RECOMMENDATIONS FOR STANDARDIZING THE REPORTING OF SEA LAMPREY MARKING DATA

A Report from the Ad Hoc Committee

by

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Committee to Recommend Standards for Reporting Sea Lamprey Marks

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INTRODUCTION

Beginning in the late 1940s, when fishery agencies on the upper Great Lakes first participated in institutional arrangements to deal with the sea lamprey problem, and continuing to the present, the interpretation of sea lamprey marking data has been confounded by a lack of consistent reporting criteria among agencies and lakes. Healed (scars) and fresh (open) sea lamprey marks were recognized on lake trout in the early reports of the Sea Lamprey Committee (late 1940s), the Great Lakes Fishery Committee (early 1950s), and the Lake Trout Committee (1940s), but marking data were expressed in a variety of ways and a universal standard for distinguishing wounds from scars and for computing marking rates was never adopted by any of these precursors of the Great Lakes Fishery Commission.

The Fishery Commission eventually emerged as the only coordinating institution with a major concern for lake trout-sea lamprey interactions, and as lake trout populations were reestablished in each Great Lake, the requirement within the Commission for a consistent protocol for reporting marking data became more apparent. However, it was recognized that before standardized reporting criteria could be adopted, a system of classifying the various stages of sea lamprey attack marks on lake trout was needed. Because of this need, the Fishery Commission sponsored research during 1976-78 which led to the printing of Great Lakes Fishery Commission Special Publication 79-1 (King and Edsall 1979), "Illustrated Field Guide for the Classification of Sea Lamprey Attack Marks on Great Lakes Lake Trout."

The field guide proposed a more detailed system of classifying sea lamprey attack marks than was formerly used, and shortly after the guide was distributed, fishery workers on the Great Lakes asked the Fishery Commission to establish uniform reporting criteria based on the guide. In 1980 the Fishery Commission formed a marking standardization committee charged with developing recommendations for standardizing the reporting of sea lamprey marking data. This committee, composed of a representative from each Great Lake (appointed by the lake committee chairmen), the authors of Special Publication 79-1, and the commission secretariat staff, held two meetings, sponsored several related projects, and submitted recommendations to the Fishery Commission in July 1982; these recommendations were subsequently adopted by the Commission in May 1983. The present paper is intended to serve as a reference document for the committee's work.

OBJECTIVES FOR RECORDING AND REPORTING SEA LAMPREY MARKS

Ambiguities in observed changes in sea lamprey marking rates have at times perplexed the most ardent of field biologists, and this problem has occasionally prompted some individuals to question the utility of maintaining any protocol within the Fishery Commission for reporting marking data. However, it is difficult to dispute the value of marking information, and well known instances can be cited for several Great Lakes species where fluctuations in marking rates were associated with changes in lamprey numbers or in prey fish abundance: lake trout (Fry 1953, Pycha 1980, Moore and Lychwick 1980); whitefish (Spangler and Collins 1980, Christie and Kolenosky 1980); white sucker (Coble 1967); and rainbow trout (Berst and Wainio 1967). Therefore, the committee recognized that marking data were very useful and that a standardized approach to reporting could enhance this information even more.

Four objectives for collecting and reporting sea lamprey marking data were identified by the committee as follows:

- provide assistance to sea lamprey control units in locating sea lamprey infestation sources not adequately controlled
- provide indicies of lamprey abundance and effectiveness of control both within and between lakes
- provide measures of the effects of lamprey predation on host species
- provide additional research needs

The significance of these objectives has changed over time and has also varied within institutions. The first objective, locating infestation sources, could be considered part of the second objective, measuring differences within lakes, but the two objectives were separated because data requirements were less stringent with the first. Within lake evaluation requires data compatibility, but this restriction is not implicit in the first objective, because intensive activity of recently transformed sea lamprey could be noteworthy even though the data were geographically isolated. The committee did recognize the difficultly in attempting to associate marking data with sea lamprey recruiting from a specific natal stream, and cautioned that observations of unusually high marking rates caused by recently transformed lampreys could at best indicate a regional problem, requiring surveys of streams over a broad area.

The second objective, providing sea lamprey abundance indicies and measures of the effectiveness of sea lamprey control, is becoming increasingly important as the Fishery Commission moves toward a concept of integrated pest management (Sawyer 1980). Policy development in the future will likely emphasize economic optimization of the control program, and this change will require extensive information on sea lamprey numbers and on their effects on fish stocks (objective 3).

Because most marking data are collected ancillary to other fish stock assessment studies and thus are inexpensive to obtain, the last objective, providing for undetermined research needs, acknowledges a practice where fishery agencies may collect and store more comprehensive data than are of immediate use.

DATA COLLECTION

Host Species

Field biologists employ various host species including lake trout, other trout, salmon, chubs, and whitefish in assessing sea lamprey activity, and in some instances different host species are used in the same lake. In Lakes Superior and Michigan and in Michigan's waters of Lake Huron, lake trout are the primary host species. Whitefish and chubs are primary host species in Ontario's waters of Lake Huron, but in the lower lakes salmon, rainbow trout, brown trout, and lake trout in that order, are considered to be most important. The utility of various host species for meeting the committee's objectives for reporting marking data is summarized in Table 1.

Table 1. 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.

Species	Superior	Michigan	Lake Huron MI	Lake Huron ONT	Erie	Ontario
Lake trout	a, b, c	a, b, c	a, b, c	b	b	a, b, c
Whitefish	-	b	b	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	-	-	-	-	-	-

Of the host species in Table 1, lake trout are most commonly used for assessing trends in lamprey abundance, and the committee recommends that this species be acknowledged as the primary reference species. However, in the lower lakes the data base is not fully developed because the stocking program is too new to expect a meaningful time series for the larger size groups of lake trout. Also, in Ontario's waters of Lake Huron, marking samples are taken from commercial catches, and the ministry is attempting to discourage catches of lake trout (in Georgian Bay a lake trout x brook trout hybrid is stocked as a substitute for lake trout). In addition, stocking of hybrids is concentrated in selected areas so that this fish is limited in distribution. Therefore, some deviation from the use of lake trout as the primary host species for reporting sea lamprey marks is expected on an interim basis.

