extensive surveys to determine larval distribution and abundance should be undertaken in Canada in 1986, and index stations for larvae also should be established. Mark and recapture population estimates should be made on two or three major rivers during the first treatment.

Because the Lake Erie sea lamprey population has never been subjected to control measures, the group. recommended transformed lampreys be marked and released before treatments. Ideally, the lampreys would be marked only in streams that have assessment traps for adults. If a sufficient number can be marked and later recaptured, estimates of the population should be possible. The group recommended that transformed. lampreys be marked over 2 years and suggested consideration be given to delay the first year of treatment until 1988 to accommodate this recommendation.

The Sea Lamprey Management Plan for Lake Erie (Lake Erie Committee Lake Trout Task Group 1985[b]) stated that lake trout wounding rates will be used as a measure of the effectiveness of lamprey control. If spawning lamprey estimates are developed and a relation with lake trout abundance is established, marking indices can be further integrated. The group further recommended the collection of parasitic lampreys from the commercial and sport fisheries and the use of trawls to survey the lake bottom for lamprey-killed lake trout.

Lake Erie, with its untreated and apparently increasing population of sea lampreys, provides a rare opportunity to assess population levels before and after initial treatments. The main justification for the assessment plan is to evaluate these treatments on Lake Erie streams and to estimate the resulting change in impacts of sea lamprey on fish populations. Further, the proposed assessment measures will answer questions about dispersal of parasitic phase lampreys (into Lake Ontario?) and if homing of lampreys exists in untreated areas.

LAKE ONTARIO GROUP

Fish Community Goals

The present fish community consists primarily of introduced salmonids throughout the lake and stable high populations of smallmouth bass (*Micropterus dolomieui*), walleye, northern pike (*Esox lucius*), yellow perch, and other warm-water species in the western area. Few of the stocked lake trout live to maturity. Present wounding rates on fish indicate a lakewide sea lamprey problem.

The goals are to preserve native, warm- and cold-water species and to rehabilitate lake trout, Atlantic salmon (*Salmo salar*), and coregonids. The annual harvest objective of lake trout is set at a maximum of 40%, but creel censuses indicate present angler harvest is beyond this objective (Lake Ontario Lake Trout Subcommittee 1984).

Present Sea Lamprey Control

Streams in Lake Ontario that contain larval sea lampreys are treated on a 3- to 4-year cycle and about 12 are treated each year. Treatment schedules are flexible, and can be accelerated to eliminate residual larvae from past treatments, or delayed because of the absence of some year classes. New and renovated barrier dams are a control measure on many streams.

Sea lamprey populations are assessed through several measures in Lake Ontario. The system of assessment traps along the U.S. and Canadian shores is one of the most complete in the Great Lakes. Unfortunately, treatments regularly are scheduled during the spawning runs and sometimes bias catch statistics.

Assessment of spawning phase lampreys is supplemented with annual *nest* counts on selected streams. Larval surveys are conducted routinely in all streams having lamprey-producing potential, but lentic surveys are seldom conducted in the lake basin. Parasitic phase populations are assessed through systematic, lakewide gillnet surveys in summer and fall and by creel censuses. Also carcass surveys for lake trout, and collections of parasitic lampreys from charterboat operators and at fish derbies supplement this assessment.

Assessment Plan

The group recognized the importance of the present assessment measures, but stated that methods need to be upgraded in some areas. A lakewide estimate of spawning phase lampreys would be ideal and could be used to evaluate the overall effectiveness of control and to aid in interpretation of lake trout wounding data, The group further recommended that treatments of streams be delayed until after 'the spring spawning runs to allow for better assessment.

Assessment of parasitic phase lampreys was discussed primarily in terms of indirect measures. A need was identified to reevaluate the use of lake trout assessment data. Suggestions included developing a detailed harvest estimate for lake trout, identifying lamprey marks on trout by age and size, obtaining more detailed incidence data in some areas, and calibrating the lake trout mortality model. Surveys for lake trout carcasses should be expanded to aid in understanding the relation of attack rates to lake trout mortality. Larval surveys should be refined and expanded. Survey effectiveness needs to be improved in some areas, specifically the Niagara, Oswego, Black, and St. Lawrence Rivers. Larvae inhabiting lentic areas have not been identified adequately.

