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EVALUATION OF LAKE TROUT INDEX NETTING METHODS IN TEN NORTHEASTERN MINNESOTA LAKES[1]

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Abstract.--Three methods of estimating relative abundance of lake trout *Salvelinus namaycush* were tested and compared in 10 inland Minnesota lake trout lakes. Monofilament gill nets were fished for 30 minutes during daylight hours at randomly selected near shore locations in spring and fall. Multifilament gill nets were fished overnight in water less than 13°C during summer. Lake trout or cisco *Coregonus artedi* often dominated the catch by each method.

In 9 of 10 lakes, more lake trout were caught in fall than in spring given equal netting effort. Summer index netting caught more lake trout than spring index netting, when summer netting was standardized at 4 overnight sets per day and spring netting was standardized at 12 short duration sets per day. Summer and fall catches were similar. Summer index netting caught a broader size range of lake trout, catching smaller fish, than the short duration spring or fall index netting. Lake trout mortality due to gill netting was 10% with 30 min sets and 70% with overnight sets. Short duration index netting could be used to minimize mortality in lakes that may have stressed lake trout populations or where mortality due to sampling is a concern.

In many cases, lake trout catches obtained by spring, summer, or fall index netting methods were not adequate for precise estimation of relative abundance, size and age structure, or growth modeling. If increased precision were required, netting effort and sample size would have to be increased. Empirically derived indices of total mortality, growth, and condition showed differences among lakes and were evaluated relative to Ontario reference values. These indices should be used to evaluate lake trout mortality, growth, and condition for Minnesota's lake trout lakes, especially those that cannot be sampled intensively and when non-lethal sampling precludes age interpretation using otoliths.

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Introduction

Gill nets have been used to sample lake trout stocks and obtain crude estimates of relative abundance in inland Minnesota lakes for at least 25 years. Standardization of sampling methods has improved in the 1990s; however, sample sizes are often small and sampling methods were not designed to allow comparison of relative abundance among lakes. Because the nets are allowed to fish overnight (≈24 h), most captured lake trout die from the netting. Lake trout mortality due to gill netting may become a social issue or a biological issue in small lakes with a limited population or in lakes having an over-exploited stock.

Prior to the early to mid-1960s, linen or cotton gill nets had been used for many years. Since the early 1960s, multi-meshed, multifilament nylon nets have been used. In Minnesota, sampling for lake trout usually occurs during the summer or early fall, when lakes are thermally stratified. Lake trout prefer cold water 10°C (50°F) and arguably may be best sampled when they are more restricted to deep water after thermal stratification. To capture lake trout in summer, gill nets are fished in relatively cold water (<13°C; <55°F), usually deeper than 8-9 m.

In Minnesota, relative abundance of lake trout is reported as catch-per-unit-effort (CPUE), usually the mean number captured in overnight gill net sets. Prior to the 1990s, the method for estimating lake trout relative abundance was not standardized among the fisheries management areas. Sometimes the abundance index was composed of the combined lake trout catch of nets set in epilimnetic, metalimnetic, and hypolimnetic zones. In other cases, the catch of deep and shallow set gill nets were reported separately. In the 1990s, greater efforts were made to standardize the summer lake trout population assessment methods. "Shallow" (≥13°C; ≥55°F) and "deep" (<13°C; <55°F) net catches are now separately summarized. The number of deep and shallow water gill nets fished increases with lake size. Minnesota's summer "deep water" index netting (SDWIN) method[1] for estimating lake trout relative abundance has become more uniform, however, problems of small sample sizes and mortality due to netting remain.

Ontario Ministry of Natural Resources (OMNR) biologists suggested a lake trout index netting method, with random sampling, that estimates relative abundance, makes among- and within-lakes comparisons possible, and substantially reduces lake trout mortality (Lester et al. 1991). The spring littoral index netting method (SLIN) involves short duration (30 min) gill net sets during daylight hours, using monofilament nets set at randomly selected near shore locations in spring after ice-out and before surface water temperature exceeds 13°C (55°F). Theoretically, the CPUE for this method represents lake trout relative abundance in the "littoral" zone during spring and it should correlate with angling CPUE. In this study, the SLIN method was adapted for fall[2] testing in Minnesota and is referred to as fall littoral index netting (FLIN).

The major objectives of the study were: to compare and evaluate lake trout sampling mortality, catch, CPUE, and size distribution data obtained by overnight summer index netting and short duration spring and fall index netting; and to determine if OMNR's SLIN method should be used to assess lake trout relative abundance in Minnesota. Secondary objectives were: to compare growth, mortality, and condition indices of lake trout captured during the three sampling periods; and to compare these parameters to Ontario reference values.

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[1] The summer deep water index netting method is commonly known as lake trout "population assessment" in Minnesota.

[2] OMNR biologists do not use the index netting method during fall. Instead they use the fall period to capture, mark, and release lake trout. Later, during winter and open water creel surveys and during spring index netting, they recapture marked individuals and estimate population size.

Study Lakes

The three index netting methods (SDWIN, SLIN, and FLIN) were tested on 10 lakes in northeastern Minnesota during 1993 or 1994. Lake size ranged from 74 to 1,704 hectares, with maximum depths ranging from 19 to 62 m (Table 1). Shoreline development indices (SDI) (Reid 1961) ranged from 1.4 to 3.4, indicating a range of lake shapes. The 10 lakes have varying amounts of cottage, home, or resort development along their shores. Nine of the 10 lakes are accessible by road. Kemo Lake was accessed by portage trail. Most of the 10 study lakes have similar fish species (Table A1). Disregarding cyprinids and other small forage species, Ojibway Lake and the 6 other lakes have more diverse ($N \geq 8$) fish populations than Kemo, Mayhew, or Trout lakes ($N \leq 5$). Chemical reclamation of Kemo Lake in 1962 and Mayhew Lake in 1969 accounts for the lower species diversity in these two lakes. Past introductions of several species, including smallmouth bass *Micropterus dolomieu*, largemouth bass *M. salmoides*, bluegill *Lepomis macrochirus*, rainbow smelt *Osmerus mordax*, cisco, or walleye *Stizostedion vitreum* account for higher species diversity of some of the study lakes. Seven of the lakes have cisco, white sucker *Catostomus commersoni*, and walleye. Burbot *Lota lota* are present in Snowbank, Gunflint, and Clearwater lakes, and are most numerous in Snowbank Lake. Rainbow smelt were unlawfully introduced into West Bearskin, Gunflint, and Trout lakes from 5 to nearly 30 years ago. Northern pike *Esox lucius* are present in five lakes: West Bearskin, Loon, Gunflint, Snowbank, and Ojibway. Walleye have not been detected in Kemo, Mayhew, and Trout lakes. Splake *Salvelinus fontinalis* (♂) X *S. namaycush* (♀), immigrants from Trestle Pine Lake, were captured in Kemo Lake along with lake trout in spring, summer, and fall 1993. All the lakes, except Trout Lake, have a long history of lake trout stocking (MNDNR lake files).

Methods

OMNR Lake Trout Index Netting

The OMNR spring littoral index netting method (SLIN) was described in detail by Lester et al. (1991) and recommended as part of a larger procedure for evaluating the status and use of lake trout populations in Ontario lakes. Three days (twelve 30 min gill net sets/day) was the minimum index netting effort recommended for Ontario "District" lakes that cannot be intensively sampled.

The gill nets used for the SLIN method are 46 m long, 2.4 m deep, consist of three 15.2 m X 2.4 m panels tied end to end, and are constructed of "Grilon" monofilament, dyed light green, with braided nylon float lines and leadcore bottom lines. Each net gang fishes an area of approximately 112 m^2. Although three mesh sizes (approx. 19, 25, and 32 mm, bar measure) are used with the SLIN method, each net gang is comprised of only one mesh size. Filament diameter of the 19 and 25 mm nets is 0.20 mm, and is 0.25 mm for the 32 mm nets.

In this study, short duration index netting methods were tested on five lakes in 1993 and another five lakes in 1994 (Table 1). Daily netting effort was twelve 30 min gill net sets (6 net-hours/day), with 4 lifts of each of the 3 mesh sizes. Set and lift times were staggered or overlapped so that one 2 person crew could achieve the 12 net lift target within an 8 h work day that included travel time to and from the lakes. Each lake was netted five days in spring and five days in fall so that 60 net lifts were made in each lake in each season.

Approximate gill net locations were selected on lake maps before index netting was begun. Each lake's shoreline, including islands, was divided into at least 120 approximately equal segments. For each day's sampling, 12 shoreline segments were selected randomly from the available choices. The starting point for each day's netting was determined at random, but the remainder of the schedule was adjusted to minimize travel time between netting locations and to adjust for

Table 1. Characteristics of 10 Minnesota lake trout lakes for which spring, summer, and fall index netting methods were compared in 1993 or 1994. Lake abbreviations:KE = Kemo; TR = Trout; WB= West Bearskin; LN = Loon; GW = Greenwood; MH = Mayhew; CW = Clearwater*; GF = Gunflint; OJ = Ojibway; and SB = Snowbank*. Lakes in or partially in the Boundary Waters Canoe Area Wilderness (BWCAW) are identified with an asterisk (*).

	Lakes sampled in 1993					Lakes sampled in 1994				
Characteristic	KE	TR	WB	LN	GW	MH	CW*	GF	OJ	SB*
Area, surface (ha)	74.5	104.0	199.9	414.8	797.3	88.8	536.2	1703.8	150.1	1336.7
Area, litt. (% <4.6 m)	9	23	19	13	27	15	20	16	-	-
Depth, mean (m)	-	-	9.4	-	-	11.3	-	-	-	-
Depth, max. (m)	19.8	23.4	23.8	61.6	34.1	25.6	39.6	61.0	35.1	45.7
Shoreline length (km)	4.8	5.1	11.7	21.4	28.6	7.9	27.8	32.8	13.5	53.1
SDI[a]	1.6	1.4	2.4	3.2	3.5	2.4	3.4	2.2	3.1	4.1
TA[b] , most recent (mg/l)	9.6	12.0	18.5	12.7	5.8	15.4	13.1	19.9	35.0	12.4
Secchi[c] (m)	5.5	5.4	5.2	4.6	4.9	7.2	7.3	4.4	4.8	5.8
Lake Class[d]	3	1	1	1	1	3	1	1	3	1

[a] SDI = shoreline length/[2(πarea)$^{0.5}$]; units of length are km; units of area are km^2 ; (Reid 1961).

[b] TA = total alkalinity, measured as $CaCO_3$, was determined in 1993 or 1994.

[c] Secchi = Secchi disk visiblity (m), summer 1993 or 1994.

[d] Lake Class = Ecological Lake Classification (Schupp 1992).

equipment problems and safety during inclement weather. Whenever possible, nets were set perpendicular to shore, with the inshore end of the net set at approximately 2.4 m (8 ft) and the offshore end set at approximately 18 m (60 ft) or less. When off-shore depths exceeded 18 m, the nets were set obliquely to the shore or moved to the nearest location with suitably shallower depths. If offshore depths were less than 2.4 m, the nearest suitably deep location was selected.

Netting efforts were distributed over the periods of warming in spring and cooling in fall so that abundance indices would be comparable among lakes and within seasons. Spring index netting began immediately after ice-out (8 May 1993 and 9 May 1994) and ceased (17 June 1993 and 31 May 1994) when lake surface temperatures exceeded 13°C. In fall 1993 and 1994, the FLIN method was applied to the same lakes, beginning when surface temperatures cooled to 13°C. The lakes cooled more slowly in fall 1994 than in fall 1993. In fall 1993, surface water temperature declined from 12°C to 5°C from late September to mid-October and index netting bracketed the lake trout spawning period. In fall 1994, surface water temperature declined from 13° to 10°C from early to mid-October 1994 and index netting was completed before the lake trout spawning was complete. Netting efforts for each lake were completed within a 20 to 35 day period in each season.

Total and fork length and weight measurements, scales, and pectoral fin rays were obtained from lake trout captured in spring and fall of 1993 and 1994. Otoliths (sagitta) were collected from dead lake trout. Length measurements were recorded for species other than lake trout.

MNDNR Summer Deep water Index Netting

Summer deep water index netting was conducted on the same 10 lakes between 5 July and 3 September in 1993 or 1994. Concern about killing too many fish, however, often limits the number of overnight gill nets fished during MNDNR lake surveys and assessments, especially on small lakes. Moyle (1949) and Moyle and Lound (1959) suggested a minimum netting effort of 9 sets to obtain reliable estimates of species abundance. In this study, summer netting effort ranged from 3 to 12 sets, increasing with lake size. Only 3 of the 10 lakes (Clearwater, Gunflint, and Snowbank) met the 9 net criterion, having 11 or 12 overnight sets. Three lakes (Loon, Greenwood, and Ojibway) were just short of the suggested minimum, having 8 sets. The remaining four smaller lakes had from 3 to 6 sets.

Minnesota DNR lake survey gill nets are 76 m long, 1.8 m deep and are constructed of #104 twisted nylon fibers, with nylon float lines and leadcore bottom lines. Each "lake survey" gill net fishes an area of approximately 139 m^2. Each multifilament, graduated mesh net is composed of 15.2 m of 5 mesh sizes (approx. 19, 25, 32, 38, and 51 mm, bar measure).

Total length, weight, scales, and fin rays were obtained from most of the lake trout captured in summer 1993 and 1994. Fork lengths were measured for lake trout from West Bearskin and Loon lakes in 1993. For the remaining eight lakes, fork lengths were estimated from a fork length - total length relationship ($FL = 0.918TL - 4.669$; (N=763, r^2=0.998, $P<0.001$), derived from lake trout measurements made during spring and fall from the 10 lakes and from lake trout measurements from West Bearskin, Loon, and Duncan lakes made in summer 1993. Otoliths were collected from dead lake trout from West Bearskin Lake in summer 1993 and from Mayhew, Clearwater, Gunflint, and Snowbank lakes in summer 1994. Summer index netting crews did not separate catches by mesh size.

Catch by mesh size

Differences among length-frequency distributions captured in 19, 25, and 32 mm mesh sizes were evaluated with the Chi-square test for independence (Conover 1980). Spring (N=226) and fall (N=460) catches from the 10 lakes were pooled by mesh size for monofilament nets because total lake trout catch for individual lakes generally was small and index netting effort was the same among lakes, seasons, and mesh sizes. ANOVA and Tukey's HSD test, adjusted for unequal sample sizes (Wilkinson 1990), were used to compare the mean lengths of lake trout among mesh sizes.

Catch Analyses

Summer and fall data sets from Greenwood, West Bearskin, Loon, and Ojibway lakes were adjusted by subtracting newly stocked yearling lake trout from the catch of individual gill net sets. Yearling lake trout (≈17-18 months old, F_2 hatchery reared Gillis Lake strain) were stocked in Greenwood Lake just before spring index netting was completed in 1993, in West Bearskin and Loon lakes in 1993, and in Ojibway Lake in 1994 just after spring index netting was completed. These yearlings were not part of the populations during spring index netting. Therefore, catch statistics include this adjustment, enabling comparisons among the spring, summer, and fall index netting methods.

Gear type and effort were equal in spring and fall, therefore spring and fall total catches from each lake were compared by maximum-likelihood-tests (G-test), using Williams' correction factor (Sokal and Rohlf 1981). The number of nets with catches of zero, one, and 2 or more lake trout were summarized by lake and season.

Relative catch rates

Spring, summer, and fall lake trout catch data were transformed to catch-per-net-hour (CPNH) and summary statistics were compared to evaluate catch rates of the two gear types (monofilament and multifilament), although gear dimensions and fishing duration differed among index netting methods. Simple linear regression was used to examine relationships among CPNH for the three methods.

Relative cost-effectiveness

Relative cost-effectiveness was evalated by comparing mean lake trout catch-per-day (CPD) for the SLIN and FLIN methods to the estimated average lake trout CPD for the SDWIN method. Spring and fall index netting methods, using a two person crew, required approximately 16 hours/day. Mean CPD was calculated for the SLIN and FLIN methods by dividing total lake trout catch by the number of days of effort. Summer lake trout population assessments require a two person crew and usually four of the standard multifilament gill nets can be set per day. Approximately 3 days of effort, or about 48 person-hours, including travel time and setting nets the first day are needed for performing 8 gill net lifts (S. Persons, personal communication 1994). Because netting effort varied with lake size, the summer lake trout catch totals and the amount of effort for each lake were adjusted on the basis of 8 nets lifted per 3 days. First, the observed mean catch/net-lift ($CPNL_{obs}$) was calculated for each lake. Then, the estimated mean catch/day (CPD_{est}) was calculated as ($CPNL_{obs}$ x 8 nets)/3 days. CPUE data was evaluated with the Chi-square test for heterogeneity. Mann-Whitney tests (Conover 1980) were used to determine if mean CPD differed among the three index netting seasons.

Length-frequency distributions and netting methods

Length-frequency distributions (25 mm length-groups) of lake trout collected by the three index netting methods were visually compared. Differences in mean length and netting method were evaluated with ANOVA and Tukey's HSD test, adjusted for unequal sample size (Wilkinson 1990). Within lakes differences in length-frequency distributions were evaluated with the Kolmogorov-Smirnov 2-sample test (Sokal and Rohlf 1981).