Coho salmon, because they are vulnerable to lamprey attack for only a single year in their life cycle, were identified as having special advantages in determining marks-of-the-year. However, salmon generally have limitations as a host species used for assessing within lake differences in marking, because anadromous fish undergo widespread migrations and it is difficult to establish where marked fish encountered sea lampreys. Anadromous species exposed to more than 1 year of lamprey predation negate the mark-of-the-year concept.

Suckers have potential as a universal host species, but collections, which would satisfy the objectives for reporting marks, are not available. An expended sampling program would be required if suckers were utilized to measure sea lamprey marking rates, and data would still have to be collected on lake trout to measure the effects of lamprey predation on this important species.

Seasons

Although it would be ideal to have collections of the same host species taken at comparable times when making between lake comparisons of marking rates, such a goal did not appear to be practical. For instance, the best correlation between marking and lamprey spawning runs was reported for spring marking data on Lake Superior, but lake trout are generally not available to assessment nets in the spring in some other lakes such as Lake Michigan. The lamprey life cycle may not be synchronized by month in each lake, and accordingly a single best season may not exist for the Great Lakes basin. However, a uniform season for data collection in each lake or basin within each lake, such as in Georgian Bay, would be a desirable goal and is recommended as a practice by the committee. Uniform reporting is presently under way in Lake Michigan where lamprey marking data on lake trout are being collected in the fall by all agencies.

The committee discouraged summer collections of lake trout marking information, because parasitic-phase lamprey are undergoing their greatest growth then and small year-to-year differences in the seasonal progression of growth could have a great impact on host survival and bias the marking statistic. Water temperature directly influences host mortality, and fall and spring water temperatures would be expected to be more consistent year to year than would summer temperatures. Movement of the thermocline in summer also complicates assessment of lake trout abundance, and some measure of host density would be needed to evaluate the significance of any changes in marking rate.

Recommendations for standardizing the season of collection within each lake or major basin could best be made by the lake technical committees where the expertise is available to choose the optimum.

Depth/Temperature

If season and host species standards were established by technical committees for each of the lakes, the committee believed that depth/temperature criteria would be unnecessary.

Collecting Gear

Some committee members expressed reservations about the comparability of marking rates estimated from net and angler catches. However, in New York waters of Lake Ontario sea lamprey marking rates on brown trout were similar regardless of whether the samples were collected in assessment gill nets or by hook and line. These data (given below) address a hypothesis that a recent lamprey attack may alter a fish's vulnerability to angling and hence distort marking rate comparisons that employ a mixture of angling and assessment samples.

Method of capture	Sample size	Marking rate (%)
Assessment gill net	282	26.6
Hook and line	969	29.9

Mark Staging

A review of agency sea lamprey marking nomenclatures on lake trout suggested that most "fresh wound" classifications correspond to stage AI of Special Publication 79-1, but the "fresh" classification may also include early stage AII marks. An exception to this practice occurs in the U.S. waters of Lake Superior where fresh corresponds to stages AI and AII combined. However, it was noted that in Lake Michigan where marking rates are relatively low, combining AII marks with AI marks would cause little change in interpretation of marking rates.

After considering several alternatives, the committee favored a concept of utilizing marks-of-the-year, which roughly approximates mark stages AI through AIII. This approach has merit in that it combines marks now considered old and not reportable with newer marks inflicted by the same parasitic-phase year-class of lamprey. The present practice of labeling stage AIII marks as old excludes them from marking reports. This exclusion is done in part to avoid having marks inflicted by more than one parasitic year-class in the same marking statistic. However, most large AIII marks would likely result from the same parasitic-phase year-class as would large AI and AII marks, and therefore inclusion would probably not bias the statistic as a measure of lamprey year-class strength. Because marking rates based on a marks-of-the-year statistic would be higher than a rate based on stages AI and II, fewer samples would be required for tests of statistical significance.

The degree of consistency that different observers could sort between stage AIII and AIV marks was a major issue for the committee. Adoption of a mark-of-the-year standard would only be practical if field technicians and biologists could accurately separate stage I, II, and III marks from stage IV. Before recommending a mark-of-the-year practice, the committee believed that it would be important to have measures of the variations in mark stage identification among observers. Consequently, the committee recommended that during 1981, field personnel stage sea lamprey marks on lake trout using Special Publication 79-1. This effort would familiarize field biologists with mark staging as described in the guide, encourage informed comment on the committee's final recommendations, and provide experience to a pool of observers needed for an experiment in mark identification. Mark staging variability would be determined by having experienced staff stage a reference collection of lake trout. The committee supplied a data form to the agencies for recording mark types, stages, and sizes during the 1981 field season, and conducted the stage identification experiment in October 1981.

Results of the staging experiment are given in Table 2, and although these data are limited, it was apparent that field classification of mark types and stages was not precise. Type B marks were frequently classified as Type A; stage IV marks were often missed; and Type A, stage II and III marks were commonly misclassified as being of the next older stage. However, Type A, stage II and III marks were generally distinguishable from Type B marks, and stage IV marks were not confused with newer stages. Improvements in field classifications may require some training of field crews.

The committee decided that it would not specify the degree of detail to which agencies should record marking data. Rather, it would recommend reporting standards based on a mark-of-the-year concept, and recognize that agencies may collect more detailed data than is routinely reported.

Mark Sizes

The committee agreed that it would be important to separate small (≤ 20 mm) marks from larger marks (≥ 30 mm) on lake trout collected during December-May. At this time lake trout are vulnerable to two parasitic-phase year-classes of sea lamprey, and the younger year-class, although actively feeding, would probably not significantly affect lake trout mortality. The alternative approach, lumping small marks with large marks, tends to inflate the spring marking rate and distort the relation between marking rate and mortality. Failure to separate large and small marks also confounds assessment of year-class strengths for parasitic-phase lampreys.