The group noted that the proposals for larval estimates did not appear adequate and offered some modifications. First, habitat inventories should be conducted on all streams containing sea lampreys. Information is needed on growth and transformation rates in all streams in order to predict numbers of transformed sea lampreys. Secondly the group recommended using the removal and mark/recapture methods to estimate larval numbers in certain critical streams. The estimates should be made by larval size groups and, to describe treatment effectiveness, before and after treatments.

The assessment plan included four main justifications: (1) evaluate the overall effectiveness of lamprey control; (2) contribute to the decision process of treatment scheduling; (3) detect sources of problem areas; and (4) assess damage to the fishery.

OVERVIEW

WESLP reiterated the importance of assessment of lamprey stocks in the continuing program to manage sea lampreys in the Great Lakes. While it was acknowledged that present assessment methods yield sound information on the relative abundance of lampreys, participants also agreed with past audits and evaluations of the control program that, although generalizations of lamprey populations were obtained through the relative indices, absolute quantifiable indicators of abundance largely were absent. In discussing present issues confronting the control program and the GLFC, those at the workshop pointed to an increasing need for better and more reliable methods of sea lamprey assessment.

The principles of integrated pest management require that accurate assessment of sea lamprey numbers should involve comparisons of point estimates throughout the three life stages. As an example, an approach designed to estimate the production of transformed sea lampreys in an area of a lake should be coordinated in succession with estimates of the parasitic stock, damage to the fishery, and a measure of the spawning population. Participants of the workshop developed specific approaches to quantify lamprey abundance in each life stage and offered priorities to implement them, but the success of any advancement in lamprey population assessment largely will be determined by the ability to verify results. With this concept in mind, the steering committee reviewed the life phase group reports, the lake trout reports, and the polls from the workshop, and developed a set of recommendations as a possible course of action for future assessment of the sea lamprey management program. Recommendations to obtain additional quantitative estimates of the numbers of spawning, larval, and parasitic sea lampreys were made with the eventual goal of developing mathematical relations among the three phases of sea lampreys. This approach would allow a decrease in the number of assessments to less costly estimates in one or two life stages, with probabilistic projections of the numbers in the other stages of the life cycle.

The recommendations for future assessment are presented in three categories. The first is a recommendation that will help all sea lamprey assessments. The second deals with specific courses of action, discussed in order of priority, for each of the life stages of the sea lamprey; through the polling process, participants placed the highest priority of assessment on the spawning phase, followed by the larval, and finally the parasitic. Recommendations relating to additional information needs were listed under the third category.

As an overall recommendation to improve sea lamprey assessment, we strongly suggest consideration be given towards dividing each lake into lamprey management units. The lakes have long been divided into districts for catch statistics from the commercial fishery (Smith et al. 1961), and in some instances information on lamprey abundance has been related to these districts, but in general the divisions may be refined further. Sea lamprey abundance and fishery management goals vary significantly by area in the Great Lakes. In the past, lamprey population assessment generally has been applied at either lakewide or individual stream levels. The establishment of management units will result in a clearer definition of lamprey population levels by region and lead to more accurate measurements of control techniques. The demarcations of these units should be defined cooperatively by lake committees and the control units, based on many factors, some of which include topography, present levels of lamprey abundance and approaches to control, fish stock community goals, and social and economic elements. Ideally, the units may correspond to boundaries in existing fishery management grids and statistical districts.' New assessment plans should be designed by unit and then results combined as a lakewide evaluation. Within each unit, complete sea lamprey habitat inventories should be undertaken (similar to that recommended by the Lake Huron Group).