Mortality due to index netting methods

Numbers of dead and alive lake trout were compared among lakes for spring and fall index netting with the Chi-square test for independence (Conover 1980). Confidence intervals (95%) were calculated for the survival data (Walpole and Myers 1978). Acute mortality information was pooled for all lakes by season and summarized by mesh size. Potential survival of lake trout caught in spring and fall was estimated when each fish was released. A survival ranking (0=dead, 1=poor, 2=fair, 3=good, or 4=excellent) was assigned to each fish, based on the handler's estimate of the fish's condition when released. A G-test for independence, with Williams' correction factor (Sokal and Rohlf 1981), was used to compare rankings for spring and fall samples for each lake.

Lake Trout Ageing

Knowledge of stocking history enabled me to assign ages to lake trout with cohort specific fin clips and to those with noncohort specific marks. Unmarked lake trout (i.e., those having no recognizable fin clip) represented natural reproduction or cohorts that were not marked with a fin clip when stocked as 9-10 month old fingerlings (Kemo Lake only). Lester et al. (1991) recommended that seven years should be the maximum age reliably determined from scales because ages determined from scales underestimate the age of mature lake trout and otoliths offer the most reliable age estimates. In this study, ages assigned to most unknown age lake trout were based on interpretation of growth patterns of pectoral fin ray thin sections or scales, both of which may underestimate age of older lake trout. Otoliths of dead lake trout were sectioned and used for estimating age.

Characterizing lake trout populations

Lester et al. (1991) described seven diagnostic variables that can be used to characterize OMNR lake trout lakes that cannot be intensively studied. Four of the variables, including relative abundance (CPD or CPNL), growth, mortality, and condition (weight-length relationship), were estimated in this study. Their approximate methods of growth and mortality estimation were developed for use when otolith ages are not available and sample sizes are relatively low. Three angling related variables could not be estimated because sport fisheries were not monitored during this study.

Relative Abundance Indices

For the SLIN and FLIN methods, relative abundance is the mean number of lake trout caught per day (CPD), when netting effort is the same each day. If daily effort is not constant from day-to-day within or among lakes, then the abundance index is calculated as the mean catch/30 min net-lift (CPNL), pooling data from the three mesh sizes. In this study, spring and fall efforts were random, equal among lakes, and distributed among the lakes throughout the sampling periods. For comparison, both expressions of relative abundance were calculated. Mann-Whitney tests (U statistic) were used to compare mean daily catches for spring and fall netting and coefficients of variation of mean daily catches. Mean CPNL was reported as the measure of central tendency because median CPNL for 30 min sets was zero for 16 of 20 spring and fall data sets.

The index of lake trout abundance for the SDWIN method is the mean number of lake trout captured/net lift for gill nets fished overnight. Daily catch statistics are not routinely calculated for MNDNR's summer index netting because daily effort often is not equal. Normal probability plots were examined to determine if CPNL data was normally distributed.

Spring and summer, or fall and summer CPNL data could not be compared directly because the gear and effort differed between the SLIN and FLIN methods and the SDWIN method. Therefore, simple linear regression (Sokal and Rohlf 1981) was used to assess how well one measure of relative abundance could be predicted from another. Mean CPD for spring and fall index netting were compared to each other and to the summer mean CPNL. Regression analysis was also used to investigate possible relationships among abundance indices and lake area.

The log of the variance of abundance index was regressed on the log of the abundance index for spring, summer, and fall to obtain an estimate of the variance of the mean abundance index. Then, approximate sample size and netting effort needed for specified levels of precision (CV= 0.15 and CV=0.20) were estimated for the three netting methods:

$$N = s^2 / (\text{mean index}^2)*(CV^2)$$

as described by Lester et al. (1991).

Estimating von Bertalanffy growth parameters

Payne et al. (1990) introduced an empirical method of estimating von Bertalanffy growth parameters ($L\infty$ and K), enabling growth comparisons among lakes that cannot be sampled intensively. The estimate of L_∞ (i.e, L_∞') is the geometric mean of the longest lengths comprising 5% of the total sample size or 10 fish, whichever is less. Payne et al. (1990) suggested that two fish is the minimum number that should be used for estimating $L\infty$. They defined K′ as the slope of regression line relating y to t, where:

$$y = -\ln(1-L_t/L_\infty')$$

and the regression is forced through the origin (t = ages 4,...,7). Because K′ is estimated from lake trout ages 4 through 7 (a restricted, younger age range) it is less likely to be biased, although it is not a solution for bias. Payne's methods were applied to length-at-age data for 19 of 30 lake trout collections for which $N \geq 40$, basing L_∞' on 2 to 5 fish. For the remaining 11 data sets, where $N<40$, the 2 fish minimum was relaxed and the largest lake trout captured was used to estimate L_∞, if only one relatively large lake trout was captured. According to Payne et al. (1990), fitting a three-parameter equation to growth data is not appropriate when data are not adequate and subject to several deficiencies including: inadequate sample sizes; age determination errors; bias due to size selectivity; bias and variance due to growth during a year; and when the shape of the growth curve is not described by the von Bertalanffy growth equation. These problems occur in lake trout survey data.

Growth Index (A400)

Variation in growth among lake trout populations in Ontario lakes was described by Payne et al. (1990), with larger asymptotic lengths (L_∞) occurring in larger lakes:

$$L_\infty = 290 + 107(\log_{10}\text{Area}),$$

where Area = hectares. Lester et al. (1991, Figure 11a) recommended using this asymptotic fork length-lake area equation to evaluate lake trout growth in Ontario lakes that cannot be studied as intensively due to personnel and economic constraints. They suggested using a growth index A400 (age at 400 mm, fork length) to approximate the growth characteristics of lake trout populations:

$$A400 = (L_\infty/94.1) / \log_e(1\text{-}400/L_\infty).$$

A400 is inversely related to L_∞ and therefore to lake area, such that, A400 decreases from 8.5 to 6 years as lake area increases from 100 to 10,000 hectares (Lester et al. 1991, Figure 11b). The A400 growth indices can be used to identify how estimated asymptotic lengths (L_∞') deviate from OMNR reference values. Predicted asymptotic lengths and corresponding reference ages at 400 mm were calculated from the above L_∞-lake area and A400-L_∞ relationships for each of the 10 study lakes.

The methods of Lester et al. (1991) were used to estimate A400 from a restricted range (300-500 mm) of fork length-at-age data. The length at age data was fitted to the equation:

$$t = x - y \log_e(1\text{-}zL)$$

where t = age, L = fork length, and x = t_0, y = 1/K = $L_\infty/94.1$, and z = $1/L_\infty$. Then, x, y, and z were used to calculate A400 as follows:

$$A400 = x - y\log_e(1\text{-}z400).$$

The authors emphasize that these growth parameters, derived from a restricted length range, are not estimates of the population growth parameters, but are used only to make an estimate of A400 for the restricted length range. The Quade Test (Conover 1980) was used to evaluate differences in estimates of A400. Each age at 400 mm was compared to the plotted OMNR reference line (A400 versus lake area) and to each predicted age at 400 mm for each index netting method by lake. Points lying above the reference curve indicate low growth (i.e., low L∞), while points lying below the curve signify high growth (i.e., high L_∞). I used regression analysis to explore relationships between estimated age at 400 mm and lake area. Assuming the previously described fork length and total length relationship applies to all 10 lakes, $A400_{FL}$ = $A441_{TL}$.

Mortality Index (ML400)

Lester et al. (1991) developed a mean length statistic, ML400 (i.e., mean fork length above 400 mm), as a growth dependent index of mortality when lake trout ages are determined from scales. The authors stated that because scale age underestimates the age of older lake trout, the preferred catch curve method of estimating mortality (Ricker 1975) should not be used. Lester et al. (1991) explained how ML400 is related to the instantaneous rate of mortality (Z) and showed how L_∞ and ML400 can be used to evaluate mortality of individual lakes relative to a 50% (Z=0.693) annual mortality guideline. ML400 is a restatement of the instantaneous rate of mortality formula (Beverton and Holt 1956):

$$Z = K(L_\infty - \bar{L}) / (\bar{L} - L').$$

Rearranged to solve for ML400, the formula is:

$$ML400 = (400Z + KL_\infty) / (Z + K)$$

where L'=400mm and $\bar{L}$ is the mean fork length above 400 mm (ML400). Lester et al. (1991) recommended calculating ML400 as the sum of the lengths of lake trout longer than 400 mm fork length divided by *N* (i.e., the number of lake trout longer than 400 mm fork length) for Ontario "District" lakes. ML400, although an imprecise indicator of total mortality, is easily calculated and can be used to categorize lakes as having high or low mortality. Values of ML400 greater than 480 mm fork length indicate annual mortality less than 50%. For values of ML400 less than 480 mm, the reference values for the mortality index depends on growth (L_∞) and the growth index must be used to evaluate mortality.

In this study, the ML400 mortality index was calculated for each lake and index netting method. The ML400 value gives a more precise indication of total mortality when sample size (*N*) is relatively large, than when *N* is relatively small. Data sets from spring, summer, and fall were pooled to obtain a single value of $ML400_p$ for each lake because the number of lake trout larger than 400 mm was small. Pooled ML400 values were plotted versus the arithmetic mean of the spring, summer, and fall estimates of A400 to evaluate the lakes relative to the OMNR 50% mortality guideline and to characterize them as having high or low mortality.

Condition

Comparisons of lake trout condition were evaluated by ANCOVA, comparing linear regression parameters of $\log_{10}$-transformed weight-length data among-lakes and within-methods (seasons) (Cone 1989). Lester et al. (1991) recommended that OMNR lakes be classified by comparing the weight-fork length relationship parameters to reference parameters developed from weight-length data collected from 23 Ontario lake trout lakes:

$$W = 3.88 \times 10^{-6} L^{3.18}$$

where W = weight (g), L = fork length (mm) (Payne et al. 1990). Parameters of the weight-fork length relationships from spring and fall 30 min index netting and from summer index netting were compared to the OMNR reference parameters and these relationships were reviewed graphically.

Fish species other than lake trout

Proportions of each species captured by the three index netting methods were examined and evaluated with the Chi-square test for homogeneity, comparing catches in spring and fall, spring and summer, and fall and summer.

Results

Duration of net sets

Generally, it was possible to adhere to the nominal 30 min set duration used in the SLIN and FLIN methods. Nearly 85% of the spring and fall sets were fished for the prescribed 30 min and nearly 97% were fished from 30 to 35 min. Only 37 nets (3.1% of the total) were fished for more than 35 min and only 9 (0.8%) nets fished from 41 to 45 min. Departures from the nominal set time did not significantly alter the individual net catch data because often no lake trout were caught in the affected nets. The mean duration of overnight gill net sets (SDWIN method) was 22.5 h (N=76, SE = 0.186; range: 19.1 - 26.8 h) for the 10 lakes in this study.

Daily sampling period (30 min index netting)

On 50 percent of the index netting days (45 of 90 days), the daily index netting effort was completed within 5.1 to 6.1 h. The average elapsed time between the setting of the first net (mean: 0934 h) and the lifting of the last (12th) net (mean: 1505 h) was 5.6 h (SE=0.07; N=90; range: 4.2 - 6.8) for pooled spring and fall data when one 2 person crew was used (9 of 10 lakes). Daily start times (range: 0817 - 1047 h) and completion times varied considerably (range: 1239 - 1637 h) and as expected, increased with distance from the area headquarters and lake size. On several occasions when very few fish were encountered on the smaller, more accessible lakes (e.g. Ojibway and Trout lakes), netting was completed before 1400 h. On these occasions, mid-to-late afternoon sampling was not as well represented as on larger, or less accessible lakes. Sampling periods for Clearwater Lake are not comparable to those of the other 9 lakes because two netting crews were used each day on that lake.

Total lake trout catch

Lake trout sample size was small in most of the study lakes, regardless of the index netting method and season, with fewer than 40 lake trout captured in 77% (23 of 30) of the collections. None of the spring lake trout catch totals exceeded 38 fish. Sample size was 40 or more for 6 of 10 lakes netted in fall, but sample size was less than 40 for 9 of 10 lakes netted in summer. The 5 day catch totals were greater for fall index netting (range: 15 to 96 fish) than for spring index netting (range: 6 to 36 fish) for 9 of the 10 lakes sampled (Wilcoxon signed ranks test, Z=2.497, P=0.013) for 1993 and 1994. Goodness-of-fit tests showed that fall catch totals were significantly greater ($P<0.05$) than in spring for 6 of the 10 lakes netted (Table 2). Sample sizes from summer index netting ranged from 6 to 48 fish, but are not directly comparable because gear and effort were not equal among index netting methods.

Mesh size and catch parameters

The number of lake trout captured in the three mesh sizes did not differ significantly for either spring ($\chi^2_{14df}=18.995$, $P=0.165$) or fall ($\chi^2_{18df}=19.190$, $P=0.380$) index netting, although fewer total lake trout were caught in the 19 mm mesh size than in either the 25 mm or 32 mm monofilament mesh sizes for the 10 study lakes (Table 3). Petzold (OMNR, personal communication 1992) also found that the number of lake trout caught in these three mesh sizes did not differ significantly for four Ontario lakes netted in spring.

In this study, the minimum size of lake trout captured in the 3 mesh sizes differed, increasing slightly from 200 mm TL in the 19 mm mesh, to 224 mm in the 25 mm mesh, and to 276 mm in the 32 mm mesh. Relatively large lake trout (>700 mm TL) composed a small proportion (<4%) of the catch, regardless of mesh size. Petzold (OMNR, personal communication 1992) reported that broad length distributions of lake trout (≈50 to 680 mm, FL) were sampled by 7 mesh sizes ranging from 12.7 - 51 mm, bar measure.

Lake trout length-frequency distributions, between 200 and 700 mm TL, did not appear to differ greatly among mesh sizes in this study (Figure 1), although Pearson's Chi-square test indicated a significant difference ($\chi^2_{18df}=49.787$, $P=0.0001$). The 25 and 32 mm mesh sizes captured lake trout of similar size ranges, catching few fish smaller than 275 mm, while the 19 mm mesh size caught lake

Table 2. Total lake trout catch from 10 Minnesota lake trout lakes sampled by short duration (30 min) index gill netting with monofilament nets in spring (SLIN) and fall (FLIN) in 1993 and 1994, and results of Goodness-of-fit tests ($G_{adjusted}$; $Chi^2=3.841$, $P=0.05_{1df}$) for spring-fall comparisons. Significantly larger fall catches ($P \leq 0.05$) are noted with an asterisk (*).

	Total lake trout catch (*N*)		Goodness-of-Fit Tests on spring versus fall lake trout catches	
	Spring	Fall		
Lake Name	SLIN	FLIN	$G_{adj.}$	*P*
		Lakes sampled in 1993		
Kemo	29	96*	36.68	<0.001
Trout	28	57*	9.40	0.001
W.Bearskin	17	90*	53.00	<0.001
Loon	34	27	0.59	0.438
Greenwood	37	41[a]	0.12	0.736
Total	145	311		
		Lakes sampled in 1994		
Mayhew	24	47*	6.93	0.006
Ojibway	6	15*[a]	3.13	0.046
Clearwater	28	39	1.50	0.178
Snowbank	9	32*	12.45	<0.001
Gunflint	18	19	0.00	0.869
Total	85	152		

[a] Lake trout identified as the newly-stocked (June) cohort are not included in the fall totals because those fish were not part of the lake trout population during the spring sampling season: Greenwood Lake (42-1=41=*N*), and Ojibway (17-2=15=*N*).