A problem in using the criteria in the field guide for separating small marks from large marks was noted for Lake Ontario. Some 19% of all lamprey marks observed on brown trout off the port of Sodus in spring 1981 were of intermediate size (23-27 mm diameter), whereas the field guide notes that small marks should be less than 20 mm and large marks greater than 30 mm during the spring. The committee recognized that size of recent transformed lampreys and their marks would vary with each lake, and that each lake technical committee would be obligated to determine a demarcation point between the two size categories in spring samples. Few (less that 2%) lamprey of spawning size in Lake Ontario would leave a mark smaller than 30 mm in diameter, and therefore little error would occur in raising the demarcation point to as high as 27 mm in this lake.

Table 2. Frequency distribution of observer identifications of sea lamprey marks on lake trout and whitefish in relation to reference stages given in Special Publication 79-1.

		Observer identification frequencies															
		Large mark								Small mark							
		Type A				Type B				Type A				Type B			
Reference type/stage[1]	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						
III	20			.35	.40		.05	.05				.15					
IV	70				.36			.14	.19				.01				
Type B																	
stage II	20			.15	.10	.10	.25	.10							.10		
stage IV	30				.33		.03	.07	.23								.03
Whitefish																	
Type A																	
stage II	10	.20	.80														
III	10		.10	.20	.20		.10	.30	.10								
IV	10			.30	.40		.10		.10								
Type B																	
stage III	30		.03		.20	.03	.07	.23	.20								
IV	10				.10			.10	.40								

[1]All reference marks were large.

The committee questioned whether data on the geographical distribution of small marks could be used to precisely identifiy sea lamprey infestation sources (natal streams). Experience in Wisconsin waters of Lake Michigan and New York waters of Lake Ontario suggested that recently transformed sea lampreys could be widely dispersed from their natal streams during the spring, and consequently it would be difficult to pinpoint these streams with marking data.

DATA REPORTING

Host Size Ranges

The current practice of reporting lake trout marking rates in 4-inch length invervals beginning at 21.0 inches was considered to be a reasonable approach and the committee recommended its continuation. Ontario marking data based on fork lengths should be reported after conversion to total lengths or in fork length size classes equivalent to the reference total length intervals.

Marking data for species other than lake trout, and considered to be of special relevance, should be reported to the Fishery Commission, but this information should not displace the lake trout requirements and it should be given in appendicies to the annual marking report. Size ranges for species other than lake trout have not been established.

Staging/Mark Sizes

Recognizing that reporting standards must balance contrasting needs for detail and generalization, the committee recommended that agencies report marking rates based on summations of large, Type A, stage I, II, and III marks. The rationale for this recommendation is that a statistic based on a larger number enhances the detection of change in trend over time information and that this statistic approximates a mark-of-the-year, which is useful in predator-prey models. Further, Type B marks likely measure sea lamprey resting rather than feeding activity, and their inclusion in marking rate estimates could distort the relation between marking and host mortality. Type B marks would not, therefore, be reported. Likewise, small marks would also be excluded in marking rate reports based on spring samples, because their frequency of occurrence is not indicative of host mortality at the time of collection, and inclusion would result in a lumping of marks from two year-classes of lamprey. Marking frequencies for small marks could, however, be provided as supplementary information in marking reports.

The above recommendation greatly reduces the reporting options consisting of two types, four stages, and two sizes of marks as detailed in the field guide to a single statistic. This is not intended to discourage collection of more detailed data, which may have great value. As noted above, agencies commonly collect information in much greater detail than is routinely reported, and this practice is encouraged.

Multiple Marks

Traditionally, marking rates have been reported as number of marks per 100 fish or percentage of fish marked. The committee agreed that marks per 100 fish was a better choice. This choice for a standardized statistic for marking rates was motivated, in part, by a need to account for multiple marks-of-the-year on a single fish. For higher marking rates, there was some concern about loss of information if only percent marked was reported. Subsequent study showed that marks per 100 fish was a basic statistic of a multiple mark model and was directly proportional to attack rates of sea lamprey. The following argument, therefore, summarizes the reasons for preferring marks per 100 fish as a standard reporting statistic.

The basic purpose of collecting data on marking rates is to estimate sea lamprey attack rates and subsequently mortality rates of lake trout. If an attack by a sea lamprey has some likelihood of causing mortality, marking rates that are estimated from samples of living fish will always be lower than the actual attack rates. Approaching similar problems in host-parasite interactions, it seems best to estimate the probability that an animal is not attacked (Smith 1968):

$$q = 1 - a/V$$

where a is the effective search area of the parasite and V is the area (or volume) in which the host occurs with the parasite. If N parasites are searching independently, the probability that any single host is not parasitized is

$$q = (1-a/V)(1-a/V)(1-a/V)...(1-a/V),$$

or

$$q = (1-a/V)^N.$$

This equation is a binomial and, when expanded, will yield not only the probability that a host was not attacked, but also the probability that it was attacked once, twice, three times, and so on.

If the probability of attack, a/V, is small and the number of parasites, N, is large, the binomial may be approximated with a Poisson. The distribution of attacks per host would then be

$$q(i) = (A^i)\exp(-A)/(i!),$$

where A is the average number of attacks per host occurring in some short time and i is the category of number of attacks per host. The probability that a host is not attacked is

$$q(0) = \exp(-A).$$

In deriving this model, two key assumptions are required: 1) the probability of a parasite attack must be independent of any other attack; and 2) the time period for observation must be short enough to ensure that the probability of attack is small. By a similar argument, it is easy to show that marking frequencies should also have a Poisson distribution.