Spawning Phase Assessment

Absolute counts of populations of spawning phase sea lampreys were identified as the prime goal of assessment in the future. Although those attending the workshop agreed that relative counts of spawners obtained from past and present methods have provided information needed to identify overall shifts in population levels, future needs in the evaluation of control techniques require lakewide estimates. The proposal by the Spawning Phase Group to estimate total numbers of spawners in index streams and then project lakewide estimates based on correlations between estimated number of lampreys and characteristics of the stream (e.g., discharge) had the highest priority in the second and third polls taken at the workshop. We recommend measures be taken to implement this approach. At present staff levels of the control units, an immediate expansion to all the Great Lakes is impractical. Rather, we suggest a trial period of 2 years on one of the Great Lakes, with Lake Superior as the first choice. Thereafter, based on the experience in Lake Superior and availability of funds, the technique will be applied to other lakes.

This technique was implemented successfully in U.S. waters of Lake Superior in 1986. By regression analysis, a highly significant correlation was demonstrated between average daily discharge of streams with assessment traps during the spawning season (x) and the estimated number of spawning phase lampreys in index streams (y). The estimate was expanded to include those streams that lacked assessment traps but were considered to have spawning sea lampreys. An estimated 61,000 sea lampreys were present in U.S. waters of Lake Superior in 1986.

The collection of spawners at index streams with assessment traps is an integral part of this approach and will be important to the continuity of data on relative abundance. Coverage of Great Lakes tributaries is adequate in some areas but lacking in others; a notable area is Lake Erie. The impending lampricide applications to streams of Lake Erie in fall 1986 make it imperative that spawner assessment be upgraded before treatments. We recommend a maximum number of index sites for assessment traps be operated in the spring of 1986 to evaluate the effectiveness of these initial treatments.

The recommendation was implemented in Lake Erie in 1986. Assessment sites were increased from three to six in U.S. waters and from none to three in Canada. Data from lampreys captured at these sites provided a basis for treatment evaluations.

Larval Phase Assessment

Larval surveys to determine instream distribution and relative abundance are vital in scheduling lampricide treatments. Posttreatment surveys evaluate the relative success of TFM applications. Surveys to obtain these measurements should continue.

The second priority developed at the workshop focused on estimates of larval lamprey abundance and production of transformed lampreys in major lamprey-producing streams in each management unit. At present, the control program has dealt little in large-scale estimates of larval populations and lacks a means of estimating or predicting numbers of transformed lampreys within a unit or lake. Several techniques were proposed to develop larval estimates, but transformation rates under controlled conditions must be defined before reliable predictors can be put into routine use. Also, a greater emphasis needs to be placed on determining the contribution of transformed sea lampreys from uncontrolled lentic areas and the interconnecting waterways of the Great Lakes. Although, as some noted in the workshop, none of the proposals on larval and transformed lampreys appeared adequate, the integrated proposal by the Larval Group to estimate production of transforming lampreys provides a basis to begin the development of an upgraded assessment.

We recommend consideration be given to developing a program to estimate larval and transformed lamprey production on a lakewide basis. To this end, we further recommend a team consisting of staff members of the control agents, assisted by outside expertise, be designated to specifically develop and implement this program.

A rare opportunity to study untreated populations of larvae exists in the streams of Lake Erie before the scheduled treatments in the fall of 1986. Strong consideration should be given to conducting detailed population estimates on these streams. Further consideration also should be given to collecting, marking, and releasing a large number of transformed lampreys before treatments. These studies would provide information on movements during the parasitic phase and point estimates during the parasitic and spawning stages.

As a final recommendation to larval assessment, consideration should be given to treating the infested tributaries of Lake Erie in two succeeding years. This intensive back-to-back approach to treatments may have the greatest effect in reducing numbers of larvae and may provide a means to evaluate the effects of connecting channels and lentic areas as important sources for recruitment to populations of sea lampreys in Lake Erie.

Parasitic Phase Assessment

Of the three life stages of the sea lamprey examined during the workshop, assessment of the parasitic phase was deemed the least critical. This delegation was not meant to imply assessment of parasitic phase stocks as unimportant. The continued collection of information on relative abundance of this stage represents an essential link for verifying estimates in the larval and spawning life stages.