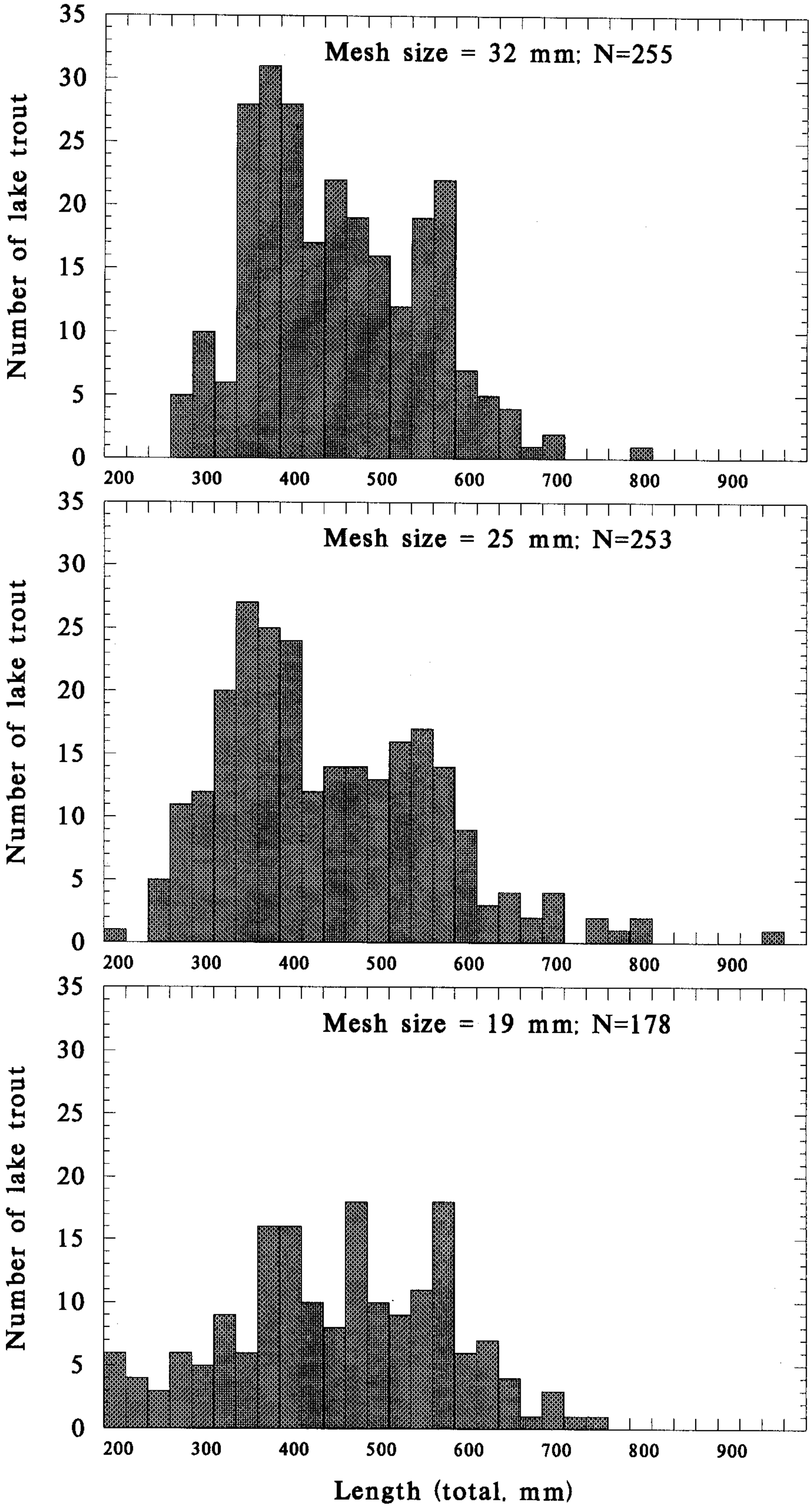

FIGURE 1. Pooled length-frequency distributions of lake trout captured in 3 mesh sizes (bar measure) of monofilament gill nets set for 30 minutes in 10 Minnesota lakes. Spring and fall data from 1993 or 1994 is pooled.

Table 3. Summary statistics for total length (mm) of lake trout captured in 3 mesh sizes (19, 25, and 32 mm, bar measure) of monofilament gill nets. Data was pooled for 10 northeastern Minnesota lake trout lakes, 1993 and 1994.

Statistic	Mesh size 19 mm	 25 mm	 32 mm
Number	178	253	255
Minimum	200	224	276
Maximum	752	963	822
Mean	465.270	455.482	464.369
Std. deviation	123.520	121.738	98.698
Std. error	9.258	7.654	6.181
Skewness (G1)	-0.098	0.791	0.439
Kurtosis (G2)	-0.578	0.731	-0.316

trout as small as 200 mm. Length-frequency distributions for the 25 and 32 mm mesh sizes were positively skewed (Table 3) and showed kurtosis with a tendency toward being bimodal.

Mean lengths of lake trout captured in the three mesh sizes (Table 3), however, did not differ significantly for 30 min sets (ANOVA, $F_{2,683}$=0.528, P=0.590). For 7 mesh sizes of 12 h monofilament gill net sets, Petzold (OMNR, personal communication 1992) found that mean fork length increased with increasing mesh size.

Sampling mortality

The SDWIN method (≈24 h sets), resulted in higher lake trout mortality than was observed for either SLIN or FLIN (30 min sets) method in both 1993 and 1994. Estimating conservatively, at least 70% of the lake trout captured by the SDWIN method were dead, or would have died as a result of their capture if release had been attempted. Only a few relatively large lake trout tangled by their teeth or maxillary bones were in good condition and were released.

In contrast, a much smaller proportion of the lake trout captured during spring and fall died due to netting and handling (Table 4). Mortality due to the 30 min index netting and handling procedure, was 10.1% (70/696 in spring and fall 1993 and 1994). In 1993, lake trout mortality was nearly 10% for spring and 15% for fall. In 1994, mortality estimates, for some undetermined reason, were lower in spring (2 to 3%) and fall (5%) than in 1993. The mortality rate (pooled for spring and fall seasons and for 1993 and 1994) was lowest in the smallest of the three mesh sizes (19 mm: 4.4%, 25 mm: 11.7%; 32 mm: 12.4%; Table 4).

Survival potential, a subjective assessment of the likelihood of survival at the time of release, was homogeneous between spring and fall for all lakes (Table 5), except for West Bearskin where the proportion of lake trout released in good to excellent condition was greater in spring than in fall 1993 ($P<0.05$). In spring and fall 1993, an average of 70% of the lake trout were released having a good to excellent chance of survival. In spring and fall 1994, 85% of the lake trout handled were released with a good to excellent chance of survival. Lake trout that were gilled, wedged, rolled in the nets, or some combination of these capture modes were less likely to be released in good to excellent condition than those that were tangled only by their teeth or maxillary bones.

Length-frequency distributions

Visual comparison of the lake trout length-frequency distributions (Tables 6 and 7), adjusted for age 1+ (yearling) lake trout stocked in spring, indicated that the SDWIN method often captured smaller, younger lake

Table 4. Mortality of lake trout captured in 3 mesh sizes of monofilament gill nets fished for 30 minutes during daylight hours in 10 Minnesota lakes in spring (SLIN) and fall (FLIN), 1993 or 1994. *N* = total catch; D = number dead; A = number alive; % = percentage dead ± $1.96_{P=0.025}\ ((D/N + A/N)/N)^{0.5}$.

	Mesh sizes (bar measure)											
	19 mm			25.4 mm			32 mm			All mesh sizes, pooled		
Year	*N*	D	%	*N*	D	%	*N*	D	%	*N*	D	%
Spring Index Netting (SLIN): 10 lakes (pooled data)												
1993	38	1	2.6	57	8	14.0	52	5	9.6	147	14	9.5 ± 4.8
1994	23	0	0.0	23	0	0.0	37	2	5.4	83	2	2.4 ± 3.3
subtotal	61	1	1.6	80	8	10.0	89	7	7.9	230	16	7.0 ± 3.3
Fall Index Netting (FLIN): 10 lakes (pooled data)												
1993	88	5	5.7	116	19	16.4	108	22	20.4	312	46	14.7 ± 4.1
1994	32	2	6.7	61	3	4.9	61	3	4.9	154	8	5.2 ± 3.5
subtotal	120	7	5.8	177	22	12.4	169	25	14.8	466	54	11.6 ± 2.9
Spring and Fall Index Netting: 10 lakes (pooled data)												
total	181	8	4.4	257	30	11.7	258	32	12.4	696	70	10.1 ± 2.2

Table 5. Survival potential (percentages by category) of lake trout sampled in spring (SLIN method) and fall (FLIN method) in 30 min gill net sets, and in summer (SDWIN method) in 24 h sets in Kemo (KE), Trout (TR), West Bearskin (WB), Loon (LN), and Greenwood (GW) lakes in 1993 and Mayhew (MH), Clearwater (CW), Gunflint (GF), Ojibway (OJ), and Snowbank (SB) lakes in 1994.

				Survival category (%)				
Lake	Season	Method	*N*	Dead	Poor	Fair	Good	Excellent
KE	Spring	SLIN	28	0.0	3.6	3.6	39.3	53.6
	Fall	FLIN	96	6.3	6.3	10.4	16.7	60.4
	Summer	SDWIN	18	[a]	-	-	-	-
TR	Spring	SLIN	28	10.7	7.1	10.7	17.9	53.6
	Fall	FLIN	57	19.3	3.5	3.5	31.6	42.1
	Summer	SDWIN	26	-	-	-	-	-
WB	Spring	SLIN	17	5.9	5.9	5.9	17.7	64.7
	Fall	FLIN	90	15.6	7.8	20.0	34.4	22.2
	Summer	SDWIN	26	73.1	7.7	11.5	7.7	-
LN	Spring	SLIN	33	15.2	9.1	6.1	36.4	33.3
	Fall	FLIN	27	25.9	7.4	29.6	25.9	11.1
	Summer	SDWIN	43	55.8	25.6	11.6	2.3	4.7
GW	Spring	SLIN	38	13.2	5.3	21.1	26.3	34.2
	Fall	FLIN	42	19.1	2.4	4.8	21.4	52.4
	Summer	SDWIN	72	[b]	-	-	-	-
MH	Spring	SLIN	24	0.0	4.2	12.5	16.6	66.7
	Fall	FLIN	47	6.4	0.0	10.6	27.7	55.3
	Summer	SDWIN	14	92.9	-	-	7.1	-
CW	Spring	SLIN	26	7.7	0.0	3.8	38.5	50.0
	Fall	FLIN	39	10.3	2.6	5.1	41.0	41.0
	Summer	SDWIN	37	94.6	-	-	-	5.4
GF	Spring	SLIN	18	0.0	0.0	5.6	22.2	72.2
	Fall	FLIN	19	0.0	5.3	10.5	15.8	68.4
	Summer	SDWIN	22	90.9	-	-	9.1	-
OJ	Spring	SLIN	6	0.0	0.0	16.7	66.7	16.7
	Fall	FLIN	17	5.9	11.8	11.8	47.1	23.5
	Summer	SDWIN	58	96.6	-	-	-	3.4
SB	Spring	SLIN	9	0.0	0.0	11.1	66.7	22.2
	Fall	FLIN	32	0.0	0.0	3.1	25.0	71.9
	Summer	SDWIN	13	92.3	-	-	7.7	-

[a] Thirteen of 18 (72%) lake trout were still alive when removed from the nets, but most would have died had they been released.

[b] The crew estimated that at least 75% of the fish would have died had they been released.

Table 6. Length-frequency distributions of lake trout captured in Kemo, Trout, West Bearskin, Loon, and Greenwood lakes in short duration (30 min) monofilament gill net sets fished in near shore waters during spring (SP) and fall (FA), and in overnight (≈24 h) multifilament gill nets set in water ≤12°C during summer (SU), 1993. Numbers in **bold type** denote yearling lake trout (1992 cohort) stocked in spring 1993 and those fish are not included in the adjusted summary statistics for West Bearskin, Loon, and Greenwood lakes, listed below.

	Lake Trout (number)														
Length-	Kemo			Trout			West Bearskin			Loon			Greenwood		
group (mm)	SP	FA	SU	SP	FA	SU	SP	FA	SU	SP	FA	SU	SP	FA	SU
100-149	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
150-199	-	-	1	-	-	-	-	-	**1**	-	-	**4**	-	-	**10**
200-249	2	-	2	-	2	2	-	1	2+**5**	-	1	**7**	**2**	**1**	1+**10**
250-299	2	12	4	-	6	4	-	-	-	2	2	2	-	1	4+**4**
300-349	-	16	1	3	10	7	3	8	3	5	3	6	-	2	7
350-399	-	-	2	5	12	1	1	34	6	15	12	13	18	13	9
400-449	2	-	-	6	5	3	-	29	3	5	5	4	10	16	17
450-499	3	4	1	4	7	4	2	2	1	2	3	7	3	6	4
500-549	4	19	4	4	6	1	-	-	2	1	-	-	3	-	3
550-599	8	34	2	3	6	1	4	8	2	1	-	-	1	1	-
600-649	5	8	1	2	-	1	2	6	-	1	-	-	-	1	-
650-699	1	1	-	-	2	-	1	2	1	1	-	-	1	-	-
700-749	-	-	-	-	1	-	3	-	-	-	1	-	-	-	-
750-799	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
800-849	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
850-899	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
900-949	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
950-999	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
not measured	1	2	-	-	-	-	-	-	-	-	-	-	1	-	
total	28	96	18	28	57	24	17	90	20+**6**	33	27	32+**11**	36+**2**	41+**1**	48+**24**
	Summary statistics														
Minimum	203	267	185	323	245	224	322	223	234	250	248	273	350	292	232
Maximum	653	651	622	790	703	606	819	661	690	690	723	494	668	629	900
Mean	506	485	394	475	420	384	556	427	415	403	385	389	425	416	421
Median	565	547	365	450	387	347	587	400	389	380	368	380	399	410	404
N (measured)	27	94	18	28	57	24	17	90	20	33	27	32	36	40	48

Table 7. Length-frequency distributions of lake trout captured in Mayhew, Ojibway, Clearwater, Snowbank, and Gunflint lakes in short duration (30 min) monofilament gill net sets fished in near shore waters during spring (SP) and fall (FA), and in overnight (≈24 h) multifilament gill nets set in water ≤12°C during summer (SU), 1994. Numbers in **bold type** denote yearling lake trout (1993 cohort) stocked in spring 1994 and those fish are not included in the adjusted summary statistics for Ojibway Lake, listed below.

	Lake Trout (number)														
Length-	Mayhew			Ojibway			Clearwater			Snowbank			Gunflint		
group (mm)	SP	FA	SU	SP	FA	SU	SP	FA	SU	SP	FA	SU	SP	FA	SU
100-149	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
150-199	-	-	-	-	-	**17**	-	-	1	-	-	-	-	-	1
200-249	-	-	2	-	**2**	6+**16**	-	-	1	-	-	-	-	-	1
250-299	-	2	6	-	3	10	-	-	5	-	-	2	-	-	1
300-349	1	3	5	1	5	5	-	2	3	-	-	2	-	-	3
350-399	3	11	-	1	-	-	-	7	7	-	1	2	-	-	-
400-449	3	9	-	-	1	-	7	5	8	3	1	2	-	-	1
450-499	4	11	-	3	1	1	6	13	6	1	2	-	12	6	3
500-549	5	4	-	-	1	-	6	5	2	1	4	1	5	8	4
550-599	5	4	1	-	-	1	1	2	2	3	14	2	1	5	2
600-649	-	1	-	1	-	-	3	3	-	1	3	-	-	-	1
650-699	1	-	-	-	1	-	1	-	-	-	4	1	-	-	1
700-749	1	1	-	-	-	-	-	2	1	-	1	1	-	-	2
750-799	1	1	-	-	1	1	-	-	-	-	-	-	-	-	-
800-849	-	-	-	-	1	-	1	-	-	-	-	-	-	-	1
850-899	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
900-949	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
950-999	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
not measured	-	-	-	-	1	-	2	-	1	-	2	-	-	-	-
total	24	47	14	6	15+**2**	25+**33**	28	39	37	9	32	13	18	19	21
	Summary statistics														
Minimum	338	285	236	335	200	174	402	311	196	402	387	263	454	483	183
Maximum	752	765	560	639	805	950	963	724	743	635	707	735	553	558	819
Mean	512	449	308	468	407	258	532	476	399	517	571	448	496	524	495
Median	515	430	291	472	330	214	496	463	407	528	579	411	490	516	510
N (measured)	24	47	14	6	15	25	28	39	37	9	32	13	18	19	21

trout than either the SLIN or FLIN methods. Kolmogorov-Smirnov tests indicated the shape and location of length-frequency distributions from the three index netting methods differed significantly ($P \leq 0.05$) for 15 of 30 within lakes comparisons (Table 8).

Mean length of lake trout captured by the 3 index netting methods differed in 9 of 10 lakes (ANOVA, $P \leq 0.014$). Mean lengths of lake trout captured during SLIN were longer than those of lake trout captured during SDWIN for all 10 lakes, and significantly longer ($P \leq 0.019$) for 8 of 10 lakes. Mean lengths of lake trout captured during FLIN were also longer than those of lake trout captured during SDWIN for all 10 lakes, and significantly longer ($P \leq 0.048$) for 7 of 10 lakes (Tables 6, 7, and 9). In contrast, mean lengths of lake trout captured by SLIN were larger than those captured by FLIN, but did not differ significantly ($P \geq 0.081$) for 8 of 10 lakes. Mean lengths were significantly smaller in fall than in spring only for Mayhew (60 mm; $P=0.040$) and West Bearskin (120 mm; $P<0.001$) lakes where yearling lake trout,

Table 8. Comparison (Kolmogorov-Smirnov two-sample test) of length distributions of lake trout caught in 10 Minnesota lake trout lakes by the 30 min duration index netting in spring (SLIN) and fall (FLIN), and by the 24 h duration index netting in summer (SDWIN) 1993 or 1994. Length distributions that differ significantly ($P \leq 0.05$) are indicated by asterisks (*).