The Poisson mark frequency model may be tested in two ways. The first procedure is a chi-square goodness-of-fit test, and the second is a heterogeneity test based on the expected equality of mean and variance of any random variable having a Poisson distribution. Two data sets were used to test this model: attack distributions from experiments on white suckers by Farmer and Beamish (1973) and lake trout marking data collected in 1981 from Cayuga Lake, New York. For the white sucker data, the experimental protocol of eight suckers with eight lampreys yields a theoretical attack probability of 0.125. Such a high attack probability may be in violation of assumption 2 above, but as indicated in Table 3, the Poisson distribution for these data cannot be rejected. The lake trout marking data in Table 3 also cannot be shown to be different from Poisson, especially when considering the more sensitive heterogeneity test. Given these results, therefore, the use of a Poisson model for multiple marks or attacks appears to be the best choice.

Table 3 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.

Data source	OBSERVED MARKS PER FISH 0	1	2	3	4	Mean	STATISTICS Chi-square	Heterogeneity
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 ($p > .05$)	392 ($p > .1$)
A1-A3	798	235	37	7	-	0.31	2.99 ($p > .1$)	1126 ($p > .1$)

Extending this analysis to a derivation of a relation between attack and marking rates requires some information on the probability of survival of attacks, an area of some uncertainty (Walters et al. 1980). Based on the results of the Salmonid/Lamprey Workshop (Koonce et al. 1982), however, two assumptions appear reasonable in the context of marking rates in the Great Lakes: (1) the probability of survival of an attack is independent of previous attacks; and (2) the probability of survival increases with the ratio of lake trout size to lamprey size. With these assumptions and the frequency distribution of attacks given a mean number of attacks per host, the survival probability for a specific size of host is

$$s = \exp(-A) + p*A*\exp(-A) + (p*A)^2*\exp(-A)/2 + \ldots$$

which is rewritten as

$$s = \exp(-A)*\exp(p*A), \text{ or}$$
$$s = \exp(-A*(1-p)), \qquad (1)$$

where A is the average number of attacks per host and p is the probability of surviving an attack. The relation between marking rate and attack rate follows directly by calculating the frequency of unmarked hosts from the frequency of unattacked hosts weighted for their differential survival over the attack period:

$$\exp(-M) = \exp(-A)/s,$$

or

$$M = Ap. \qquad (2)$$

Because equation 2 is linear, marking rates increase in proportion to attack rates. The slope, however, is a function of the probability of surviving a single attack. From equation 1, instantaneous mortality due to lamprey predation is also proportional to attack rates and to marking rates:

$$Z_L = A(1-p), \text{ and}$$
$$Z_L = M(1-p)/p.$$

In contrast, percent of fish marked has a non-linear relationship to lamprey mortality:

$$Z_L = (\log(1-P_M))(p-1)/p, \text{ and}$$
$$P_M = 1 - \exp(-M)$$

The consequences of these differences is illustrated in **Fig.** 1 for two levels of p. Therefore, not only is a marking statistic based on mark Per 100 **fish** the parameter of the multiple mark model, but it also requires no **transformation** to estimate a relation between lamprey induced mortality and marking **rates (cf. Pycha 1980).**

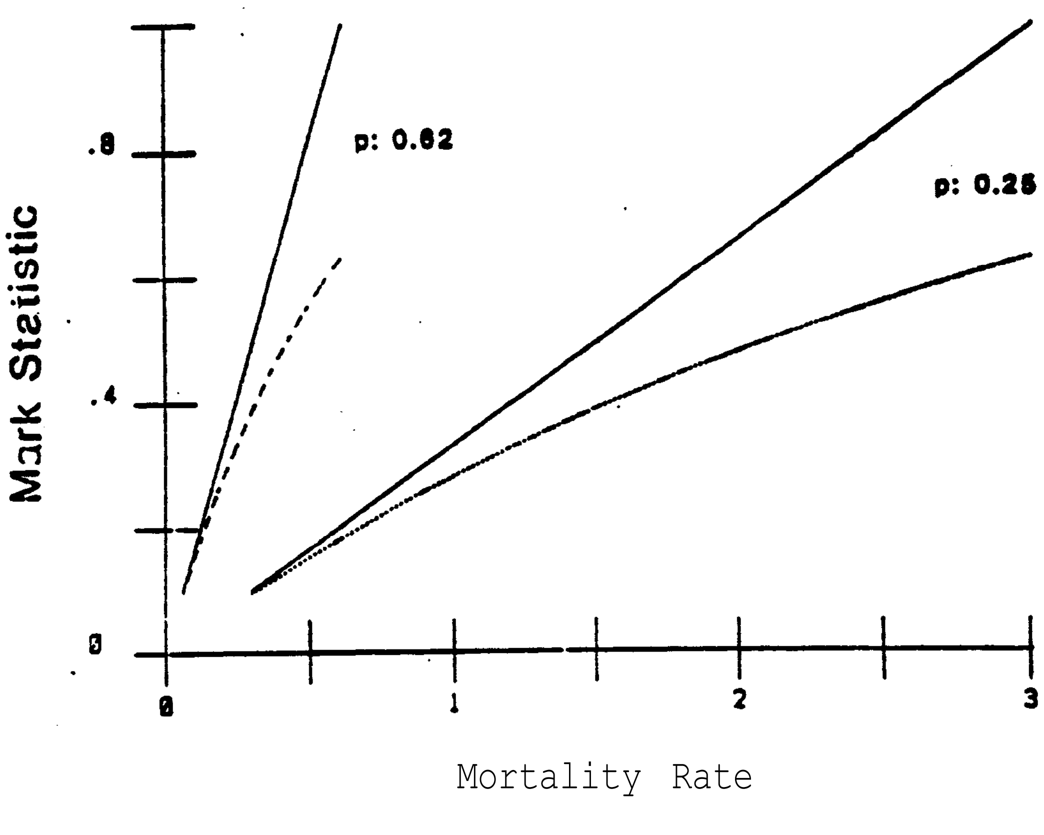

Fig. 1 Mark statistics for mortality due to lamprey attacks **versus** different reporting statistics (marks per *fish*, solid **line;** fraction of fish marked, broken lines). Probability *of* survival of a single attack was either 0.25 (upper solid and dashed lines) or 0.62 (lower solid and dotted lines).