Indirect and direct methods can be used for the parasitic phase assessment. The indirect approach involves counts of lamprey-induced 'marks on fish, and estimates of mortality based on mark and carcass counts. Methods used to measure and analyze counts of lamprey marks on fish should be upgraded to improve overall assessment. Because such information has been collected by many different groups (Federal, State, and Provincial agencies, and native Americans), inconsistencies have occurred. We recommend further efforts to standardize collections. The best approach to follow appears to be that described by Eshenroder and Koonce (1984). Carcass counts of lamprey-killed lake trout in Lake Ontario directly estimate fish mortality and also are an indirect index of lamprey abundance. We recommend that this assessment be further verified and expanded where possible.

Direct methods depend on actual counts of incidentally-captured lampreys in the commercial and sport fisheries. Information *on* relative abundance of parasitic phase sea lampreys has been compiled since 1967 from the commercial fishery and since 1983 from the sport fishery. Although participants at the workshop did not place high priority on this information in relation to that for the spawning and larval stages, continued collection of meaningful data remains essential. The report from the Parasitic Phase Group identified the need to have adequate coverage of the lakes through collections from the commercial and sport fisheries as the most crucial step 'in improving assessment of parasitic phase numbers. We recommend continued collection of these data and we further recommend the work be reviewed to ensure that effort is concentrated in areas where the greatest return for investment will be realized. Some of this data collection may be incorporated into fishery surveys that are conducted by the U.S. States and the Canadian Province of Ontario.

The workshop participants identified a mark and release study to estimate populations of parasitic phase lampreys by lake or lamprey management units as a necessary step in an integrated assessment approach. We recommend that an expanded version of the study (Heinrich et al. 1985) be conducted, and further suggest that a group from the control agents be chosen to prioritize a list of areas to conduct this experiment.

Recommended Informational Needs

The following list includes critical issues where information is limited. These items are broad and comprehensive, and solutions to each may require large-scale research projects. They are not listed in priority.

-- determine precise effectiveness of sampling tools for sea lamprey larvae;

-- develop an improved marking technique for larval and transformed lampreys for long-term population studies;

-- determine mortality of sea lampreys between transformation and first feeding;

-- determine the effects of prey density and size and species preferences that determine predatory/prey interactions and result in the marking data;

-- determine the factors that cause spawning phase sea lampreys to select certain streams; and

-- determine the effect of blocked spawning runs on the spawning population numbers in adjacent streams.

As a final note, the steering committee reaffirms the critical role of assessment in the sea lamprey management program in the Great Lakes. Although some of the studies recommended in this paper can be undertaken through present assessment staff levels of the control agents, others cannot. Manager should carefully evaluate the recommendations of WESLP when developing budget requests. Assessment studies need adequate staff and funds to meet the increased demands of control. For special, short-term studies, requests for additional funds may be possible through non-operational budgetary allotments.

Figure D-1. Lake Superior, showing 11 lake management units in which to assess sea lamprey populations, as proposed by the Lake Superior Group.

