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[1]A contribution from Dingell-Johnson Project F-35-R, Michigan.

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Evaluation of Sampling Methodologies of the Lake Michigan Creel Survey

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Abstract.—The Michigan Department of Natural Resources conducts creel surveys to characterize the Great Lakes sport fisheries and provide fisheries managers with information on catch composition, catch rates, and fishing pressure. Most anglers seek coho salmon *Oncorhynchus kisutch,* chinook salmon *O. tshawytscha*, and other salmonids, and approximately 800,000 salmonids are harvested annually from the Great Lakes. The creel survey is an access site survey with interviews and counts performed at ports along the Lake Michigan shoreline. Sportfishing access sites are discrete and a major portion of the fishing effort and catch occurs at relatively few sites. The creel survey was not designed to yield estimates of total catch and total effort for Lake Michigan, but rather to provide fishery managers with catch rate, sportfishing effort, and harvest estimates at specific sites. Although data from the Lake Michigan creel survey have met a critical need in fisheries management, the present fiscal climate requires a more economical operation. We examined the current (stratified) design with respect to how reduction and pooling of sites would affect precision of catch-rate and fishing-effort estimates; in particular, we considered the feasibility of monitoring the fisheries by surveying three northern and four southern sites in Lake Michigan. Estimates of mean fishing effort were significantly different among sites considered for pooling. In general, the current sampling intensity permitted detection of a 30% or 50% change in fishing effort with at least 75% certainty for boat and pier fisheries but not for shore fisheries. Although trends in fishing effort at the southern sites were similar to those at northern sites, catch rates of the five major salmonid species varied between northern and southern sites. Recent declines in chinook salmon catch rates may have resulted in increased fishing for rainbow trout *Oncorhynchus mykiss*, and lake trout *Salvelinus namaycush*, and coho salmon at the northern sites, and for coho salmon at the southern sites.

The fishery resources of the Great Lakes were dramatically altered by the introduction of Pacific salmonids in the mid-1960s. In the 25 years since the stocking of these exotic fishes, Great Lakes fisheries have provided outstanding recreational opportunities. The new fisheries resulted from the efforts of various state and federal agencies: the Michigan Department of Natural Resources (MDNR) introduced coho salmon

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Oncorhynchus kisutch and chinook salmon *O. tshawytscha*, and increased plantings of rainbow trout *O. mykiss* and brown trout *Salmo trutta*; pink salmon *O. gorbuscha* were accidentally introduced by a Canadian hatchery (Schumacher and Eddy 1960); the U. S. Fish and Wildlife Service stocked lake trout *Salvelinus namaycush*; and the Great Lakes Fishery Commission established a program to control the sea lamprey *Petromyzon marinus*. The development of Great Lakes fishery resources brought an increase in the number of anglers as measured by the number of fishing licenses sold in Michigan (Figure 1). As the fisheries grew, it became apparent that knowledge of the status of the stocks would be needed to ensure their appropriate stocking levels.

In the early 1980s, MDNR began to explore the potential of recreational angler surveys to provide critical information for fisheries management. In 1985, a Great Lakes Creel Census Program was initiated to characterize the sport fisheries of Lake Michigan and to provide fishery managers with information on catch composition, catch rates, and fishing effort (Rakoczy and Rogers 1988). Indirectly, the creel survey data also measured the contribution of Great Lakes stocking programs by monitoring the occurrence of marked hatchery fish in the creel. Annually, MDNR stocks approximately 7 million salmonids in Lake Michigan (MDNR, Fisheries Division stocking records) and recreational anglers harvest about 800,000 salmonids. Although yellow perch *Perca flavescens* predominate in the catch (70% of the estimated harvest), most anglers seek coho salmon, chinook salmon, and other salmonids (Rakoczy and Rogers 1988).