Statistical Evaluation

Two issues dominate the concern about the reliability of marking rate data. The first relates to the number of lake trout required to detect changes in marking rate. The second is a more general question about the relation between marking rate and various lake trout assessment statistics (i.e., reference catch per unit effort, mean size of reference catch, etc.). The sample size question does not appear to be a serious problem. Major changes in mortality due to sea lamprey attacks can be detected with observations of fewer than 100 fish. Detecting the fundamental relation between marking rates and other lake trout assessment statistics, however, is much more complex.

In statistical terms, estimation of a sample size necessary to detect a specified difference in marking rate requires explicit consideration of both type I and type II errors. Steele and Torrie (1960) recommended the following general formula for sample size where true variance is unknown:

$$n = 2(t_0 + t_1)^2 S^2/d_2, \qquad (3)$$

where t_0 and t_1 are Student-t values for type type I and type II errors respectively, s^2 is the estimated variance, and d is the difference in means. Assuming marking rates are Poisson distributed, some modification of equation 3 is required. For Poisson distributed random variables, mean and variance are equal. If one assumes that

$$d = M_C - M_t,$$

where M_c is the observed marking rate and M_t is the marking rate for a specified difference from M_c, then equation 3 becomes:

$$n = \left((Z_0 sqr(2M_c) + Z_1 sqr(M_c+M_t))/M_t-M_c)\right)^2, \qquad (4)$$

where we assume, substituting standard normal Z variables for Student-t variables, that Z_0 is 1.96 (alpha/2 = 0.025) and Z_1 is 1.64 (beta = .05).

The sample size required to detect a specified change is clearly a function of the observed marking rate. For example, about 300 fish must be sampled to detect a 0.05 fixed change from an observed marking rate of 0.03 (new marking rate = 0.08), but almost 10 times more fish must be sampled to detect the same difference from an observed marking rate of 0.4 mark per fish (Fig. 2). Fixed differences in marking rate or percent changes in marking rate, therefore, have limited utility. A firmer basis for developing expectations about sample size would be to specify a detectable difference in survival rate. Combining equations 1 and 4, a decrease in survival of 0.05 can be detected with fewer than 200 fish if the marking rate were initially low and the probability of surviving an attack is about 0.62 (Fig. 3). For higher marking rates, larger sample sizes are necessary to detect the same percent change in survival, but in general sample sizes of about 100 or less seem adequate to detect a 0.20 decrease in survival. Sample size, therefore, does not seem to be an impediment to collection of informative marking rate data.

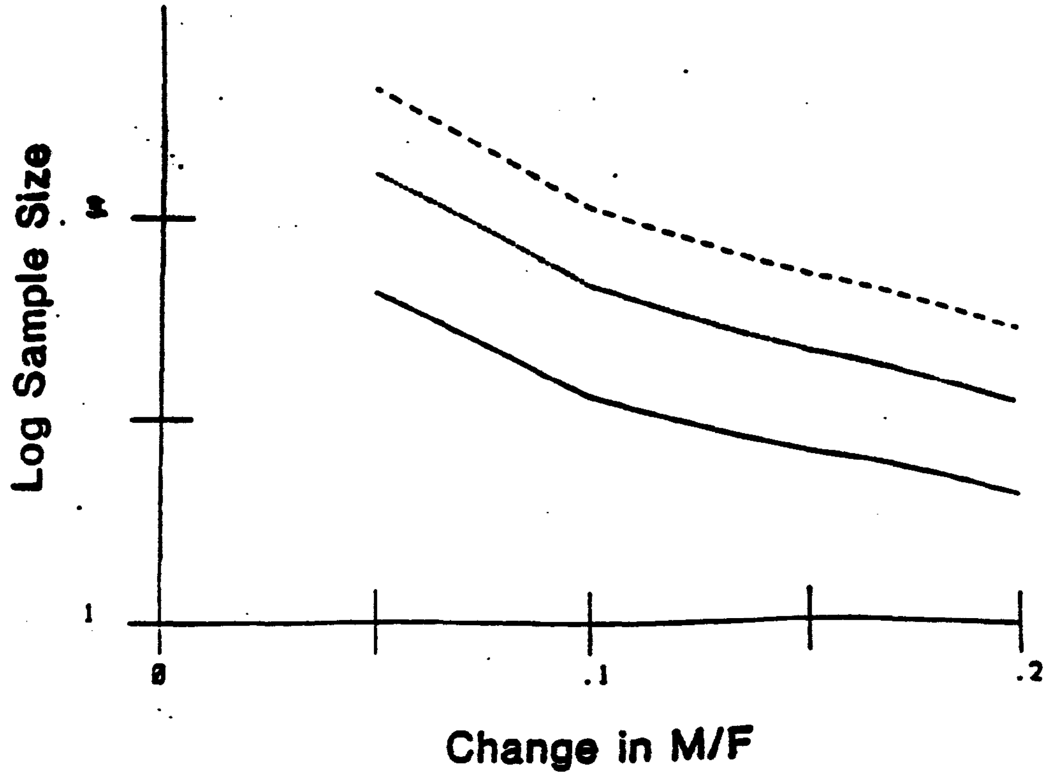

Fig. 2 Sample sizes required to detect various fixed changes in observed marking rates. The solid line is for an observed marking rate of 0.03, dotted line for 0.15, and dashed line for 0.40 mark per fish.