Lake name	Statistic	Comparisons SLIN-FLIN	 SLIN-SDWIN	 FLIN-SDWIN
Lakes sampled in 1993				
Kemo	max. diff.	0.190	0.426	0.387
	2-sided *P*	0.415	0.037*	0.016*
Trout	max. diff.	0.312	0.470	0.261
	2-sided *P*	0.047*	0.004*	0.164
W.Bearskin	max. diff.	0.574	0.534	0.263
	2-sided *P*	<0.001*	0.003*	0.105
Loon	max. diff.	0.229	0.164	0.186
	2-sided *P*	0.395	0.725	0.650
Greenwood	max. diff.	0.136	0.250	0.183
	2-sided *P*	0.849	0.138	0.429
Lakes sampled in 1994				
Mayhew	max. diff.	0.433	0.887	0.822
	2-sided *P*	0.005*	<0.001*	<0.001*
Ojibway[a]	max. diff.	0.429	0.760	0.529
	2-sided *P*	0.351	0.007*	0.013*
Clearwater	max. diff.	0.231	0.590	0.412
	2-sided *P*	0.347	<0.001*	0.003*
Snowbank	max. diff.	0.344	0.504	0.582
	2-sided *P*	0.385	0.106	0.002*
Gunflint	max. diff.	0.450	0.333	0.381
	2-sided *P*	0.035*	0.216	0.110

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[a] Lake trout length-frequency distributions were compared after adjusting for the catch of the most recently stocked cohorts (1992 cohort in West Bearskin, Loon, and Greenwood lakes in 1993; 1993 cohort in Ojibway Lake in spring 1994).

Table 9. Analysis of variance (ANOVA) and comparison of mean length (TL) of lake trout captured by 3 index netting methods in 10 Minnesota lake trout lakes in 1993 or 1994. Asterisks (*) denote significantly different ($P\leq0.05$) means. The Tukey-Kramer adjustment for unequal sample size was applied to the Tukey HSD test (Wilkinson, L. 1990).

			Multiple comparisons (Tukey's Honest-Significant Difference)					
			SLIN & SDWIN		SLIN & FLIN		SDWIN & FLIN	
	ANOVA		mean diff.		mean diff.		mean diff.	
Lake name	F-ratio	*P*	(mm)	*P*	(mm)	*P*	(mm)	*P*
Kemo	4.653	0.011	-112.056	0.011*	-21.370	0.725	90.686	0.016*
Trout	4.578	0.012	-91.506	0.011*	-55.622	0.081	35.884	0.384
W. Bearskin	15.452	<0.001	-187.382	<0.001*	-130.060	<0.001*	57.322	0.048*
Loon	4.487	0.014	-62.020	0.013*	-18.559	0.722	43.461	0.142
Greenwood	5.199	0.007	-62.098	0.019*	-3.456	0.990	58.642	0.025*
Mayhew	18.214	<0.001	-203.280	<0.001*	-62.559	0.040*	140.720	0.001*
Clearwater	11.601	<0.001	-133.284	<0.001*	-56.500	0.109	76.784	0.009*
Gunflint	0.497	0.611	-0.833	1.000	28.711	0.683	29.544	0.647
Ojibway	10.999	<0.001	-210.241	0.003*	-60.625	0.655	149.616	0.001*
Snowbank	7.303	0.002	-68.667	0.247	54.400	0.317	123.067	0.001*

stocked several years earlier, recruited to the gear between spring and fall.

Relative catch rates of gear types

On a catch/net-hour basis, monofilament gill nets fished in spring and fall were 4.3 and 8.5 times more effective in capturing lake trout than the multifilament gill nets fished in summer. Mean lake trout catch rate for spring netting (30 min duration sets) was 0.77 fish/h, for fall it was 1.53, and for summer (24 h sets) it was 0.18 (Table 10). Adjusting for gill net dimensions would increase the effectiveness of the monofilament net by an additional 20% relative to the multifilament net.

Relative cost-effectiveness of index netting methods

Cost-effectiveness, estimated as mean catch/day (CPD), was relatively low for the 10 lakes, regardless of the index netting method. Daily catches, unadjusted for newly stocked yearlings, averaged 4.6 (range: 1.2 to 7.8) lake trout/day for the SLIN method, 12.7 (range 2.9 to 24.0) for the SDWIN method, and 9.3 (range: 3.4 to 19.2) for the FLIN method (Table 11). Adjusted for newly stocked yearlings, the average daily catches decreased to 10.2 for SDWIN and 9.3 for FLIN.

Spring index netting was less cost-effective in capturing lake trout than either fall or summer index netting ($U=8.617$, $P=0.013$, 2df). For 9 of the 10 lakes, mean CPD was greater in fall than in spring, and was significantly greater ($P\leq0.05$) for 6 of 10 lakes. Thus, the FLIN method captured an average of 2.3 (range: 0.8 to 5.3) times as many lake trout/day as the SLIN method. Data sets were homogeneous among lakes ($\chi^2=19.9$, $P=0.341$, $df=18$). The SDWIN method, assuming 4 overnight sets/day, was more cost-effective than the SLIN method for all 10 lakes, averaging 2.6 times as many lake trout/per day (range: 1.3 to 6.9). The SDWIN method also tended to be more effective than the FLIN method, but not consistently so, averaging 1.1 times as many lake trout/day (range: 0.5 to 2.8) in summer as were captured in fall.

Abundance Indices

In this study, each day's netting effort was equal for spring and fall index netting, therefore, spring and fall relative abundance indices were expressed as the mean number of lake trout captured/day and are identical to the

Table 10. Relative catch rate [mean number of lake trout captured per net-hour (CPNH) and standard error (SE)] of monofilament gill nets set for 30 min during daylight hours during spring (SLIN) and fall (FLIN), and of multifilament gill nets set overnight (≈24 hours) during summer (SDWIN) in 10 Minnesota lakes, 1993 or 1994.

	Number of lake trout per net-hour (CPNH)					
	Spring (SLIN)		Fall (FLIN)		Summer (SDWIN)	
Lake name	mean	(SE)	mean	(SE)	mean	(SE)
			Lakes sampled in 1993			
Kemo	0.93	(0.18)	3.13	(0.47)	0.20	(0.07)
Trout	0.90	(0.22)	1.93	(0.32)	0.29	(0.07)
West Bearskin	0.57	(0.17)	3.00	(0.34)	0.22 0.17[a]	(0.05) (0.05)
Loon	1.13	(0.25)	0.90	(0.22)	0.24 0.18[a]	(0.04) (0.03)
Greenwood	1.34	(0.27)	1.40 1.37[a]	(0.22) (0.23)	0.39 0.26[a]	(0.07) (0.04)
			Lakes sampled in 1994			
Mayhew	0.80	(0.18)	1.57	(0.24)	0.22	(0.14)
Ojibway	0.20	(0.08)	0.57 0.43[a]	(0.16) (0.14)	0.31 0.14[a]	(0.09) (0.03)
Clearwater	0.93	(0.17)	1.30	(0.22)	0.16	(0.03)
Snowbank	0.30	(0.10)	1.07	(0.20)	0.05	(0.01)
Gunflint	0.60	(0.14)	0.63	(0.15)	0.08	(0.03)
Mean of means	0.77		1.55 1.53[a]		0.22 0.18[a]	

[a] For West Bearskin, Loon, Greenwood, and Ojibway lakes, mean catch-per-net-hour (CPNH) was estimated with and without the catch of newly stocked yearling lake trout, resulting in reductions in CPNH, as shown above.

relative cost-effectiveness for SLIN and FLIN, described above (Table 11). Reported as number/net-lift, the mean abundance index for spring netting was 0.39 (range of means: 0.10 - 0.64), while the mean index for fall netting was 0.77 (range of means: 0.25 - 1.60) (Table 12). Catch/net-lift data were not normally distributed and usually were positively skewed, regardless of netting method. The median CPNL for 30 min sets was zero for all 10 lakes in spring and for 6 of 10 lakes in fall. In contrast, the median CPNL for 24 h sets, made during summer, was greater than zero for all 10 lakes and ranged from 1.0 to 8.0.

At least one lake trout was caught in each of 76 gill nets fished overnight during summer, whereas the majority (≥55%) of short duration sets caught zero lake trout during spring and fall. Summer abundance indices for the 10 lakes averaged 3.8 lake trout/net-lift (range: 1.1 - 6.5; Table 13). In spring, lake trout were caught at only 28% of the net locations, but in fall, at least one lake trout was caught at 45% of the net sites. Only 7% of the locations netted yielded two or more lake trout during spring, while for the FLIN method, this statistic was 20%, perhaps indicating that lake trout are less dispersed in fall than in spring.

Table 11. Relative cost-effectiveness of spring (SLIN) and fall (FLIN) short duration index netting, expressed as the mean lake trout number/day, for 60 monofilament gill nets (30 min sets during daylight hours) and of summer index netting (SDWIN), expressed as estimated number/day, for multifilament gill nets (≈24 h, over-night sets) in 10 Minnesota lakes, 1993 or 1994. Lakes for which fall CPUE is significantly greater ($P \leq 0.05$) than that of spring are marked with asterisks (*).

	Lake trout captured by 30 min index netting (mean number per day)						Lake trout captured by overnight index netting (Estimated[a] number/day)
	Spring (SLIN)			Fall (FLIN)			
Lake name	mean	SE	CV	mean	SE	CV	Summer (SDWIN)
West Bearskin*	3.4	1.21	0.80	18.0	2.55	0.32	11.6
							(8.9)[b]
Trout*	5.6	1.12	0.45	11.4	2.38	0.47	17.3
Kemo*	5.8	0.92	0.35	19.2	3.40	0.40	12.0
Loon	6.8	1.16	0.38	5.4	0.81	0.36	14.3
							(10.7)[b]
Greenwood	7.8	2.80	0.80	8.4	2.29	0.61	24.0
				(8.2)[b]	2.15	0.59	(16.0)[b]
Ojibway*	1.2	0.58	1.09	3.4	1.17	0.77	19.3
				(3.0)[b]	1.34	1.00	(8.3)[b]
Snowbank*	1.8	0.37	0.47	6.4	1.29	0.45	2.9
Gunflint	3.6	0.51	0.32	3.8	1.24	0.73	4.7
Mayhew*	4.8	1.74	0.81	9.4	0.87	0.21	12.4
Clearwater	5.6	1.29	0.51	7.8	1.46	0.42	8.9
Average	4.64	0.48	0.73	9.32	0.92	0.70	12.74
				(9.26)[b]	0.93	0.71	(10.21)[b]

[a] The estimated lake trout number/day was calculated for each lake as the mean observed catch/net-lift multiplied by 8 nets/3 days.

[b] The mean catch/day was adjusted by subtracting the number of the newly stocked cohorts from each net total before averaging the daily catches.

Simple linear regression indicated a significant positive relationship ($r^2=0.522$, $P=0.018$) between spring CPD and summer CPNL. Linear relationships between spring and fall abundance indices and between summer and fall abundance indices, however, although positive, were not significant ($r^2<0.121$, $P>0.325$) and are not predictive. Neither lake area nor $\log_{10}$ of lake area accounted for a significant proportion of the variance of abundance indices ($r^2<0.387$, $P>0.05$).

Precision of abundance indices

All three relative abundance indices were imprecise, none having a relative precision better than 43%. Spring and fall indices were less precise than the summer indices, as indicated by coefficients of variation for spring (mean CV = 1.94) and fall (mean CV = 1.46) catch/lift data (Table 12) that were larger than those for summer (mean CV = 0.73, Table 13). Linear regressions of $\log_{10}$ variance of the abundance index on $\log_{10}$ of the index (Table 14) were highly significant for spring ($r^2=0.928$, $P<0.001$) and fall ($r^2=0.912$, $P<0.001$) index netting. The variance-index relationship was also significant for summer index netting, but of less predictive value ($r^2=0.602$, $P=0.008$). Based on these regression relationships, many more gill net sets would have been required to attain relative precision of 15% or 20% for the SLIN method than for the FLIN or SDWIN methods (Table 14).

Ageing lake trout

Difficulty in assigning ages to lake trout varied among lakes. Known age lake trout composed a relatively small proportion

Table 12. Lake trout catch per 30 min net-lift for 10 Minnesota lake trout lakes, captured during spring (SLIN) and fall (FLIN) index netting methods with monofilament gill nets, 1993 and 1994, and results of rank sum tests (Mann-Whitney U statistic) comparing spring and fall catch-per-net-lift. Asterisks (*) denote lakes having significant differences ($P \leq 0.05$) in the distributions of spring and fall individual net catches.

	Catch per net-lift						Mann-Whitney test statistic		Chi-square approx.
	Spring (SLIN)			Fall (FLIN)					
Lake Name	mean	SE	CV	mean	SE	CV	U	*P*	1 df
Lakes sampled in 1993									
W.Bearskin*	0.28	0.08	2.26	1.50	0.17	0.89	714.5	<0.001	38.460
Trout*	0.47	0.11	1.79	0.97	0.16	1.31	1392.0	0.016	5.841
Kemo*	0.48	0.09	1.45	1.60	0.25	1.91	1142.0	<0.001	13.862
Loon	0.57	0.12	1.70	0.45	0.11	1.85	1932.0	0.402	0.704
Greenwood	0.64	0.13	1.55	0.68[a]	0.11	1.28	1638.5	0.541	0.374
Total	0.49	0.05	1.72	1.04	0.08	1.32			
Lakes sampled in 1994									
Ojibway	0.10	0.04	1.39	0.25[a]	0.07	2.29	1664.0	0.115	2.485
Snowbank*	0.15	0.52	3.03	0.53	0.10	1.48	1332.5	0.001	10.294
Gunflint	0.30	0.07	2.70	0.32	0.08	1.89	1813.0	0.929	0.008
Mayhew*	0.40	0.09	1.73	0.78	0.12	1.18	1371.5	0.011	6.527
Clearwater	0.47	0.08	1.77	0.65	0.11	1.29	1627.5	0.304	1.057
Total	0.28	0.03	1.95	0.51	0.05	1.54			

[a] Lake trout identified as the newly stocked (June) cohort were subtracted from the fall totals because those fish were not part of the lake trout population during the spring sampling season.

Table 13. Summary of netting effort, catch, and relative abundance indices (catch per net-lift) for lake trout captured during summer deep water index netting (SDWIN) in overnight (approximately 24 h) gill sets in 10 Minnesota lakes in summer 1993 and 1994. Asterisks (*) denote catch totals and means from which recently stocked spring yearling lake trout were subtracted.

	Effort		Total catch	SDWIN Abundance Index (lake trout catch/lift)		
Lake name	Net-lifts (*N*)	Days (*N*)	(*N*)	mean	SE	CV
1993 netting						
West Bearskin	6	4	20*	3.33*	0.955	0.701
	6	4	26	4.33	1.022	0.578
Loon	8	5	32*	4.00*	0.707	0.500
	8	5	43	5.38	0.885	0.466
Kemo	4	2	18	4.50	1.658	0.737
Trout	4	3	26	6.50	1.500	0.462
Greenwood	8	5	48*	6.00*	0.906	0.427
	8	5	72	9.00	1.488	0.468
1994 netting						
Snowbank	12	5	13	1.08	0.260	0.831
Gunflint	12	7	21	1.75	2.261	1.292
Ojibway	8	3	25*	3.13*	0.743	0.672
	8	3	58	7.25	2.102	0.820
Clearwater	11	5	37	3.36	0.717	0.707
Mayhew	3	3	14	4.67	2.728	1.013

Table 14. Relationships between the variance of abundance indices and abundance indices (mean number per net-lift), and estimates of netting effort needed to provide specified levels of relative precision (CV). Abundance indices are means from 10 Minnesota lake trout lakes sampled by 30 min index netting in spring (SLIN) and fall (FLIN) and 24 h index netting in summer (SDWIN). The relationship between variance of the abundance index and the abundance index is described by the function: $s^2 = a(\text{abundance index}^b)$ as per Lester et al. (1991).

Index netting method	Constant a	Abundance index (no./lift)	Exponent b	Variance (s^2)	Estimated effort needed for: CV=15%	CV=20%
12 lifts per day (30 min duration)						
SLIN	1.466	0.386	1.194	0.470	30 days 363 nets	17 days 204 nets
FLIN	1.403	0.772	1.160	1.039	9 days 100 nets	5 days 57 nets
4 lifts per day (24 h duration)						
SDWIN	1.282	3.832	1.206	6.481	2 days 6 nets	1 day 3 nets

(range: 0-30%) of the total number of lake trout captured in 7 of the 10 study lakes. In the other three lakes (West Bearskin, Loon, and Ojibway), stocked yearlings, having cohort identifying fin clips, composed 74, 42, and 41 % of the lake trout captured. Lakes, such as Kemo, Trout, and Clearwater, having a large proportion of the unknown age fish, may have a higher proportion of incorrectly aged lake trout than lakes having more known age fish. Because ages derived from lake trout scales and fin rays tend to underestimate true age, especially for older fish, a higher proportion of unmarked fish may have been "under aged" than "over aged", potentially biasing estimates towards faster growth.

Growth Index: A400

Estimates of L_∞ tended to be greater than those predicted from OMNR reference values (Table 15 and Figure 2, left side panels), regardless of index netting method or season.

Lake trout growth, as described by A400, varied among lakes, ranging from 4.1 to 9.9 years among lakes and index netting methods (Table 16). Estimates of A400 also varied among spring, summer, and fall collections within lakes, but differences were not related to index netting method ($T=1.13<F_{2,18,P=0.05}=3.55$). Differences in A400 estimates among index methods, particularly for Ojibway, Snowbank and Gunflint lakes likely were due to inadequate sample sizes.