The purpose of our study was to evaluate sampling methodologies of the Lake Michigan creel survey and to appraise some of the proposed, fiscally mandated modifications of design. The objective of the creel survey was to provide fishery managers with site-specific information on catch rates, sportfishing effort, and estimated harvest of the principal species in Lake Michigan. The size of Lake Michigan and the complexity of the fisheries precluded estimation of total catch for the entire lake, but sportfishing trends were ascertainable for the major fishing ports. Using previous creel surveys and historical data, researchers selected 69 ports from Menominee to New Buffalo for inclusion in the creel survey of Lake Michigan (Figure 2). These ports most likely represent the major portion of all possible fishing ports. There is no appreciable fishing activity at sites between them because of the terrain (steep cliffs or dunes) and the lack of public access sites such as boat launch ramps or piers. The concentration of sport fisheries at some public access sites has been remarkable: fishing activities at seven ports (Frankfort, Manistee, Ludington, Muskegon, Grand Haven, St. Joseph, and New Buffalo) constituted approximately 56% of the fishing effort and 62% of the estimated recreational catch of five salmonids (coho salmon, chinook salmon, lake trout, brown trout, and rainbow trout) for all 69 ports (Rakoczy and Lockwood 1988). Our evaluation of the sampling methods for the Lake Michigan creel survey covered the sampling period from its inception in 1985 through 1988 and focused on the open-water season from April to November. In addition, we examined data from the 1989 creel survey where noted.

The creel survey design for Lake Michigan was modified as a result of the initiation of creel surveys on lakes Erie, Superior, and Huron. Reductions in the numbers of sites surveyed and in the number of total counts and interviews per site began in 1986 and have continued to the present. The loss of site-specific fishing effort and catch-rate estimates for discontinued sites has prompted fishery managers to question whether estimates from adjacent sites may be used to gauge fisheries. This called for a comparison of creel survey estimates from a reduced survey (seven or fewer ports) with a relatively comprehensive survey (69 ports). The proposed reduction would retain four sampling sites (New Buffalo, St. Joseph, Grand Haven, and Muskegon) along southern Lake Michigan and three sites (Ludington, Manistee, and Frankfort) in more northern waters (Figure 2). An alternative proposal would eliminate the southern sites altogether.

An agreement between the State of Michigan and local native American tribes required MDNR to provide annual estimates of sport harvest and fishing effort for treaty waters, which are bounded in the south by an imaginary line running from Grand Haven, Michigan, to the Michigan-Wisconsin border, and in the north by an imaginary line near Escanaba, Michigan, to the Michigan-Wisconsin border in Green Bay (Figure 2). Because the creel survey's northern sites are well within treaty waters, they will probably continue to be surveyed; but the southern sites may be excluded from further surveys.

The objective of our analysis was to evaluate two current methodological practices and two proposed changes in the creel survey. We examined (1) the effect of pooling sites and the appropriateness of analyzing and reporting fishing effort without specifying mode of fishing, (2) the precision of fishing-effort estimates when the number of survey counts was reduced, and (3) the ability to monitor trends in fishing effort and catch rates at southern sites from creel data collected at northern sites.

Lake Michigan Survey Design

The design of the Lake Michigan creel survey was described in Rakoczy and Lockwood (1988). We here summarize aspects of the design crucial to understanding our evaluation of methodology.

The creel survey on Lake Michigan relies on the access site method: creel clerks perform boat and angler counts and conduct angler interviews at specific sites along Lake Michigan's 1,661-mile shoreline. All counts and interviews are conducted at the same set of sites by creel clerks who travel in motor vehicles. The access point survey was chosen for Lake Michigan because anglers are able to fish at relatively few discrete sites along the shore, thus they can be enumerated (Malvestuto 1983). Although clerks did not remain at a particular site for the entire day or sampling period, we refer to this survey as an access point survey because anglers were contacted only at access points. In addition, all boat anglers and most shore (71%) and pier (93%) anglers had completed their fishing trips at the time of the interview. Some sites were omitted from surveys in 1986-1988; consequently, we reported only on the subset of sites surveyed from 1985 to 1988. By 1988, only 22 of the original sites continued to be surveyed for shore fisheries.