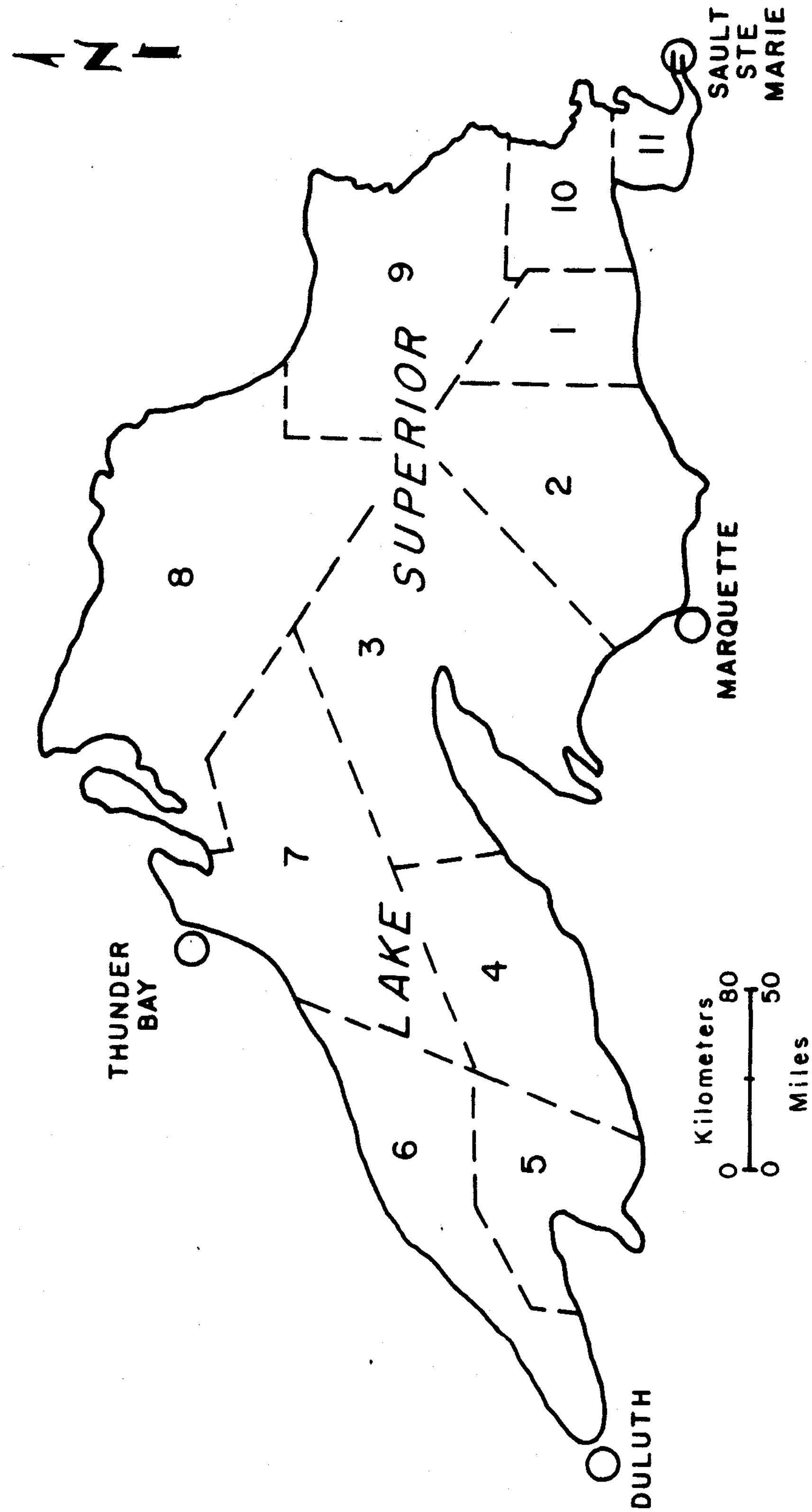


Figure D-2. Lake Michigan, showing five lake management units in which to assess sea lamprey populations, as proposed by the Lake Michigan Group.