For Kemo, Trout, Mayhew, and West Bearskin lakes (<200 ha), A400 indices were less than the OMNR reference values of A400 for lakes of that size, indicating faster growth rates for juvenile fish and perhaps lower abundance (Figure 2, right side panels). A400 indices for Loon, Clearwater, and Greenwood lakes, 3 of 5 lakes larger than 200 hectares, tended to be larger than the reference values for lakes of similar size and indicate slower than expected growth rates for lakes of those sizes.

Table 15. Lake area, predicted asymptotic fork and total lengths (L_∞), and A400[a], the predicted age at 400 mm FL, which is equivalent to A441, the age at 441 mm TL, for 10 Minnesota lake trout lakes.

Lake name	Lake area (ha)	L_∞ Fork length[b] (mm)	L_∞ Total length[c] (mm)	A400 (age at 400 mm) (years)
Kemo	74.5	490	539	8.8
Mayhew	88.8	499	548	8.6
Trout	104.0	506	556	8.4
Ojibway	150.1	523	575	8.1
W. Bearskin	199.9	536	589	7.8
Loon	414.8	570	626	7.3
Clearwater	536.2	582	639	7.1
Greenwood	797.3	600	659	7.0
Snowbank	1336.7	625	685	6.8
Gunflint	1703.8	636	698	6.7

[a] $A400 = -(L_\infty/94.1)\ln(1-400/L_\infty)$; Lester et al. (1991).

[b] $L_\infty = 290 + 107(\log_{10}\text{Area})$; Payne et al. (1990).

[c] Predicted asymptotic total length was derived from fork length using the following linear regression relationship: total length = (fork length + 4.669) / 0.918, $r^2=0.998$, $P<0.001$ (Siesennop, unpublished data).

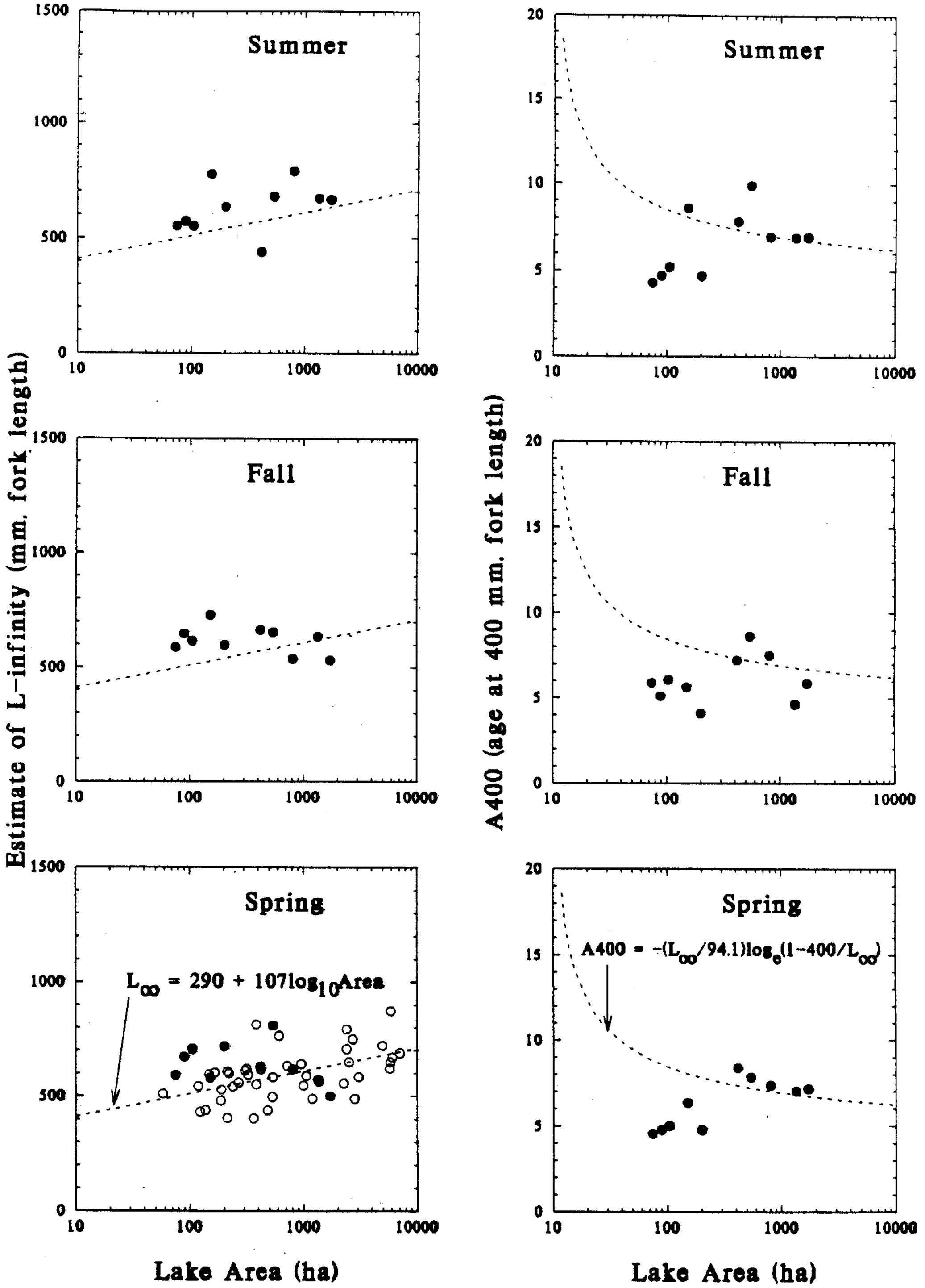

Figure 2. Estimates of asymptotic fork length (L∞) and age at 400 mm (A400) for lake trout collected in spring, fall, and summer 1993 or 1994 in 10 Minnesota lakes (filled circles) related to lake area. OMNR criteria (dashed lines) for evaluating growth in terms of asymptoc length (Payne et al. 1990) and age at 400 mm (Lester et al. 1991), and 47 Ontario lakes less than 10,000 hectares (open circles) data from Payne et al. 1990).

Table 16. Number of lake trout (*N*), indices of lake trout abundance (CPUE), mortality (ML400 and ML441), growth (A400), empirical estimates (FL) of von Bertalanffy growth parameters (L_∞' and K'), and condition parameters (a, b) estimated from data collected during spring (SLIN) and fall (FLIN) littoral index netting and summer, deep water index netting (SDWIN) in 10 northeastern Minnesota lakes in 1993 or 1994 and comparisons to OMNR reference values (Lester et al. 1991).

Lake[a]	Season	Index netting method	Abundance index: number per net-lift (*N*)	Abundance index: number per net-lift (CPUE)	(*N*)	Mortality index mean length greater than: 400 mm (FL) ML400	Mortality index mean length greater than: 441 mm (TL) ML441	Empirical estimates of von Bertalanffy parameters: L_∞' (cm)	Empirical estimates of von Bertalanffy parameters: K'	Growth index A400: age at 400 mm (years)	Condition: weight-length parameters ($W = aL^b$) a*10^{-6}	Condition: weight-length parameters ($W = aL^b$) b
reference values[b]:		SLIN	not yet available			see 50% line in Fig. 3		-	-	see Fig. 2	3.88	3.18
KE	Spring	SLIN	29	0.47	22	509	559	59.0	0.352	4.5	11.508	2.99
	Fall	FLIN	96	1.60	66	511	562	58.7	0.200	5.9	33.343	2.83
	Summer	SDWIN	18	4.5	8	492	541	55.0	0.344	4.3	56.364	2.74
Pooled estimates:					**96**	**510**	**561**	**58.5**		**4.9**		
MH	Spring	SLIN	24	0.40	17	514	565	67.1	0.173	4.8	39.994	2.79
	Fall	FLIN	47	0.78	24	480	528	64.7	0.186	5.1	7.674	3.07
	Summer	SDWIN	14	4.7	1	509	560	56.9	0.254	4.7	17.378	2.93
Pooled estimates:					**42**	**493**	**542**	**67.8**		**4.9**		
TR	Spring	SLIN	28	0.47	18	485	533	70.5	0.163	5.0	0.305	3.62
	Fall	FLIN	57	0.95	22	496	545	61.5	0.162	6.1	1.603	3.34
	Summer	SDWIN	26	6.5	8	460	507	54.8	0.226	5.2	0.899	3.43
Pooled estimates:					**48**	**486**	**534**	**61.4**		**5.4**		
OJ	Spring	SLIN	6	0.10	4	472	520	57.8	0.196	6.3	7.447	3.08
	Fall	FLIN	15	0.25	5	587	644	72.9	0.110	5.6	5.012	3.14
	Summer	SDWIN	58	3.1	4	620	681	77.3	0.084	8.6	19.364	2.90
Pooled estimates:					**13**	**566**	**622**	**75.0**		**6.8**		
WB	Spring	SLIN	17	0.28	13	569	625	71.6	0.203	4.8	9.795	3.05
	Fall	FLIN	90	1.50	19	524	576	59.6	0.330	4.1	8.570	3.06
	Summer	SDWIN	32	4.3	7	506	556	63.1	0.219	4.7	2.178	3.30
Pooled estimates:					**39**	**542**	**596**	**65.6**		**4.5**		
LN	Spring	SLIN	34	0.55	6	482	530	62.8	0.112	8.4	0.877	3.44
	Fall	FLIN	27	0.45	5	481	529	66.4	0.116	7.2	1.442	3.34
	Summer	SDWIN	43	5.4	9	425	469	44.0	0.272	7.8	3.327	3.21
Pooled estimates:					**20**	**460**	**506**	**56.6**		**7.8**		

Table 16. Continued.

Lake[a]	Season	Index netting method	Abundance index: number per net-lift (*N*)	Abundance index: number per net-lift (CPUE)	(*N*)	Mortality index mean length greater than: 400 mm (FL) ML400	Mortality index mean length greater than: 441 mm (TL) ML441	Empirical estimates of von Bertalanffy parameters: L_∞' (cm)	Empirical estimates of von Bertalanffy parameters: K'	Growth index A400: age at 400 mm (years)	Condition: weight-length parameters ($W = aL^b$) $a*10^{-6}$	Condition: weight-length parameters ($W = aL^b$) b
CW	Spring	SLIN	26	0.47	21	509	560	80.7	0.104	7.8	4.853	3.14
	Fall	FLIN	39	0.65	25	475	522	65.3	0.129	8.6	9.772	3.02
	Summer	SDWIN	37	3.4	11	472	519	67.7	0.119	9.9	2.113	3.28
Pooled estimates:					**57**	**487**	**536**	**71.6**		**8.8**		
GW	Spring	SLIN	39	0.66	9	473	520	61.6	0.141	7.3	3.041	3.22
	Fall	FLIN	42	0.68	11	441	486	53.6	0.101	7.5	1.102	3.37
	Summer	SDWIN	72	1.5	10	552	606	78.8	0.102	6.9	7.413	3.06
Pooled estimates:					**30**	**488**	**537**	**62.1**		**7.3**		
SB	Spring	SLIN	9	0.15	8	483	531	57.0	0.172	7.0	20.941	2.91
	Fall	FLIN	32	0.53	29	525	577	63.5	0.210	4.6	1.138	3.38
	Summer	SDWIN	13	1.1	5	559	614	67.0	0.139	6.9	1.306	3.37
Pooled estimates:					**42**	**522**	**574**	**64.6**		**6.2**		
GF	Spring	SLIN	18	0.30	18	450	496	49.9	0.330	7.1	0.474	3.52
	Fall	FLIN	19	0.32	19	477	524	53.0	0.286	5.9	1135.011	2.25
	Summer	SDWIN	21	1.8	14	536	589	66.4	0.147	6.9	2.449	3.26
Pooled estimates:					**51**	**484**	**532**	**69.0**		**6.6**		

[a] Lake name abbreviations: KE = Kemo; TR = Trout; WB = West Bearskin; LN = Loon; GW = Greenwood; MH = Mayhew; CW = Clearwater; GF = Gunflint; OJ= Ojibway; and SB = Snowbank.

[b] OMNR reference values, including the reference lines in figures 3 and 4 are reproduced from figures 11 and 14 from Lester et al. 1991.

Linear regression of age at 400 mm on $\log_{10}$ of lake area did not adequately explain the variation in age at 400 mm, regardless of the collection period. Linear regression explained less of the variation in A400 relative to lake area for fall ($r^2=0.054$; $P=0.517$) or summer ($r^2=0.278$; $P=0.117$) data sets than for the spring ($r^2=0.596$; $P=0.009$) data sets. Residuals were normally distributed, and not serially correlated, errors appeared to be independent, and Cook's distances were small (<0.5), however, variances were dissimilar.

Mortality Index: ML400

Mean length above 400 mm FL ranged from 425 to 587 mm, varying with lake, index netting method, and season (Table 16). The pooled mortality index, $ML400_p$ (i.e., the mean fork length of all lake trout greater than 400 mm captured in all three index netting periods) ranged from 460 to 566 mm. The relationship of $ML400_p$ to asymptotic fork length is shown in Figure 3 (upper panel). This mortality index, being growth dependent, was evaluated relative to the A400 growth index (Figure 3, lower panel). Relative to the OMNR 50% annual mortality criterion (Lester et al. 1991), lake trout mortality may be considered high in 4 of 9 lakes and low in the remaining 5 lakes. Lake trout annual mortality appears to be in the 40-55% range for Mayhew, Trout, Kemo, and West Bearskin lakes. For Snowbank, Greenwood, Gunflint, Loon, and Clearwater lakes, annual mortality may be less than 30%, although $ML400_p$ values for Loon and Greenwood lakes are considered less reliable because sample size was small ($N \leq 30$). Sample size for Ojibway Lake was too low ($N=13$) to rely on the A400 estimate.

Condition

Small sample sizes limited precision of condition estimates (weight-length relationships) for many index netting collections. Only 8 of 30 weight-length relationships were estimated from sample sizes larger than 40 lake trout, with small and large fish composing only a small proportion of each collection (Tables 4 and 5). Some weight-length relationships were similar (Tables 16 and A2), but a single function does not describe condition of lake trout for all 10 study lakes. Slopes of the $\log_{10}$ weight-$\log_{10}$ length relationships were heterogenous for spring ($P<0.001$), summer ($P<0.001$), and fall ($P<0.001$) data sets (Table A3). Among season comparisons of spring, summer, and fall regression lines for 8 of 10 lakes indicated that slopes were homogeneous within lakes ($P>0.065$). Slopes for Kemo and West Bearskin lakes were heterogeneous ($P<0.009$). Y-intercepts were different among seasons ($P<0.026$), for Loon and Greenwood lakes, while those for Trout, Mayhew, Clearwater, and Snowbank lakes were homogeneous ($P>0.065$).

Weight-length relationships indicate that lake trout from Kemo and Mayhew lakes were less plump than the OMNR "standard" while, lake trout from Trout and West Bearskin lakes were more plump than the OMNR standard, regardless of collection season. The lake trout from Loon, Greenwood, and Clearwater lakes, depending on season, tended to be similar to or more plump than the OMNR standard. The lake trout captured during fall index netting in Snowbank Lake tended to be more slightly more plump than the OMNR standard, but sample sizes from spring and summer collections were small (<15 fish). Because sample sizes from Gunflint and Ojibway lakes were usually less than 20 fish, or represented a narrow weight-length range, weight-length relationships for these lakes are inadequate.