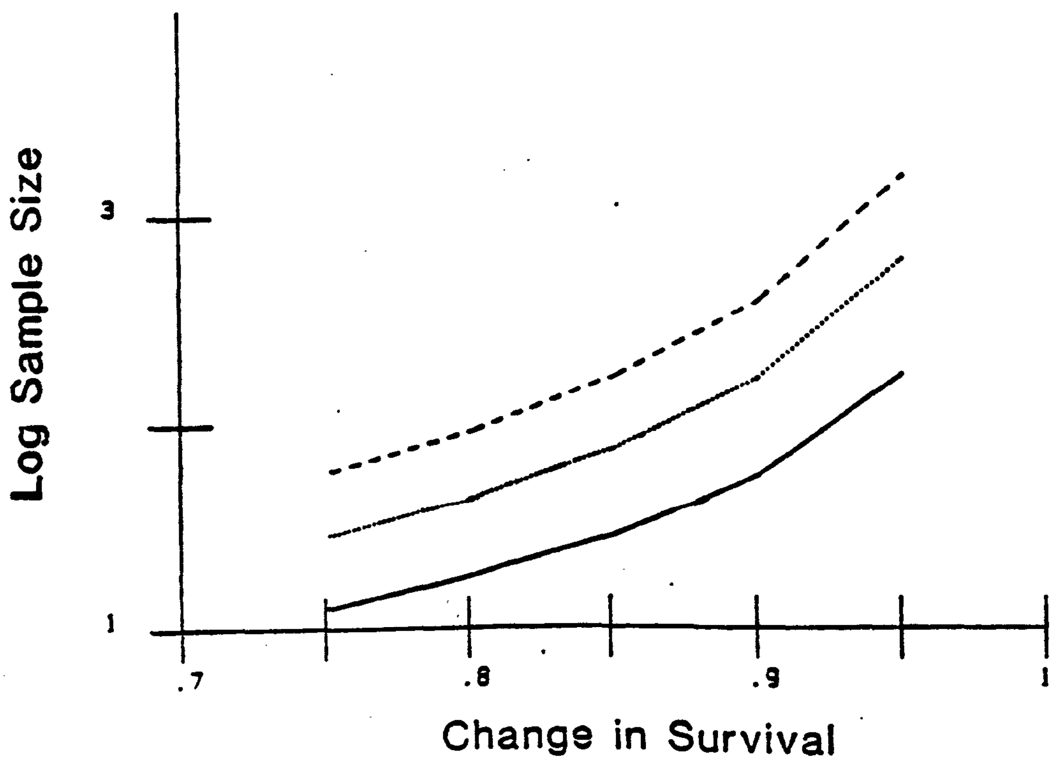

Fig. 3 Sample sizes required to detect various fractional changes in survival for three observed marking rates (0.03, solid line; 0.15, dotted line; and 0.40 dashed line). The assumed probability of surviving an attack was 0.62.

Intuitively, marking rates should be directly proportional to other assessment statistics for lake trout. The relation derived above for the marking statistics, however, were for specific sized lake trout. In a population, age structure ensures variablity in marking rates if sea lamprey are size selective, or if there is size selective variability in survival from lamprey attacks. Lake trout assessment statistics commonly include catch per unit effort in reference gear and mean length of fish in the assessment catch. To explore the relation between marking rates and these statistics, we developed a steady-state version of the Salmonid/Lamprey Model (Koonce et al. 1982; Appendix I). The relation between reference length and marking rate (Fig. 4) is representative of the pattern of both statistics. Although a general negative correlation exists between marking rate and mean reference size, fishing mortality variation can cause substantial change in the relation. It must be emphasized that Fig. 4 is based on a steady-state model. If there is substantial variability in hisory of exploitation, it might be impossible to detect a relation between marking rates and other assessment statistics. Of course, this possibility does not negate a fundamental relation between marking rates and other assessment statistics, but it does suggest that observation of these relations may not always be possible.

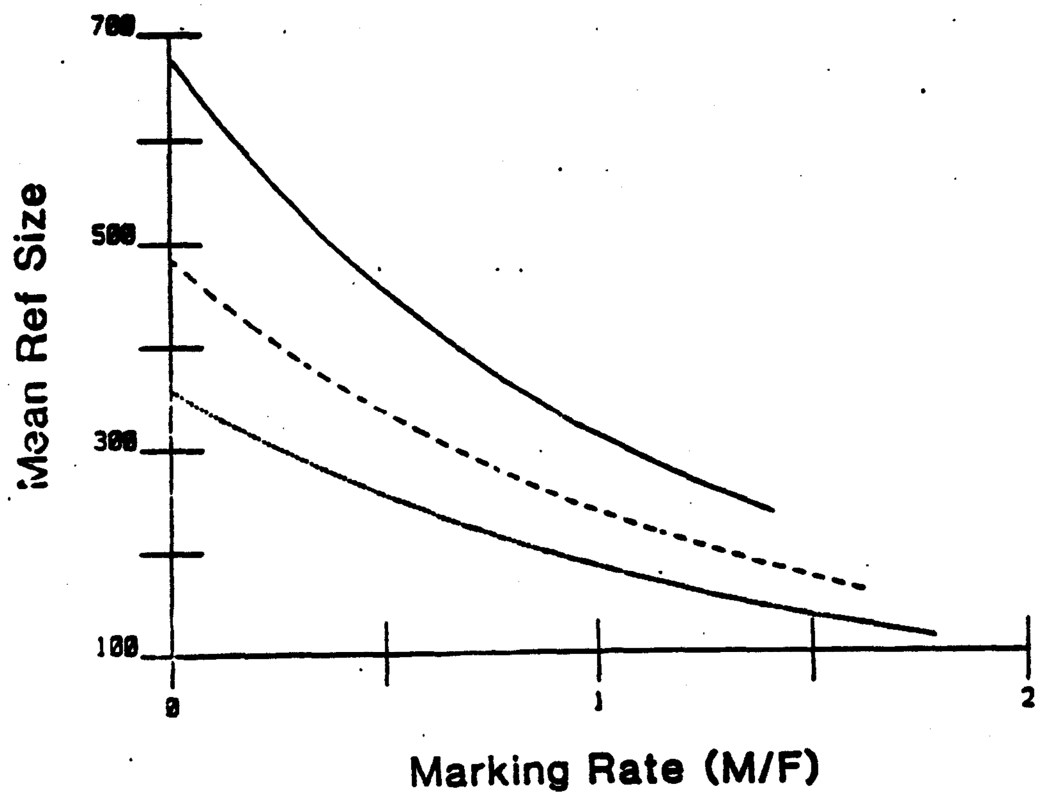

Fig. 4 Effects of various levels of fishing mortality (0.3 yr^{-1}, solid line; 0.5 yr^{-1}, dashed line; and 0.7 yr^{-1}, dotted line) on the relation between mean reference size and marking rate. Mean reference size is the difference between average length of lake trout in the reference catch and the length of 5-yr old lake trout.