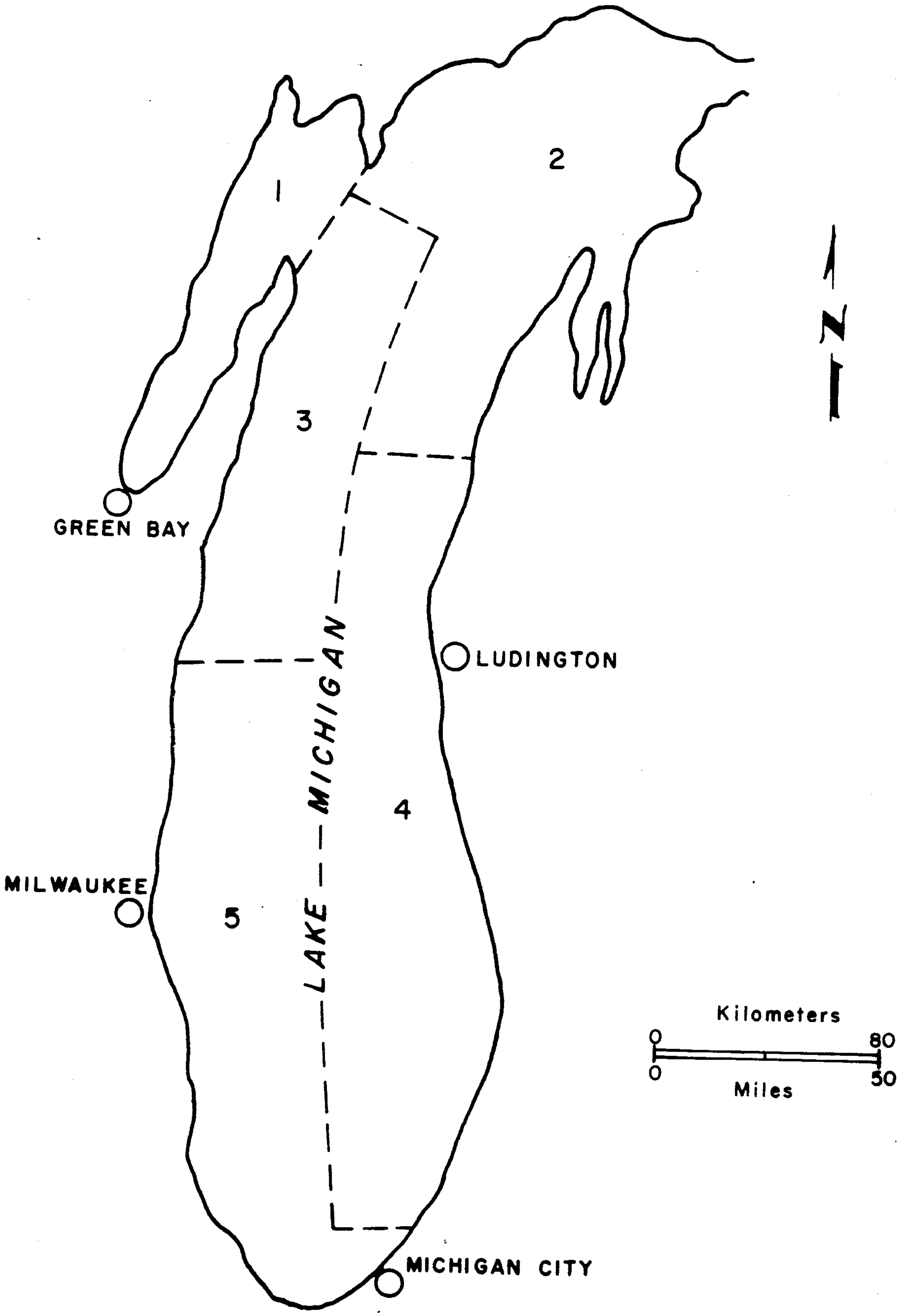