Species composition among index netting methods

Neither the monofilament gill nets used in the SLIN and FLIN methods nor the multifilament gill nets used in the SDWIN method sample all major species present in the lakes (Table A1), although they catch several species in addition to lake trout (Tables A4 and A5). In 8 of 10 lakes, either lake trout or cisco dominated the net catch, regardless of index netting method. The proportion of lake trout

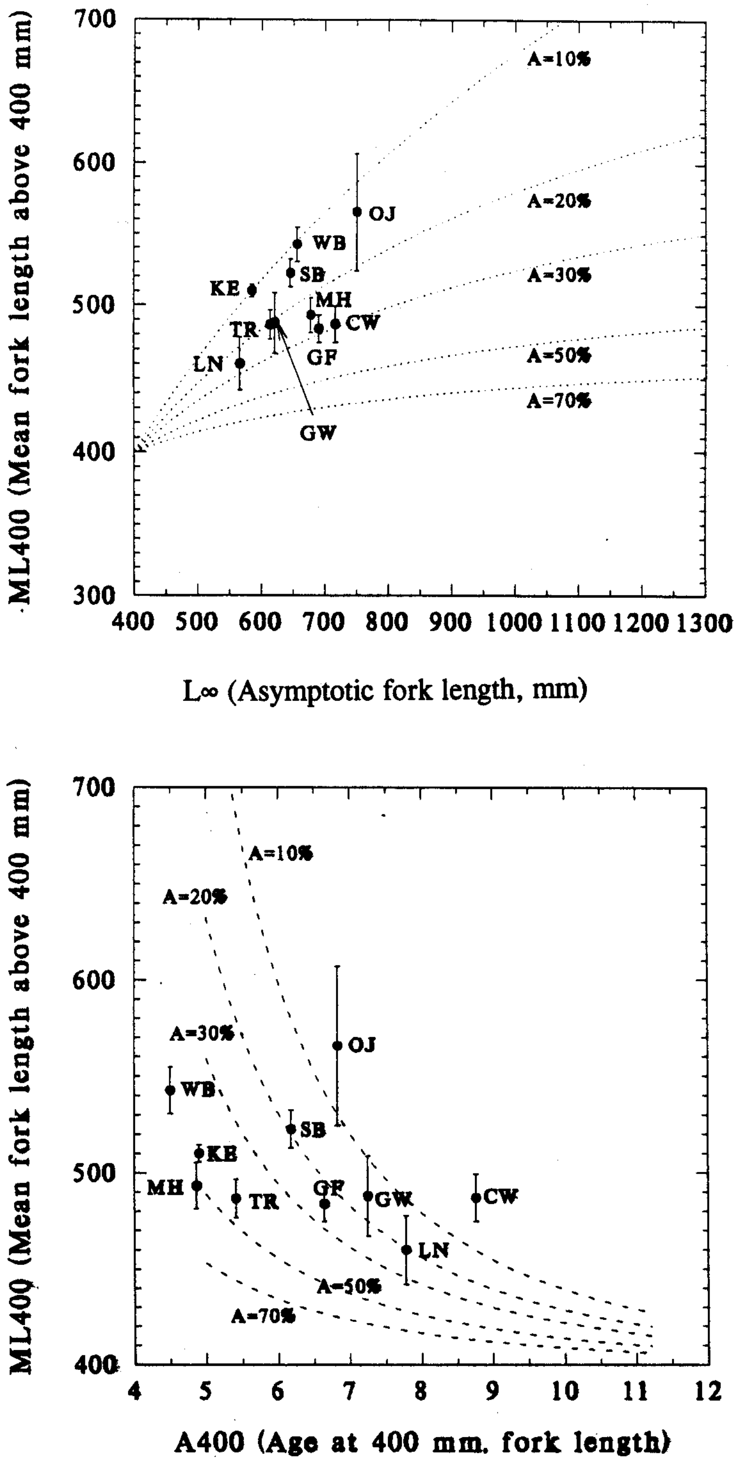

Figure 3. Mean length above 400 mm (ML400) as an index of mortality is shown in the upper figure, as per Lester et al. (1991). The expected relationship between ML400 and L∞ is shown for selected annual mortality rates. ML400 and L∞ for 10 Minnesota lakes (filled circles) were calculated from pooled data from spring, summer, and fall index netting data, 1993 or 1994. In the lower figure, L∞ has been transformed to age at 400 mm (A400) for the same lakes. Error bars = SE.

in the catch, however, varied greatly among lakes and index netting methods, ranging from 7 to 100%. Coregonids, when present, usually were the largest component of the bycatch (range: 21 - 81%) of spring, summer, and fall index netting. Cisco CPNL, however, was highly variable (Tables A4 and A5) and probably is related to their schooling behavior. Warm or cool water species, such as centrarchids, walleye, and northern pike usually composed only a small portion of the net catch, regardless of index netting method. Burbot were captured in Clearwater, Snowbank, and Gunflint lakes by the SDWIN method, but none were captured by the SLIN or FLIN methods. Smaller forage species, such as trout perch *Percopsis omiscomaycus* and rainbow smelt, were not captured by the smallest mesh (19 mm) of the mono- or multifilament netting gear, but are present in several study lakes and susceptible to capture in 10 and 13 mm mesh sizes (MNDNR, unpublished data).

For 7 of 10 lakes, lake trout composed a larger proportion of the total catch during fall index netting than during the spring index netting (Table A4). Yellow perch and brook trout composed greater proportions of the 30 min net catch in fall than in spring, whereas, cisco, rainbow trout, splake, and white sucker were more common in spring catch than in fall. Lower catch of rainbow trout and splake in fall may have resulted from mortality throughout the angling season. Proportions of various species captured in spring and fall were homogeneous ($P \geq 0.07$) only for Clearwater and Loon lakes (Table A6).

Lake trout and burbot, when present, composed a higher proportion of the summer catch than they did in the spring index netting catch. Other species including white sucker, rainbow trout, splake, cisco, and yellow perch were more common in the spring index netting catch than in the deep water gill netting catch during summer. No rainbow trout were caught in deep water sets in Trout Lake during the summer. Proportions of species captured in spring and fall were heterogeneous ($P \leq 0.0082$) for all 10 lakes (Table A6).

Lake trout, cisco, and burbot composed larger proportions of the total catch of summer deep water index netting than of fall index netting. Brook trout, rainbow trout, and yellow perch, however, tended to be better represented in the fall index netting than during summer index netting. Proportions of species captured in spring, summer, and fall were homogeneous ($P \geq 0.08$) only for West Bearskin and Loon lakes (Table A6).

Discussion

Short duration index netting in near shore waters in spring or fall can be used to minimize lake trout mortality, while obtaining estimates of their relative abundance. The 10% average mortality for spring and fall observed in this study is similar to the 9% (43/485 - pooled mesh sizes and lakes) mortality reported for tests of the 30 min index netting procedure in spring for 3 Ontario lakes (Petzold, personal communication 1992). In contrast to short duration netting, overnight summer index netting in off-shore waters can be expected to kill 75% or more of the captured lake trout. Differences in acute mortality between spring and fall sampling periods in this study may be related to differences in fish condition, the amount of time individual fish were caught in the nets, or differences in the abilities of various crews to remove lake trout from the nets and process them.

Length-frequency distributions showed that smaller lake trout were caught in the smallest of the three monofilament mesh sizes and that a broad range of lake trout sizes were caught in all three mesh sizes. Size ranges were broad because gill nets have two capture modes. Relatively small fish are caught by gilling or wedging in the meshes, while relatively large fish cannot be gilled or wedged, but are initially caught by their teeth or maxillary bone(s) and may become rolled or wrapped in the net. Since overall differences in the length-frequency distributions were small, it was reasonable to pool data from the three mesh sizes and calculate spring or fall abundance indices as mean catch/day or as mean catch/net-lift.

The three index netting methods sampled somewhat different segments of the lake trout population. The summer 24 h population assessment netting in deeper, thermally stratified water tended to catch more small, young lake trout than the 30 min index netting used in near shore areas in spring or fall. Size and age related differences in lake trout behavior that vary seasonally probably account for some of the differences in length-frequency distributions of lake trout captured by the three index netting methods. This is consistent with Evans et al. (1991) hypothesis that deep, cold water provides a refuge in summer for juvenile lake trout from larger, potentially cannibalistic subadults and adults. In midsummer, in South Wildcat Lake, Ontario, juvenile lake trout (<240 mm TL) were sampled in water <4.5°C and deeper than 30 m, while subadults (>240 mm TL) and adults, with few exceptions, were found in shallower (10-25 m) and warmer (approximately 4.5 - 9°C) water (Casselman 1987).

Cost-effectiveness of the spring index netting method (4.6 lake trout/day) was approximately one-half that of fall index netting (9.3) and summer index netting (10.5) in this study, but was similar to the low average catch/day (4.9) reported by Petzold (OMNR, personal communication 1992). On average, the summer MNDNR lake trout index netting (assuming 4 overnight gill net sets/day) might be expected to catch more lake trout/day than the 30 min method applied in either spring or fall, but SDWIN would kill a much higher proportion of the lake trout catch.

Relative abundance indices for the SLIN method for the 10 lakes in this study were similar to those for 14 Ontario lakes that averaged 0.4 lake trout/net-lift (range of means: 0.02 - 1.66). The latter information is from 22 data sets (1988-1992) in which at least 50 short duration sets were made (Petzold, personal communication 1992). In this study, abundance indices derived from the SLIN method were positively related to those derived from the SDWIN method and may have some predictive value. The spring and summer abundance indices, however, were not useful in predicting relative abundance indices derived from fall catch data. Lake trout prespawning and spawning activity in fall may explain why fall CPUE tended to be greater than spring CPUE.

Summer abundance indices for lake trout can be compared among years for a given lake, but among lakes comparisons of relative abundance may not be valid if summer netting locations are not randomly selected. Spring or fall abundance indices obtained from randomly selected netting locations, can be compared among lakes and years.

Relative abundance indices may be useful descriptors of lake trout populations if they can be shown to have a significant relationship with lake trout population size or angler catch rates. If the SLIN, FLIN, or SDWIN indices do not relate to actual lake trout abundance or to angling catch rates, index netting may be an expensive way to capture relatively small numbers of lake trout. Therefore, index netting needs to be done in conjunction with estimates of population size and catch rate for lake trout sport fisheries (Lester et al. 1991). Alternatively, Minnesota might extrapolate from relative abundance, population size, and angling data from Ontario's more intensively studied Fisheries Assessment Unit (FAU) lakes, when such data becomes available.

The amount of spring index netting effort (net-lifts or days) needed to achieve 15% or 20% relative precision for relative abundance indices would be impractical for most lakes based on variance-abundance index relationships observed in this study. Relatively precise abundance indices, however, may be more easily attained by the SDWIN and FLIN methods than by the SLIN method, especially for lakes having large populations (high CPUE's). For lakes with small populations (low CPUE) it may not be feasible to precisely estimate relative abundance by any of the three methods. The SLIN or FLIN index netting methods would be unlikely to give precise relative abundance estimates, if netting effort (12 lifts/day) were limited to 3 to 5 days.

Petzold (OMNR, personal communication 1992), using data from 14 Ontario lakes, estimated that 17 days of spring index netting (204 net-lifts) may be needed to achieve 15% relative precision, assuming effort of twelve 30 min sets/day and a mean index of 0.4 fish/lift. He stated that this effort exceeds the "practical" sampling goal of 10 days per lake.

The greater relative precision of the SDWIN method compared to the SLIN or FLIN methods depends on several factors, including set duration, selection of net locations, and seasonal differences in the amount of thermally suitable habitat for lake trout. These factors tend to make it more likely that at least one lake trout would be captured/net-lift for the SDWIN method than for the SLIN or FLIN methods. In this study, more than one-half the 30 min spring and fall sets caught zero lake trout, but none of the 24 h summer sets had zero catches. The chance of a lake trout encountering a 24 h gill net set is greater than for a lake trout encountering a short duration set. Lake trout, being more confined by temperature to a smaller lake volume in summer than in spring or fall, may be more likely to be captured in summer. Summer relative abundance indices may also be biased (up or down) because different netting crews may have used different criteria when they originally chose netting locations, although all summer netting locations theoretically are in suitable thermal zones.

Several feeding and growth scenarios may explain the empirical lake trout growth indices. Lake trout in Mayhew, Trout, and Kemo lakes showed relatively fast growth (low A400), faster than that predicted by the OMNR reference equation, perhaps because their food (zooplankton and various cyprinids) may be more abundant in the absence of potential competitors, including smallmouth bass, walleye, and northern pike. In these lakes, foraging efficiency may be influenced more by intraspecific competition, including cannibalism, and other lake specific factors, than by interspecific competition for food. In West Bearskin Lake, juvenile growth may be slow initially due to interspecific (smallmouth bass) and intraspecific competition for food, but it accelerates at about age 3 to 5 (Siesennop 1992), as lake trout begin to prey on rainbow smelt (Hassinger and Close 1984), resulting in faster growth and a low A400.

Foraging efficiency may be reduced in lakes having one or more potential competitor species and may result in slower growth, particularly for juvenile lake trout. For Loon, Clearwater, Greenwood, Snowbank, and Gunflint lakes, A400 growth indices were similar to or higher than those predicted for lakes of similar size. In these lakes, relatively slow growth of juvenile lake trout may be the result of competition with introduced coregonids, centrarchids, or walleye. A400 values were lower in Mayhew, Kemo, and Trout lakes where smallmouth bass were not present. Matuszek et al. (1990) described changes in growth and mortality rates of lake trout in Lake Opeongo, and related them to introductions of cisco. Eiler and Sak (1993) reported that growth rates of juvenile lake trout tended to be higher in lake trout lakes without smallmouth bass than in lakes with smallmouth bass.

The OMNR mortality index is easy to calculate, and when evaluated along with the growth index and OMNR reference values it could be a starting point for comparing and evaluating some of Minnesota's lake trout populations. In this study, the ML400 indices show that mortality may be less than 40% in some lakes and over 40% in others, thus, some lakes may be stressed. Payne et al. (1990) indicated lake trout populations experiencing 50% annual mortality ($Z=0.693$) are almost certainly being over-exploited. Lester et al. (1991) recommended "that a total annual mortality of 50% be used to classify district lakes" and that 50% "be interpreted as the maximum acceptable level of mortality." This may be a dangerous level that may not allow a lake trout population to survive without regular maintenance stocking. "Safe" levels of total mortality have not yet been determined (Lester et al. 1991). More conservative annual mortality rates, perhaps less than 30% ($Z=0.355$), are more likely to result in continued successful natural reproduction. This issue, however, is being researched by

OMNR biologists (R. Korver, OMNR, personal communication 1996).

Among-lakes differences in lake trout weight-length relationships, disregarding seasonal effects, relate to differences in kind (quality) and quantity of forage, lake trout abundance, the kind and abundance of potential competitors, and relative stomach fullness when lake trout are weighed in the field. Lake trout condition may also correlate with environmental or man induced stresses. Lake trout from Kemo and Mayhew lakes, without rainbow smelt or coregonines, tended to be less plump than lake trout from the other lakes and were less plump than the OMNR "standard." They were different than the heavier bodied lake trout from Trout and West Bearskin lakes, having smelt or ciscos as forage, that were more plump than the OMNR standard. The weight-length relationships for the remaining lakes were between the extremes (Mayhew and Kemo lakes compared to Trout and West Bearskin lakes) and were often similar to the weight-length relationship of the OMNR standard. Inadequate sample sizes, poorly represented size classes, larger pre-spawn weights, or lower post-spawn weights for mature fish resulted in variable or unreliable weight-length relationships for some data sets.

All three index netting methods were effective in that they successfully targeted coldwater species, mainly lake trout and cisco for the 10 study lakes. Catch/effort data also provides imprecise but useful relative abundance indices for other species commonly captured by the short duration SLIN and FLIN methods, including other salmonids and coregonids, catostomids, or percids, but not for infrequently captured centrarchids, northern pike, burbot, and small forage species. Catch/effort data from the overnight SDWIN method may yield useful relative abundance indices for cisco, burbot, and white sucker in addition to lake trout, but not for warm or cool water species.

The three index netting methods have different favorable and unfavorable characteristics. Much of the effort expended applying the SLIN method seemed unproductive because a high proportion of the 30 min net sets caught no lake trout. The SLIN method was less cost-effective in terms of the lake trout number/effort expended than either the FLIN or the SDWIN methods. Although the estimated mean catch/day for the SDWIN method was only slightly greater than that of the FLIN method in this study, the SDWIN method is less desirable because of high trout mortality. If large sample size and minimal sampling mortality are high priorities, then fall index netting would seem to be the best choice. Fall index netting and summer netting, to a lesser extent, however, sample lake trout in varying states of gonadal development, complicating growth modeling and condition analyses, whereas spring index netting would minimize this variation. Regardless of which netting method was used to obtain an index of lake trout relative abundance, sample sizes were often marginal or inadequate for describing population structure and estimating growth, mortality, and condition. If it is necessary to estimate population parameters with high precision, then larger sample sizes are needed than can be expected from 60 short duration monofilament gill nets or from 6 to 10 overnight multifil-ament gill nets.

Precision of abundance, growth, mortality, and condition indices could be increased by increasing sampling effort. This may be done by some combination of making more net lifts, increasing the length of the gill nets, or increasing the fishing time of individual nets, with an accompanying increase in lake trout mortality due to netting and handling. These kinds of modifications to the originally described SLIN method are being studied by OMNR biologists (Lester, personal communication 1996).

Effectiveness of the summer index netting method probably could be increased significantly by changing the kind of gill net webbing from the more coarse, more visible, twisted multifilament to finer, less visible monofilament. Before considering a change to monofilament nets, the effectiveness of monofilament webbing of the same mesh sizes must be compared to that of the current MNDNR nets. A calibration factor, derived from concurrent monofilament and multifilament gill netting during a gear transition period, should be applied to historic lake trout CPUE data so that previous data sets could be compared.

One of the deficiencies of the OMNR "research" gill net, however, is the relative fragility of the monofilament webbing. These gill nets are easily damaged, especially if caught on angular rock substrate or submerged trees or branches. The problem worsens when winds are strong and the nets cannot be rapidly lifted. Stronger meshes, without a significant increase in net visibility, would improve monofilament net durability.

Less visible monofilament gill nets are also more effective for sampling other salmonids (rainbow trout, splake, brown trout *Salmo trutta*) stocked in lakes than multifilament lake survey gill nets (MNDNR, unpublished data). A large proportion of these species caught in short duration sets may also be released in good condition.