Predator-Prey

The committee recognized that marking data do not provide measures of sea lamprey abundance without some accounting of prey availability. Thus, reporters should discuss marking rates in relation to prey stock abundance. Several approaches to this problem for lake trout are evident. In situations where the abundance and size distribution of lake trout stocks are relatively stable, marking data can be presented in a time series without adjustment. Alternatively, changes in abundance within the reference size classes, as detected in assessment or commercial sampling, can be used as a basis to adjust marking rates. If direct adjustment of the marking rates is not desirable because of imprecise estimates of prey abundance, then best estimates of prey availability derived from stocking rates or assessment data should be provided as supplemental information to the marking rates.

CRITIQUES

Before being submitted to the Fishery Commission, the recommendations of the marking standardization committee were critiqued by Great Lakes fishery biologists who routinely collect or report sea lamprey marking data, and pertinent comments from these critiques are discussed here. Most criticisms were directed at emphasis rather than the substance of certain recommendations. In this regard a number of reviewers thought that information on small marks, Type B marks, stage IV marks, and marks on species other than lake trout should be given more attention in marking reports. In contrast, the committee recommended appended status for this information. However, it was not the committee's intention to discourage analysis of appended marking information, which may at times provide valuable insights. Rather, the committee believed that if marking reports were to be easily comprehended from a Great Lakes basinwide standpoint, they would have to center on the most fundamental concerns. The committee believed that these concerns relate primarily to sea lamprey induced mortality on large lake trout and that the most universal measure of this mortality is the large, Type A mark, which was given primary emphasis in the committee's recommendations.

One reviewer suggested separating the marking rates for hatchery origin and wild lake trout, because the marking rates for each group can differ in catches taken from the same area. This suggestion is noteworthy, but until such time as naturally produced lake trout are readily available from lakes other than Superior, and until the phenomenon is understood, it is recommended that this type of analysis be given appended status in marking reports.

Another reviewer indicated a preference for smaller, even-metric length intervals in contrast to the traditional, English reference size classes of lake trout recommended by the committee. The committee avoided suggesting changes in marking protocols where the existing approach was clearly standardized and reasonable, and opted for continuing with the traditional reference size classes.

Lastly, it was recommended that marking rates be quantified by the coefficients obtained from regressions of marking on fish length. This suggestion may have merit, but its utility would have to be more firmly established before it could be adopted. It may be noteworthy that a similar proposal was discussed at a meeting of the Lake Superior Committee (Great Lakes Fishery Commission 1970). Marking rates for lake trout 22 inches long were determined from regressions of marking on fish length, and this rate for a standardized length was used as a basis for assessing lamprey activity. However, after several years this practice was discontinued.

The standardization committee was very appreciative of the critiques received from the reviewers. Lamprey-host fish interactions are poorly understood and this deficiency makes a number of the committee's recommendations somewhat arbritrary and subject to debate. We recognize that the recommendations will likely be revised as knowledge is acquired.

SUMMARY OF RECOMMENDATIONS[1]

Based on the above discussion the marking standardization committee recommends that

- reports on sea lamprey marking rates be standardized among all agencies collecting data from the same lake or major basin (such as Georgian Bay) within a lake. Standardization across all lakes, although desirable, is not seen to be practical because of constraints in agency sampling programs. Lake committees are requested to provide, annually, an integrated marking report for each lake.
- lake trout be regarded as the primary host species for purposes of reporting sea lamprey attack marks. Rates should be reported for reference size classes of lake trout at 4-inch intervals, beginning at 21.0 inches total length.
- marking data for each lake be reported for either spring or fall collections of lake trout. If data can be collected in either season, fall data are favored because recent marks at that time are associated with only one parasitic-phase year-class of sea lamprey (spring marks may also be caused by recently transformed lampreys).
- a reportable mark include any Type A lesion in stages I-III of healing as illustrated in Special Publication 79-1.
- small sea lamprey marks of the type inflicted by recent transformers not be included in spring marking rate estimates.
- marking rates be reported as the number of wounds per 100 fish from the sampled reference size group, and that reporters provide some indication of relevant changes in prey density that influence the interpretation of the marking statistic.
- other available marking data, more detailed than that emphasized here, be included as appended material to lake committee reports. Examples of this type of information are distributions of Type B or small marks, marking rates for other species, and marking data for smaller geographical units. It is recognized that agencies commonly collect more refined data than is routinely reported and this practice is encouraged.
- nominal field training in the use of Special Publication 79-1 be provided for assessment crews. Improvement in the accuracy of staging sea lamprey marks is much needed.

ACKNOWLEDGMENTS

We thank the other members of the committee (see page iii) for their help in carrying out this assignment. We also are very grateful to D. S. Robson for reviewing the material on statistical evaluation.

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[1]These recommendations were approved by the Fishery Commission for implementation in 1984.