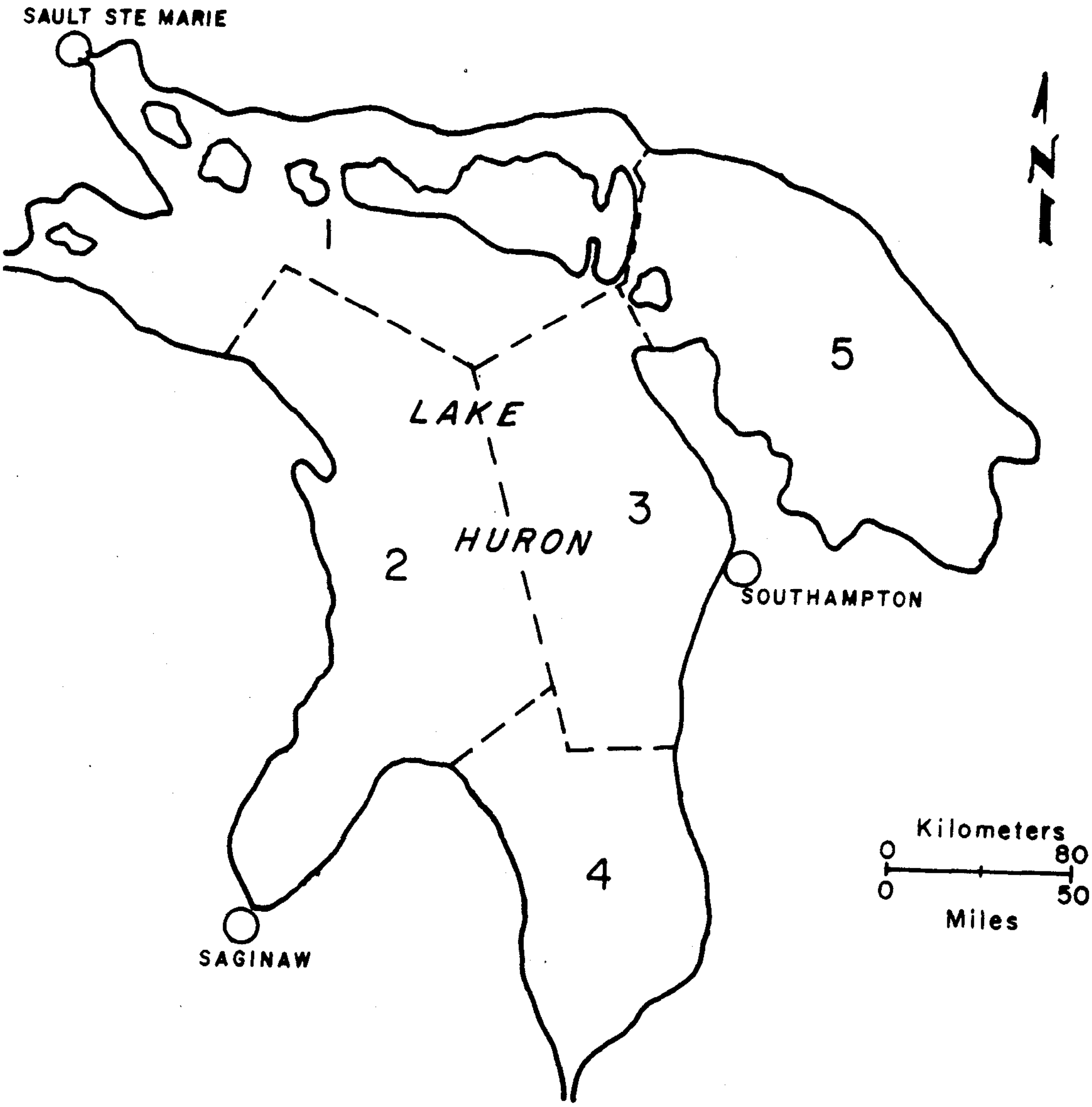