Management Implications

Fisheries managers need the ability to evaluate, manage, and preserve lake trout in lakes with suspected small population size or those with over-exploited, remnant, or genetically distinct populations. In these situations, nonlethal methods of obtaining abundance indices or population sampling may be necessary. A broad range of lake trout sizes can be captured in short duration monofilament gill nets fished in near shore waters during spring or fall, but fall CPUE often may be greater than spring CPUE for a given lake. Using either of these methods, 80-90% of the captured lake trout may be released with good expectation of long term survival. Before adopting a nonlethal index netting procedure, MNDNR fisheries managers should wait for OMNR's evaluation of modifications to the SLIN method which is expected in 1997 (Lester, personal communication 1996). Deep water netting in summer also samples a broad range of lake trout sizes and is an appropriate index netting method when sampling mortality is not an issue. Mesh sizes smaller than 19 mm, fished in water deeper than 15 meters, may be needed to sample juvenile lake trout (1-3 years old), particularly in lakes where juvenile growth is slow.

If managers and biologists, for whatever reason, cannot sample intensively, then their estimates of relative abundance, growth, mortality, and condition will be relatively imprecise, and they will be at greater risk of making incorrect decisions about management of lake trout lakes. Fifty lake trout may be a reasonable minimum sample size for estimating the empirical indices, depending on size and age distribution, but even that sample size was not often achieved by the amount of effort allotted to spring or fall index netting in this study or in typical lake trout assessment netting efforts in Minnesota. Lester et al. (1991) suggested, that when sample sizes are small it is acceptable to pool data among seasons and sampling methods. For example, data from angler-caught lake trout in the open water season and data from those caught during spring or summer index netting could be combined to estimate growth, mortality, and condition indices.

The OMNR growth, mortality, and condition indices recommended for Ontario lakes are readily calculated and useful. They should be calculated for lake trout collected from Minnesota lake trout lakes, compared to OMNR standard values (Lester et al. 1991), and used to characterize Minnesota lake trout populations, especially those lakes that cannot be sampled intensively enough to obtain sample sizes that permit rigorous growth modeling and mortality estimation. Until safe levels of total mortality are determined for Minnesota's inland lake trout lakes, fisheries managers should adopt a conservative threshold of 30% total annual mortality. Angling exploitation of unstocked lake trout lakes, especially the native or "heritage" lakes, may need to be reduced if total mortality rates or mortality indices are found to exceed this threshold.

Many practical considerations influence a crew's ability to complete 12 short duration net sets within an 8 h work day, including handling time for nets and fish, lake size and shape, and weather conditions. Snagging gill nets on submerged trees or extremely rugged lake bottom, or other equipment maintenance problems may also disrupt work schedules. Under most conditions, however, daily effort of twelve 30 min net-lifts is possible for small lakes, for those less distant from headquarters, or when the randomly selected net locations are not widely separated. Larger lakes (i.e., >500 ha) may need to be divided into smaller units to reduce travel time between netting locations. If distances between netting locations are relatively long, then a relatively large boat with outboard motor is needed to minimize travel time. Using a canoe or nonmotorized boat would increase travel time between net locations and would make it impossible to complete 12 net-lifts per 8 h day. Therefore, if a short duration index netting method were to be attempted without motorized watercraft, the method would have to be modified, reducing daily netting effort and efficiency. Finally, working gill nets from a canoe is potentially hazardous, particularly just after ice-out and before freeze-up.

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Table A1. Fish species, exclusive of cyprinids and small forage species, known to be present (p) in 10 northeastern Minnesota lake trout lakes.

	Species		Lake name abbreviation[a]									
Common name	code	Species name	KE	MH	TR	WB	LN	GW	CW	GF	OJ	SB
Cisco	TLC	*Coregonus artedi*	-	-	p	-	p	p	p	p	p	p
Lake whitefish	LKW	*Coregonus clupeaformis*	-	-	-	-	-	p	-	-	-	-
Shortjaw cisco	SJC	*Coregonus zenithicus*	-	-	-	-	-	-	-	p	-	-
Rainbow trout	RBT	*Oncorhynchus mykiss*	-	-	p	-	-	-	-	-	-	-
Round whitefish	RDW	*Prosopium cylindraceum*	-	-	-	-	-	p	p	-	-	-
Brook trout	BKT	*Salvelinus fontinalis*	p	-	p	-	p	p	-	-	-	-
Lake trout	LAT	*Salvelinus namaycush*	p	p	p	p	p	p	p	p	p	p
Splake	SPT	*S.fontinalis x S.namaycush*	p	-	-	-	-	-	-	-	p	-
Rainbow smelt	RBS	*Osmerus mordax*	-	-	p	p	-	-	-	p	-	-
Northern pike	NOP	*Esox lucius*	-	-	-	p	p	-	p	p	p	p
Longnose sucker	LNS	*Catostomus catostomus*	-	-	-	-	-	-	p	-	-	-
White sucker	WTS	*Catostomus commersoni*	p	p	-	p	p	p	p	p	p	p
Trout-perch	TRP	*Percopsis omiscomaycus*	-	-	-	-	-	-	-	p	-	-
Burbot	BUB	*Lota lota*	-	-	-	-	-	-	p	p	-	p
Rock bass	RKB	*Ambloplites rupestris*	-	-	-	-	p	-	-	p	p	-
Green sunfish	GSF	*Lepomis cyanellus*	-	p	-	p	p	p	p	-	p	-
Pumpkinseed	PMK	*Lepomis gibbosus*	-	-	-	-	-	-	-	p	p	-
Bluegill	BLG	*Lepomis macrochirus*	-	-	-	p	p	-	p	-	p	-
Smallmouth bass	SMB	*Micropterus dolomieu*	-	-	-	p	p	p	p	p	p	p
Largemouth bass	LMB	*Micropterus salmoides*	-	-	-	-	-	-	-	-	p	-
Yellow perch	YEP	*Perca flavescens*	-	p	p	p	p	p	p	p	p	p
Walleye	WAE	*Stizostedion vitreum*	-	-	-	p	p	p	p	p	p	p
Known species number:			4	4	5	9	11	10	12	13	13	8

[a] Lake name abbreviations: KE = Kemo; MH = Mayhew; TR = Trout; WB = West Bearskin; LN = Loon; GW = Greenwood; CW = Clearwater; GF = Gunflint; OJ = Ojibway; and SB = Snowbank.

Table A2. Parameters of $\log_{10}$weight-$\log_{10}$fork length relationships, r^2, sample size, and calculated weights at selected fork (FL) and total (TL) lengths for lake trout captured in 10 northeastern Minnesota lakes in spring (SLIN), summer (SDWIN), and fall (FLIN) index netting in 1993 or 1994. Summary statistics from 23 Ontario lakes (Payne et al. 1990) are included for comparison with those from 10 lakes from this study.

			Index	Weight-length relationship:			Sample		Calculated weight (g) at selected fork and total lengths (mm)						
			netting	$W = aL^b$			size	TL:	223	277	332	386	441	550	659
Lake name	Year	Season	method	"a"x10^{-6}	"b"	r^2	*N*	FL:	200	250	300	350	400	500	600
Mayhew	1993	Spring	SLIN	39.994	2.787	0.965	24		104	193	320	492	714	1331	2212
		Summer	SDWIN	17.378	2.930	0.973	14		96	184	315	494	731	1406	2399
		Fall	FLIN	7.674	3.067	0.983	44		88	174	304	487	734	1455	2545
Kemo	1993	Spring	SLIN	11.508	2.994	0.994	26		89	174	300	476	710	1386	2392
		Summer	SDWIN	56.364	2.742	0.993	18		115	212	349	533	769	1418	2337
		Fall	FLIN	33.343	2.827	0.986	88		107	200	336	519	757	1422	2381
West Bearskin	1993	Spring	SLIN	9.795	3.085	0.983	16		104	205	358	573	861	1702	2970
		Summer	SDWIN	2.178	3.298	0.995	32		85	176	322	535	831	1735	3165
		Fall	FLIN	8.570	3.063	0.964	98		96	190	331	531	800	1585	2770
Ojibway	1994	Spring	SLIN	7.447	3.080	0.994	6		91	181	317	510	770	1530	2683
		Summer	SDWIN	19.364	2.903	0.989	56		93	177	301	470	693	1325	2249
		Fall	FLIN	5.012	3.137	0.990	16		83	167	296	479	729	1468	2601
Snowbank	1994	Spring	SLIN	5.283	3.136	0.970	8		87	175	310	502	764	1538	2724
		Summer	SDWIN	1.306	3.368	0.994	13		73	156	288	483	758	1607	2970
		Fall	FLIN	1.138	3.383	0.965	30		69	147	273	460	723	1537	2849
Clearwater	1994	Spring	SLIN	4.853	3.140	0.975	25		81	164	291	472	719	1448	2567
		Summer	SDWIN	2.113	3.281	0.987	36		75	156	283	470	728	1514	2754
		Fall	FLIN	9.972	3.011	0.963	39		85	166	287	456	682	1335	2312
Greenwood	1993	Spring	SLIN	3.041	3.221	0.959	37		78	161	290	476	732	1501	2700
		Summer	SDWIN	5.834	3.107	0.979	65		82	165	290	468	709	1418	2499
		Fall	FLIN	1.102	3.366	0.954	43		61	130	240	403	632	1339	2474
Loon	1993	Spring	SLIN	1.261	3.378	0.981	31		75	159	294	495	777	1651	3057
		Summer	SDWIN	3.327	3.206	0.986	42		79	162	291	477	732	1496	2684
		Fall	FLIN	1.442	3.338	0.980	21		69	146	268	448	699	1473	2707

Table A2. Continued.

			Index	Weight-length relationship:			Sample		Calculated weight (g) at selected fork and total lengths (mm)						
			netting	$W = aL^b$			size	TL:	223	277	332	386	441	550	659
Lake name	Year	Season	method	"a"x10^{-6}	"b"	r^2	*N*	FL:	200	250	300	350	400	500	600
Gunflint	1994	Spring	SLIN	0.474	3.521	0.902	18		60	132	250	430	688	1510	2868
		Summer	SDWIN	2.449	3.257	0.985	19		76	158	286	473	731	1512	2738
		Fall	FLIN	1135.011	2.250	0.728	19		170	282	425	601	812	1342	2022
Trout	1993	Spring	SLIN	0.305	3.624	0.989	27		67	149	289	506	821	1842	3567
		Summer	SDWIN	0.899	3.433	0.967	26		71	153	287	487	770	1657	3099
		Fall	FLIN	1.603	3.343	0.989	57		79	166	306	512	801	1689	3107
Mean:	1993-	Spring	SLIN	8.396	3.193	0.971	10		84	169	302	493	756	1544	2774
Median:	1994	(10 lakes)		5.068	3.138	0.978	10		84	169	297	494	748	1520	2712
Minimum:				0.305	2.787	0.902	--		60	132	250	430	688	1331	2212
Maximum:				39.994	3.624	0.994	--		104	205	358	573	861	1842	3567
Mean:	1993-	Summer	SDWIN	11.121	3.153	0.985	10		85	170	301	489	745	1509	2689
Median:	1994	(10 lakes)		2.888	3.232	0.987	10		81	163	290	480	731	1504	2711
Minimum:				0.899	2.742	0.967	--		71	153	283	468	693	1325	2249
Maximum:				56.364	3.433	0.995	--		115	212	349	535	831	1735	3165
Mean:	1993-	Fall	FLIN	7.762	3.171	0.975	9		82	165	293	477	728	1478	2638
Median:	1994	(10 lakes)		5.012	3.137	0.980	9		83	166	296	479	729	1468	2601
Minimum:				1.102	2.827	0.954	-		61	130	240	403	632	1335	2312
Maximum:				33.343	3.383	0.990	-		107	200	336	531	801	1689	3107
Mean:		Spring	----	4.12	3.18	0.99	23		84	166	292	473	720	1484	2730
Median:		(23 lakes)		3.88	3.18	----	23		80	162	292	475	727	1503	2766
Minimum:				0.59	2.40	----.	--		63	121	214	345	522	1043	2365
Maximum:				375.	3.50	----	--		124	213	335	810	1614	1614	3041

Table A3. Results of tests for homogeneity of slopes and y-intercepts (ANCOVA) for among seasons within lakes, comparisons of $\log_{10}$weight-$\log_{10}$ length regressions (condition) of lake trout captured in the 10 study lakes in spring, summer, and fall 1993 or 1994. Asterisks (*) denote $P \leq 0.05$; na = not applicable. See also Table A2.

		Slopes		Y-intercepts	
Lake name	Seasons compared	Result	*P*	Result	*P*
Kemo	Spring-Summer-Fall	different	**0.008***	na	
	Spring-Summer	different	**0.001***	na	
	Spring-Fall	different	**0.015***	na	
	Summer-Fall	similar	0.236	similar	0.350
Trout	Spring-Summer-Fall	similar	0.144	similar	0.117
	Spring-Summer	similar	0.310	similar	0.243
	Spring-Fall	different	**0.007***	na	
	Summer-Fall	similar	0.416	similar	0.114
West Bearskin	Spring-Summer-Fall	different	**0.006***	na	
	Spring-Summer	different	**0.020***	na	
	Spring-Fall	similar	0.968	different	**0.042***
	Summer-Fall	different	**0.003***	na	
Loon	Spring-Summer-Fall	similar	0.294	different	**0.026***
	Spring-Summer	similar	0.124	similar	0.242
	Spring-Fall	similar	0.263	different	**0.005***
	Summer-Fall	similar	0.865	similar	0.157
Greenwood	Spring-Summer-Fall	similar	0.160	different	**<0.001***
	Spring-Summer	similar	0.432	similar	0.622
	Spring-Fall	similar	0.340	different	**<0.001***
	Summer-Fall	similar	0.080	different	**<0.001***
Mayhew	Spring-Summer-Fall	similar	0.106	similar	0.201
	Spring-Summer	similar	0.448	similar	0.961
	Spring-Fall	different	**0.033***	na	
	Summer-Fall	similar	0.430	similar	0.339
Clearwater	Spring-Summer-Fall	similar	0.069	similar	0.064
	Spring-Summer	similar	0.266	similar	0.418
	Spring-Fall	similar	0.359	different	**0.044***
	Summer-Fall	different	**0.023***	na	
Gunflint	Spring-Summer-Fall	similar	0.065	similar	0.252
	Spring-Summer	similar	0.608	similar	0.482
	Spring-Fall	different	**0.008***	na	
	Summer-Fall	different	**0.048***	na	
Ojibway	Spring-Summer-Fall	different	**0.008***	na	
	Spring-Summer	similar	0.279	different	**0.016***
	Spring-Fall	similar	0.842	similar	0.361
	Summer-Fall	different	**0.003***	na	
Snowbank	Spring-Summer-Fall	similar	0.567	similar	0.553
	Spring-Summer	similar	0.338	similar	0.690
	Spring-Fall	similar	0.319	similar	0.709
	Summer-Fall	similar	0.919	similar	0.200

Table A4. Total catch, netting effort, catch-per-day (CPD), and catch-per-net-lift (CPNL) and selected summary statistics for various species captured during spring (SLIN) and fall (FLIN) index gill netting in 10 northeastern Minnesota lake trout lakes, in 1993 or 1994.