We used a stratified sampling design in which counts and interviews were scheduled within a stratum by simple random sampling. The strata consisted of month (April to November) and day of week (weekdays and weekends). Within each month, the design called for sampling two weekend days and three weekdays each week. (However, rarely was this frequency of angler contact achieved.) A day, defined as the period from dawn to 1 h after dusk, varied in duration depending upon season. Because the number of hours in a day exceeded the allowable number of hours that a clerk could work per day, each day was divided into two shifts: 6 a.m. to 3 p.m. (shift A) and 2 p.m. to 11 p.m. (shift B). These hours allowed enough time for travel to and from ports and were based on the maximum hours of available daylight in Michigan. Shifts were randomly assigned to each of three weekdays and each of two weekend days per week for each month. The actual time that a clerk visited a particular port was then determined randomly within each shift. In general, counts were made twice a day (twice per shift) at a given site.

Creel clerks also recorded whether anglers fished from a boat, from the shore, or from a pier. Pier fisheries were restricted to 12 sites along the Lower Peninsula of Michigan and one site in the Upper Peninsula. Counts of shore and boat anglers made up approximately 75% of the total counts for any given year (Table 1).

In this analysis we used estimates of fishing effort derived from instantaneous and from interval counts. All shore and pier angler counts were instantaneous counts. Boat counts were either instantaneous or interval, depending on the nature of the fishery. Instantaneous counts were recorded when all boats at a particular site could be observed from a given point at one time.

Interval counts were recorded at 11 ports where important boat fisheries could not be assessed by instantaneous count because all boats were not within site of the access point. An interval count is the number of boats leaving port over a given time period, e.g., a 30-minute period. Because interval duration varied between years, we used interval counts only where specifically noted.

Catch rate and length of fishing trip were estimated from interview data. Anglers were interviewed at a boat launch ramp, marina, pier, or along the shoreline. Interview data also provided a measure of the average number of anglers per fishing party. Typically, a fishing party of two or more boat anglers pooled their catch, so estimates of individual catch rates were calculated from the total number of fish landed and the number of anglers in the party.

Rakoczy and Lockwood (1988) and Rakoczy and Rogers (1987, 1988) estimated catch and effort for each site by month and species but did not provide mode-specific estimates, thus pier, shore, and boat fisheries were not evaluated separately in their reports. In this analysis we examined mode-specific estimates of catch and effort.

Methods

Pooling of sites.—We began our evaluation of the Lake Michigan creel survey by examining data for sites sampled from 1985-1988. (The 1989 survey had been reduced to seven sites and was therefore not included in this analysis.) Our evaluation was complicated by the fact that several sites (designated by numerical code) were combined in 1987. Unfortunately, the composite sites were not assigned a new code; therefore, creel survey data for site 20, for example, represented information from a single site in 1985 and 1986, but site 20 was a composite of data from five subsites (sites 20, 21, 22, 23, and 24) in 1987 and 1988. If fishing effort estimates were equal across subsites, then there was no appreciable effect on effort estimates caused by pooling subsite data. We tested this hypothesis with the analysis of variance for pooled sites 20 (Escanaba), 95 (East Grand Traverse Bay), and 100 (West Grand Traverse Bay). Fishing effort estimated from instantaneous counts of boat and shore anglers was analyzed because there were no significant pier fisheries in these three regions.

Detection of differences in fishing effort.—We estimated the sample size necessary to detect a given percentage change in estimated fishing effort by month and day type (weekend and weekday) with 75% and 95% confidence, respectively. By sample size, we mean the number of counts made by a creel clerk per year. (On most days, two counts per site are made (Table 2) and the number of clerk days approximately equals half the number of counts.) Necessary sample sizes (number of counts) for shore, boat, and pier fisheries were obtained from standard statistical charts (Wallis and Roberts 1956) and were based on previously collected count data. These charts are based on the formula:

$$N = \frac{t^2 \ s^2}{L^2}$$

where N is the sample size, s^2 is the estimate of the population variance, t is Student's t, and L is the confidence limits expressed as a percentage of the estimate.

The use of these charts required us to estimate the standard deviation of mean effort and the percentage of difference we wished to detect. We estimated standard deviations of effort for the three types of fisheries from the error mean square term from factorial analyses of variance (ANOVAs) in which year (1985-1988), site, month, and day type were considered as factors. (We included interval count data in the ANOVA for boat counts, and we standardized counts to adjust for different interval durations.) The mean square error terms provided satisfactory estimates of the pooled sampling (error) variance, that is, the variance remaining after the components due to the fixed effects are removed.