Figure D-3. Lake Huron, showing five lake management units in which to assess sea lamprey populations, as proposed by the Lake Huron Group.



APPENDIX D-I

WORKSHOP ORGANIZATION AND ATTENDANCE

STEERING COMMITTEE:

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LAKE ONTARIO GROUP:

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SUPPORT STAFF:

B. Berndt, M. F. Fodale, A. M. Little, and B. J. McEachern

[1]**Chairman,** [2]Vice-Chairman

APPENDIX D-II

RESULTS OF THE THREE POLLS IN WHICH PARTICIPANTS VOTED ON THE PRIORITY OF **THE** ASSESSMENT PROPOSALS

The number before each proposal in the three polls indicates the rank on overall preference, practicality, and cost.

POLL ONE

The 14 proposals (4 for spawning, 6 for parasitic, and 4 for larval) are listed as direct quotes as they were originally submitted by the life phase groups.

1. The measurement of annual changes in the relative abundance of spawning phase sea lampreys at index rivers.

2. Estimating absolute numbers of spawning phase sea lampreys in index rivers and transforming the estimates into lakewide estimates.

3. Estimate production of transformed sea lampreys from larval populations in streams tributary to a lake basin, Lake Superior used. as an example.

4. Use of lamprey wounding as an index of relative abundance of parasitic phase sea lampreys.

5. Abundance of parasitic phase sea lampreys as determined by lampreys collected from sport fishermen.

6. Mark and recapture study for population estimates of parasitic phase sea lampreys.

7. Use of the removal method *to* estimate populations of larval and transforming sea lampreys.

8. The absolute estimate of a population of spawning phase sea lampreys based on the mass release of marked lampreys into open lake waters.

9. Efficiency of control agent evaluation of' sea lamprey ammocoete populations.

10. Examination of lampricide treatments and subsequent effects on lamprey wounding of lake trout for determination of origins and movements of parasitic phase sea lampreys.

11. The use of sea lamprey statolith composition to determine stream of origin (parasitic phase).

12. The measurement of annual changes in the biological characteristics of spawning phase sea lampreys.

13. Commercial large-mesh trap nets used to determine abundance of parasitic sea lampreys.

14. Combined ammocoete and spawning adult assessment program.

POLL TWO

Voting was held after presentation, discussion, and changes in the original proposals (2 for spawning were combined, 1 added for parasitic, and the 4 were combined for larval). Revised assessment proposals included 3 for spawning, 7 for parasitic, and 1 for larval in the second poll.'

1. Estimating absolute numbers of spawning phase sea lampreys in index rivers and transforming the estimates into lakewide estimates.

2. Mark and recapture study for population estimates of parasitic phase sea lampreys.

3. The measurement of annual changes in the relative abundance and biological characteristics of spawning phase sea lampreys at index rivers.

4. Integrated use of gill nets, trawls, and remote sensing to estimate the impact of parasitic phase sea lampreys on the Lake Ontario lake trout population.

5. Estimate production of transformed sea lampreys from larval populations in streams tributary to a lake basin.

6. The absolute estimate of a population of sea lampreys based on the mark and release of transformed larvae and recapture as spawning adults, Lake Erie as the primary example. Sea lampreys marked as spawning adults and recaptured as spawners in areas where the sterile male technique is used.

7. Estimation of relative abundance of parasitic sea lampreys from lake trout assessment data.

8. Abundance of parasitic phase sea lampreys as determined by lampreys collected from sport fishermen.

9. Examination of lampricide treatments and subsequent effects on lamprey wounding of lake trout for determination of origins and movements of parasitic sea lampreys.

10. Commercial large-mesh trap nets to determine abundance of parasitic phase sea lampreys.

11. The use of sea lamprey statolith composition to determine stream of origin (parasitic phase).

POLL THREE

Voting was held at the end of the workshop after proposals listed on the second ballot had been revised or deleted (2 for parasitic) following the lake group reports. Final assessment proposals included 3 for spawning, 5 for parasitic, and 1 for larval in the third poll.

1. Estimating absolute numbers of spawning phase sea lampreys in index rivers and transforming the estimates into lakewide estimates.

2. To estimate production of transformed sea lampreys from larval populations in streams tributary to a lake basin.

3. The absolute estimate of a population of sea lampreys based on the mark and release of transformed larvae and recapture as spawning adults, Lake Erie as the primary example. Sea lampreys marked as spawning adults and recaptured as spawners in areas where the sterile male technique is used.

4. The measurement of annual changes in the relative abundance and biological characteristics of spawning phase sea lampreys at index rivers.

5. Mark and recapture study for population estimates of parasitic phase sea lampreys.

6. Integrated use of gill nets, trawls, and remote sensing to estimate the impact of sea lampreys on the Lake Ontario lake trout population.

7. Estimation of relative abundance of parasitic sea lampreys from lake trout assessment data.

8. Abundance of parasitic phase sea lampreys as determined by lampreys collected from sport fishermen.

9. Commercial large-mesh trap nets to determine abundance of parasitic phase sea lampreys.

SECTION E

REFERENCES AND ACKNOWLEDGEMENTS OF THE

WORKSHOP TO EVALUATE SEA LAMPREY POPULATIONS (WESLP) IN THE

GREAT LAKES, AUGUST 1985

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