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Appendix 1. Documentation of Steady-State Lamprey Marking Model

Three kinds of statistics are commonly obtained from assessment samples of lake trout in the Great Lakes: lamprey marking frequency, average size, and catch per unit effort. Interpretation of lamprey marking frequencies requires some understanding of the relation of these statistics. As an aid to this understanding, a steady-state Sea Lamprey/Lake Trout Model was adapted from the Salmonid/Lamprey Workshop Model (Koonce et al. 1982). Like the workshop model, the steady-state model assumes that lamprey attacks may be described with a multiple prey disc equation, but the steady-state model has simpler prey selection. Only lake trout are considered as prey, and probabilities of attack and mortality from lamprey vary with age. To allow for alternative mortality sources, fishing effort may be changed and each age group has a characteristic catchability coefficient. Unlike the workshop model, each age group of lake trout has a different attack rate. Key parameters as a function of age are

Age	Size (mm)	p(i)	q(i)
1	1524	0.001	0.001
2	2692	0.001	0.005
3	4039	0.01	0.05
4	5080	0.8	0.5
5	5867	0.9	1.0
6	6477	0.9	1.0
7	6934	0.95	1.0
8	7290	1.0	1.0
9	7544	1.0	1.0
10	7874	1.0	1.0

where p(i) is the probability of attack given an encounter and q(i) is catchability. The probability of surviving an attack increases linearly with the size of lake trout as in the workshop model.

The model is set up for use with SIMCON on an APPLE II+ computer. Instead of simulation through time, however, the model allows for the time variable, TI, to increment lamprey abundance. For each level of lamprey abundance, the model performs a 15-year simulation to allow lake trout abundance to reach a steady-state. The model listed in Table A1 is overlayed onto the SIMCON simulation package developed by Carl Walters and his associates at the Univeristy of British Columbia. The SIMCON Z variables are defined in Table A2.

Table A1. Listing of the Steady-State Lamprey/Lake Trout Model

```
18      FOR TIME = ZS TO NT
20      RESTORE: IF TI > 0 GOTO 100
99      L0 = 500:LI = 10000
100     FOR JI = 0 TO 15
105     IF JI > 0 GOTO 1000
110     I1 = 1:I2 = 10:I3 = 5
120     FOR I = I1 TO I2:  READ P(I):  NEXT
130     FOR I = I1 TO I2:  READ TL(I):  NEXT
140     FOR I = I1 TO I2:  READ Q(I):  NEXT
150     Z = .6:S = 1E6
160     T(I) = S:  FOR I = I1 + I1 TO I2:T(I) = T(I - 1) * Z:  NEXT
170     L = L0 + LI * TI
180     E = .7
190     M1 = 6E - 6:M3 = 3560:M4 = .292:M5 = 3.42
200     NM = .2:K = 3.28E - 7:  LZ = .33
210     FOR I = I1 TO I2:LC(I) = K * TL(I) * P(I):F(I) = E * Q(I)
             :SF(I) = EXP ( - NM - F(I)):AH(I) = LC(I) * M1 * TL(I):  NEXT
300     DATA  .001,.001,.01,.8,.9,.9,.95,1,1,1
310     DATA  1524,2692,4039,5080,5867,6477,6934,7290,7544,7874
320     DATA  .001,.005,.05,.5,1,1,1,1,1,1
1000    REM START
2000    KK = 0:  FOR I = I1 TO I2:KK = KK + AH(I) * T(I):  NEXT
2100    KK = L / (1 + KK)
2200    FOR I = I1 TO I2:LA(I) = LZ  * LC(I) * KK:J1 = TL(I) / M3:J1 = J1 * M4
             * (J1 < M5) + (J1 > = M5)
2250    SL(I) = EXP (LA(I) * (J1 - 1)):LM(I) = LA(I) * (1 - J1)
2260    Z0 = EXP ( - LA(I))
2300    X = SL(I):XM = Z0 / (X + (1 - X) * Z0):M(I) = - LOG (XM)
2400    NEXT
3000    T(I2) = T(I2) * SL(I2) * SF(I2) + T(I2 - I1) * SL(I2 - I1) * SF(I2 - I1)
3050    NS = TL(I2) * T(I2):NL = T(I2):NM = T(I2) * M(I2):NA = LA(I2) * T(I2)
3100    FOR I = I2 - I1 TO I1 + I1 STEP - I1:J = I - I1:T(I) = T(J) * SF(J) * SL(J)
3200    IF I > = I3 THEN NS = NS + TL(I) * T(I):NL = NL + T(I):
             NM = NM + M(I) * T(I):NA = NA + LA(I) * T(I)
3300    NEXT  :T(I1) = S
3500    IF NL < = 0 THEN NL = 1
3600    NEXT JI
4000    Z(1,TI) = M(4):Z(2,TI) = M(5):Z(3,TI) = M(6):Z(4,TI) = M(7):Z(5,TI) = M(8)
             :Z(6,TI) = M(9):Z(7,TI) = M(10):Z(8,TI) = LM(5):Z(9,TI) = LM(7):Z(10,TI)
             = LM(9)
4010    Z(11,TI) = NS / NL:Z(12,TI) = NM / NL
4020    Z(13,TI) = LA(5):Z(14,TI) = LA(7):Z(15,TI) = LA(9)
4030    Z(16,TI) = L:Z(17,TI) = NL
4040    Z(18,TI) = NM:Z(19,TI) = NS / NL - TL(5):Z(20,TI) = NA / NL
5000    PRINT NA / NL;"  ";NM / NL;"  "; NS / NL
```

Table A2. Description of variables in Z array of the steady-state Lamprey/Lake Trout Model.

Z variable	Description
1	Mark frequency of 4 year-old lake trout
2	Mark frequency of 5 year-old lake trout
3	Mark frequency of 6 year-old lake trout
4	Mark frequency of 7 year-old lake trout
5	Mark frequency of 8 year-old lake trout
6	Mark frequency of 9 year-old lake trout
7	Mark frequency of 10 year-old lake trout
8	Instantaneous lamprey mortality 5 year-old lake trout
9	Instantaneous lamprey mortality 7 year-old lake trout
10	Instantaneous lamprey mortality 9 year-old lake trout
11	Average size of assessment lake trout
12	Mean mark frequency of assessment lake trout
13	Attack frequency of 5 year-old lake trout
14	Attack frequency of 7 year-old lake trout
15	Attack frequency of 9 year-old lake trout
16	Lamprey abundance
17	Abundance of assessment lake trout
18	Total number of marks
19	Reference size of assessment lake trout
20	Mean attack frequency of assessment lake trout