Index Species code[a]	Netting method	Catch		Net-lifts	Days	Catch/day		Catch-per-net-lift			
		N	%			CPD	SE	Median	Mean	SE	CV
						Kemo Lake: 1993					
LAT	**SLIN**	**29**	**40**	**60**	**5**	**5.8**	**0.917**	**0.483**	**0.090**	**0.090**	**1.450**
LAT	**FLIN**	**96**	**71**	**60**	**5**	**19.2**	**3.397**	**1.000**	**1.600**	**0.246**	**1.191**
SPT	SLIN	29	40	60	5	5.8	1.800	0.483	0.120	0.120	1.923
SPT	FLIN	35	26	60	5	7.0	2.168	0.000	0.583	0.135	1.794
WTS	SLIN	15	20	60	5	3.0	1.342	0.250	0.134	0.134	4.142
WTS	FLIN	1	<1	60	5	0.2	0.200	0.000	0.017	0.017	7.746
BKT	SLIN	0	-	60	5	-	-	-	-	-	-
BKT	FLIN	4	3	60	5	0.8	0.374	0.000	0.067	0.032	3.773
						Trout Lake: 1993					
RBT	SLIN	100	76	60	5	20.0	2.236	0.500	1.667	0.338	1.573
RBT	FLIN	42	39	60	5	8.4	1.939	0.000	0.700	0.137	1.518
LAT	**SLIN**	**28**	**21**	**60**	**5**	**5.6**	**1.122**	**0.000**	**0.467**	**0.108**	**1.785**
LAT	**FLIN**	**58**	**54**	**60**	**5**	**11.5**	**2.482**	**0.000**	**0.967**	**0.161**	**1.291**
BKT	SLIN	1	<1	60	5	0.2	0.200	0.000	0.017	0.017	7.746
BKT	FLIN	5	5	60	5	1.0	0.632	0.000	0.083	0.043	4.008
YEP	SLIN	3	2	60	5	0.6	0.400	0.000	0.050	0.037	5.734
YEP	FLIN	2	2	60	5	0.4	0.400	0.000	0.033	0.023	5.431
RBS	SLIN	0	-	60	5	-	-	-	-	-	-
RBS	FLIN	1	<1	60	5	0.2	0.200	0.000	0.017	0.017	7.746
						West Bearskin Lake: 1993					
LAT	**SLIN**	**17**	**85**	**60**	**5**	**3.4**	**1.208**	**0.000**	**0.283**	**0.083**	**2.260**
LAT	**FLIN**	**90**	**97**	**60**	**5**	**18.0**	**2.550**	**1.000**	**1.500**	**0.172**	**0.889**
SMB	SLIN	3	15	60	5	0.6	0.600	0.000	0.050	0.028	4.396
SMB	FLIN	3	3	60	5	0.6	0.600	0.000	0.050	0.028	4.396
						Loon Lake: 1993					
TLC	SLIN	132	79	60	5	26.4	9.877	0.000	2.200	5.191	2.359
TLC	FLIN	53	61	60	5	10.6	2.482	0.000	0.883	0.294	2.579
LAT	**SLIN**	**34**	**20**	**60**	**5**	**6.8**	**1.158**	**0.000**	**0.567**	**0.124**	**1.700**
LAT	**FLIN**	**27**	**31**	**60**	**5**	**5.4**	**0.812**	**0.000**	**0.450**	**0.107**	**1.849**
WTS	SLIN	0	-	60	5	-	-	-	-	-	-
WTS	FLIN	4	5	60	5	0.8	0.374	0.000	0.067	0.040	4.676
NOP	SLIN	1	<1	60	5	0.2	0.200	0.000	0.017	0.017	7.746
NOP	FLIN	1	1	60	5	0.2	0.200	0.000	0.017	0.017	7.746
SMB	SLIN	1	<1	60	5	0.2	0.200	0.000	0.017	0.017	7.746
SMB	FLIN	1	1	60	5	0.2	0.200	0.000	0.017	0.017	7.746
BKT	SLIN	0	-	60	5	-	-	-	-	-	-
BKT	FLIN	1	1	60	5	0.2	0.200	0.000	0.017	0.017	7.746
						Greenwood Lake: 1993					
TLC	SLIN	274	81	58	5	54.8	16.478	2.000	4.724	0.889	1.433
TLC	FLIN	105	62	60	5	21.0	2.881	0.000	1.750	0.392	1.737
LAT	**SLIN**	**39**	**12**	**58**	**5**	**7.8**	**2.800**	**0.000**	**0.672**	**0.133**	**1.510**
LAT	**FLIN**	**42**	**25**	**60**	**5**	**8.4**	**2.293**	**0.000**	**0.700**	**0.112**	**1.242**
WTS	SLIN	17	5	58	5	3.4	2.909	0.000	0.293	0.161	4.191
WTS	FLIN	4	2	60	5	0.8	0.800	0.000	0.067	0.052	6.093
LKW	SLIN	2	<1	58	5	0.4	0.400	0.000	0.034	0.024	5.338
LKW	FLIN	10	6	60	5	2.0	0.837	0.000	0.167	0.064	2.957
BKT	SLIN	5	1	58	5	1.0	0.447	0.000	0.086	0.037	3.284
BKT	FLIN	6	4	60	5	1.2	0.735	0.000	0.100	0.070	5.431
SMB	SLIN	0	-	58	5	-	-	-	-	-	-
SMB	FLIN	2	1	60	5	0.4	0.400	0.000	0.033	0.033	7.746

Table A4. Continued.

Index Species code[a]	Netting method	Catch		Net-lifts	Days	Catch/day		Catch-per-net-lift			
		N	%			CPD	SE	Median	Mean	SE	CV
					Mayhew Lake: 1994						
WTS	SLIN	21	44	60	5	4.2	2.010	0.000	0.350	0.146	3.235
WTS	FLIN	50	33	60	5	10.0	2.408	0.000	0.833	0.184	1.714
LAT	**SLIN**	**24**	**50**	**60**	**5**	**4.8**	**1.744**	**0.000**	**0.400**	**0.090**	**1.734**
LAT	**FLIN**	**47**	**31**	**60**	**5**	**9.4**	**0.872**	**1.000**	**0.783**	**0.119**	**1.177**
YEP	SLIN	3	6	60	5	0.6	0.400	0.000	0.050	0.028	4.396
YEP	FLIN	55	36	60	5	11.0	6.885	0.000	0.917	0.631	5.334
					Clearwater Lake: 1994						
TLC	SLIN	116	76	60	5	23.2	11.914	0.000	1.933	1.093	4.379
TLC	FLIN	219	84	60	5	43.8	20.343	0.000	3.650	1.451	3.079
LAT	**SLIN**	**28**	**18**	**60**	**5**	**5.6**	**1.288**	**0.000**	**0.467**	**0.084**	**1.393**
LAT	**FLIN**	**39**	**15**	**60**	**5**	**7.8**	**1.463**	**0.000**	**0.650**	**0.108**	**1.293**
WTS	SLIN	9	6	60	5	1.8	1.356	0.000	0.150	0.106	5.465
WTS	FLIN	3	1	60	5	0.6	0.600	0.000	0.050	0.050	7.746
					Gunflint Lake: 1994						
LAT	**SLIN**	**18**	**100**	**60**	**5**	**3.6**	**0.510**	**0.000**	**0.300**	**0.068**	**1.768**
LAT	**FLIN**	**19**	**46**	**60**	**5**	**3.8**	**1.241**	**0.000**	**0.317**	**0.077**	**1.883**
WAE	FLIN	10	24	60	5	2.0	1.049	0.000	0.167	0.076	3.552
NOP	FLIN	5	12	60	5	1.0	0.316	0.000	0.083	0.036	3.345
WTS	FLIN	4	10	60	5	0.8	0.374	0.000	0.067	0.040	4.676
SMB	FLIN	1	2	60	5	0.2	0.200	0.000	0.017	0.017	7.746
YEP	FLIN	1	2	60	5	0.2	0.200	0.000	0.017	0.017	7.746
RBS	FLIN	1	2	60	5	0.2	0.200	0.000	0.017	0.017	7.746
					Ojibway: 1994						
TLC	SLIN	44	52	60	5	8.8	2.200	0.000	0.733	0.262	2.772
TLC	FLIN	25	21	60	5	5.0	1.761	0.000	0.417	0.165	3.071
WTS	SLIN	25	29	60	5	5.0	1.871	0.000	0.417	0.126	2.350
WTS	FLIN	13	11	60	5	2.6	1.166	0.000	0.217	0.076	2.699
YEP	SLIN	2	2	60	5	0.4	0.400	0.000	0.033	0.023	5.431
YEP	FLIN	51	42	60	5	10.2	9.952	0.000	0.850	0.833	7.593
LAT	**SLIN**	**6**	**7**	**60**	**5**	**1.2**	**0.583**	**0.000**	**0.100**	**0.039**	**3.025**
LAT	**FLIN**	**17**	**14**	**60**	**5**	**3.4**	**1.166**	**0.000**	**0.283**	**0.079**	**2.164**
SPT	SLIN	8	9	60	5	1.6	0.400	0.000	0.133	0.050	2.918
SPT	FLIN	0	-	60	5	-	-	-	-	-	-
SMB	SLIN	0	-	60	5	-	-	-	-	-	-
SMB	FLIN	8	7	60	5	1.6	1.030	0.000	0.133	0.050	2.918
NOP	SLIN	0	-	60	5	-	-	-	-	-	-
NOP	FLIN	3	2	60	5	0.6	0.245	0.000	0.050	0.028	4.396
LMB	SLIN	0	-	60	5	-	-	-	-	-	-
LMB	FLIN	3	2	60	5	0.6	0.600	0.000	0.050	0.050	7.746
BLG	SLIN	0	-	60	5	-	-	-	-	-	-
BLG	FLIN	1	<1	60	5	0.2	0.200	0.000	0.830	0.043	7.746
					Snowbank: 1994						
WTS	SLIN	84	76	60	5	16.8	7.566	0.000	1.400	0.436	2.411
WTS	FLIN	40	21	60	5	8.0	3.146	0.000	0.667	0.157	1.825
YEP	SLIN	0	-	60	5	-	-	-	-	-	-
YEP	FLIN	90	47	60	5	18.0	16.053	0.000	1.500	1.369	7.072
LAT	**SLIN**	**9**	**8**	**60**	**5**	**1.8**	**0.374**	**0.000**	**0.150**	**0.052**	**2.696**
LAT	**FLIN**	**32**	**17**	**60**	**5**	**6.4**	**1.288**	**0.000**	**0.533**	**0.102**	**1.483**
WAE	SLIN	17	15	60	5	3.4	2.400	0.000	0.283	0.101	2.764
WAE	FLIN	12	6	60	5	2.4	1.288	0.000	0.200	0.082	3.162
SMB	SLIN	0	-	60	5	-	-	-	-	-	-
SMB	FLIN	14	7	60	5	2.8	0.970	0.000	0.233	0.080	2.660
NOP	SLIN	0	-	60	5	-	-	-	-	-	-
NOP	FLIN	5	3	60	5	1.0	0.548	0.000	0.083	0.043	4.008

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[a] Species codes: see Table A1.

Table A5. Catch, percentage by species, catch per net-lift (CPNL), and selected summary statistics for fish species captured during summer (SDWIN) 24 h duration index gill netting in ten northeastern Minnesota lake trout lakes in 1993 or 1994.

	Catch		Net-lifts	Catch/net-lift			
Species	(*N*)	(%)	(*N*)	Median	Mean	SE	CV
Kemo Lake: Summer 1993							
Lake trout	**18**	**67**	**4**	**3.5**	**4.500**	**1.658**	**0.737**
Splake	5	19	4	1.0	1.250	0.250	0.400
White sucker	4	15	4	1.0	1.000	0.577	1.155
Brook trout	0	-	4	-	-	-	-
Trout Lake: Summer 1993							
Lake trout	**26**	**93**	**4**	**8.0**	**6.500**	**1.500**	**0.462**
Rainbow smelt	1	4	4	0.0	0.250	0.250	2.000
Brook trout	0	-	4	-	-	-	-
Rainbow trout	0	-	4	-	-	-	-
West Bearskin: Summer 1993							
Lake trout	**26**	**100**	**6**	**5.0**	**4.333**	**1.022**	**0.578**
Loon Lake: Summer 1993							
Cisco	60	58	8	2.5	7.500	3.311	1.249
Lake trout	**43**	**42**	**8**	**5.5**	**5.375**	**0.885**	**0.466**
Brook trout	0	-	8	-	-	-	-
Greenwood Lake: Summer 1993							
Cisco	81	49	8	9.0	10.125	2.022	0.565
Lake trout	**72**	**44**	**8**	**8.5**	**9.000**	**1.488**	**0.468**
Lake whitefish	11	7	8	1.0	1.375	0.263	0.541
White sucker	1	<1	8	0.0	0.125	0.125	2.828
Brook trout	0	-	8	-	-	-	-
Mayhew Lake: Summer 1994							
Lake trout	**14**	**93**	**3**	**3.0**	**4.667**	**2.728**	**1.013**
White sucker	1	7	3	0.0	0.333	0.333	1.732
Yellow perch	0	-	3	-	-	-	-
Ojibway Lake: Summer 1994							
Cisco	159	73	8	15.5	19.875	7.386	1.051
Lake trout	**58**	**27**	**8**	**6.0**	**7.250**	**2.102**	**0.820**
Splake	1	<1	8	0.0	0.125	0.125	2.828
Northern pike	1	<1	8	0.0	0.125	0.125	2.828
Clearwater Lake: Summer 1994							
Cisco	67	59	11	4.0	6.091	1.771	0.964
Lake trout	**37**	**33**	**11**	**2.0**	**3.364**	**0.717**	**0.707**
White sucker	1	1	11	0.0	0.091	0.091	3.317
Burbot	8	7	11	1.0	0.727	0.237	1.081
Snowbank Lake: Summer 1994							
Cisco	66	41	12	5.0	5.500	1.564	0.985
Burbot	48	30	12	3.0	4.000	1.008	0.873
White sucker	35	22	12	1.0	2.917	1.264	1.501
Lake trout	**13**	**8**	**12**	**1.0**	**1.083**	**0.260**	**0.831**
Walleye	0	-	12	-	-	-	-
Gunflint Lake: Summer 1994							
Lake trout	**21**	**38**	**12**	**1.0**	**1.750**	**0.653**	**1.292**
Cisco	15	27	12	1.0	1.250	0.305	0.844
Burbot	14	26	12	1.0	1.167	0.345	1.023
Longnose sucker	3	6	12	0.0	0.250	0.250	3.464
White sucker	2	4	12	0.0	0.167	0.112	2.335

Table A6. Summary of the results of Chi^2 tests for homogeneity of the proportions of various species captured in spring and fall index netting (30 min set duration) with monofilament gill nets and summer index netting (≈24 h set duration) with multifilament gill nets in 10 Minnesota lake trout lakes, 1993 or 1994. Asterisks (*) denote significant Chi^2 values ($P \geq 0.05$). Species codes: see Table A1.

Lake name	Overall Chi^2	*P*-value	df	Relative contribution to Chi^2 1st	2nd	3rd	4th	5th	6th	7th
Spring and Fall (30 min sets)[a]										
Kemo	32.97*	<0.0000	3	WTS	**LAT**	**BKT**	SPT	---	---	---
Trout	29.41*	<0.0000	4	**LAT**	RBT	**BKT**	**RBS**	YEP	---	---
W.Bearskin	8.79*	0.0030	1	SMB	**LAT**	---	---	---	---	---
Loon	9.56	0.0888	5	**WTS**	**LAT**	TLC	**BKT**	NOP	SMB	---
Greenwood	15.88*	0.0072	5	**LAT**	**LKW**	TLC	**BKT**	WTS	**SMB**	---
Mayhew	27.46*	<0.0000	2	**YEP**	LAT	WTS	---	---	---	---
Ojibway	82.93*	<0.0000	8	**YEP**	TLC	SPT	WTS	**SMB**	**NOP**	---
Clearwater	7.20	0.0657	3	WTS	**SMB**	LAT	TLC	---	---	---
Snowbank	95.27*	<0.0000	5	**YEP**	WTS	**SMB**	WAE	**LAT**	**NOP**	---
Gunflint	71.97*	<0.0000	6	**WAE**	LAT	**NOP**	**WTS**	**SMB**	**YEP**	**RBS**
Spring (30 min sets) and Summer (24 h sets)[b]										
Kemo	15.87*	0.0004	2	SPT	**LAT**	WTS	---	---	---	---
Trout	122.15*	0.0000	4	RBT	**LAT**	**RBS**	YEP	BKT	---	---
W.Bearskin	16.22*	0.0001	1	SMB	**LAT**	---	---	---	---	---
Loon	13.74*	0.0082	4	**LAT**	TLC	---	---	---	---	---
Greenwood	36.28*	0.0000	4	**LAT**	TLC	**LKW**	WTS	BKT	---	---
Mayhew	45.77*	0.0000	2	WTS	**LAT**	YEP	---	---	---	---
Ojibway	58.12*	0.0000	5	WTS	**LAT**	**SPT**	YEP	**NOP**	**TLC**	---
Clearwater	17.12*	0.0007	3	**BUB**	**LAT**	WTS	TLC	---	---	---
Snowbank	115.75*	0.0000	4	**TLC**	WTS	**BUB**	WAE	LAT	---	---
Gunflint	88.85*	0.0000	4	**TLC**	LAT	**BUB**	**LNS**	**WTS**	---	---

Table **A6**. Continued.

Lake name	Overall Chi^2	*P*-value	df	Relative contribution to Chi^2 1st	2nd	3rd	4th	5th	6th	7th
				Fall (30 min sets) and Summer (24 h sets)[c]						
Kemo	16.40*	0.0009	3	WTS	**BKT**	**SPT**	**LAT**	---	---	---
Trout	54.88*	0.0000	4	**RBT**	LAT	**BKT**	**YEP**	RBS	---	---
W.Bearskin	3.05	0.0810	1	**SMB**	LAT	---	---	---	---	---
Loon	6.69	0.2451	5	**WTS**	LAT	**BKT**	**NOP**	**SMB**[d]	**TLC**	---
Greenwood	12.16*	0.0327	5	LAT	**BKT**	**TLC**	**SMB**	**WTS**	LKW	---
Mayhew	83.90*	0.0000	2	**YEP**	LAT	**WTS**	---	---	---	---
Ojibway	95.99*	0.0000	8	**YEP**	TLC	**WTS**	LAT	**SMB**	**WAE`**	---
Clearwater	21.08*	0.0003	4	LAT	BUB	**TLC**	**SMB**	WTS	---	---
Snowbank	137.26*	0.0000	7	**YEP**	TLC	BUB	**SMB**	**WAE**	**LAT**	---
Gunflint	102.33*	0.0000	9	TLC	BUB	**WAE**	**NOP**	LNS	**WTS**	---

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[a] Species that composed a greater proportion of spring catch than fall catch are underlined. Those that composed a greater proportion of fall catch than spring catch are shown in bold type.

[b] Species that composed a greater proportion of spring catch than summer catch are underlined. Those that composed a greater proportion of summer catch than spring catch are shown in bold type.

[c] Species that composed a greater proportion of fall catch than summer catch are underlined. Those that composed a greater proportion of summer catch than fall catch are shown in bold type.

[d] Brook trout, northern pike, and smallmouth bass contributed equally to the Chi^2.