Relationship between northern and southern fisheries.—Estimates of angler hours (fishing effort), catch, and catch rates for the five major salmonids (lake trout, rainbow trout, brown trout, chinook salmon, and coho salmon) were examined for changes in precision as a function of sample size (measured as the number of clerk days spent at northern sites and southern sites). Data for all seven sites were available for the years 1985 to 1989. Because there were practically no shore fisheries at these seven sites, we explored relationships of characteristics of the boat and pier fisheries.

We used an estimate of the standardized, approximate 95% confidence limit to compare precision of (boat and pier) angler hours and catch rates at different sampling intensities. The approximate limit, estimated as 2.0 times the standard error, was standardized by dividing by the mean. We used 2.0 as an approximation of the t statistic because the value of t varies between 2.021 and 1.960 for degrees of freedom between 40 and infinity, and because all our sample sizes were greater than 40. The confidence limit was standardized because estimates of mean effort and catch rate varied by a factor of two over the years we examined. Ordinary confidence limits were larger when effort or catch rates were high and tended to obscure the relationship of relative precision to actual number of days sampled.

Estimates of the fishing effort and catch rates from three northern sites were compared with those from four southern sites to determine the relationship, if any, between these areas in terms of angler effort and catch through time.

Results

Pooling of sites

Results of the examination of subsites at the East Grand Traverse Bay, West Grand Traverse Bay, and Escanaba areas indicated significant differences ($P < 0.05$) in mean fishing effort between subsites by shore and boat anglers in 1985 and also in 1986 (Tables 3, 4, and 5). This was true for weekday and weekend fishing effort. Pooling is not recommended for these areas because mean fishing effort varies significantly between subsites within a site.

Mean annual fishing effort between 1985 and 1986 was significantly different ($P < 0.05$) both for weekend and weekday shore anglers in West Grand Traverse Bay, but shore fishing effort was not significantly different between 1985 and 1986 in East Grand Traverse Bay and Escanaba (Table 6). The reverse was true of fishing effort for boat anglers: there was no significant difference ($P \geq 0.05$) in mean fishing effort between 1985 and 1986 in West Grand Traverse Bay, but the yearly difference was significant in East Grand Traverse Bay and Escanaba (Table 6). From these results we conclude that comparisons of estimates of fishing effort may be misleading if they are not reported by mode, and we recommend separate estimation and reporting of fishing effort for shore, boat, and pier anglers.

Detection of Differences in Fishing Effort

Our estimates of the sampling variance of the creel survey for shore, boat, and pier anglers indicated that large sample sizes (number of counts) are required to detect changes in fishing effort of 30% and 50%, and that more counts are required to detect a smaller change. The ability to detect a change in fishing effort for a given sample size varies by month and mode of fishing (Figures 3-5). In addition, more samples are required to detect weekday than weekend changes in fishing effort.

The number of creel survey counts necessary to detect a 30% or 50% change in effort by shore anglers peaked during July and August for both weekday and weekend fishing (Figure 3). Actual sample sizes (number of counts per year) for Lake Michigan shore fisheries averaged 93 per year per site; so, given the current creel survey (1988 sampling level) we could state with approximately 75% certainty that a change in fishing effort of 50% was detectable only for weekend estimates. We could not detect changes of 30% in shore fishing effort with 75% or 95% certainty when using the 1988 sampling schedule.

Detection of a 30% change in fishing effort by boat anglers with either 75% or 95% certainty varied greatly, depending on weekday type (Figure 4). For either weekday or weekend boat-angler fishing effort, the number of creel survey counts required decreased during July and August, a trend opposite that of the sample requirements for shore-angler fishing effort. The average of 131 boat counts per site per year permitted detection of a 50% change in weekend effort with 95% certainty and weekday effort with 75% certainty. At this same sampling intensity, a 30% change could be detected with 75% certainty for estimates of weekend boat-angler effort (Figure 4).

In general, fewer survey counts were required to detect changes in the fishing effort of pier anglers (Figure 5). Sample-size requirements for pier fishing followed a pattern opposite that of shore fishing: fewer counts were required to detect changes of 30% or 50% in fishing effort by pier anglers in July and August. With the exception of estimates for 4 months, we could detect a 30% change in pier fishing effort with 95% certainty for weekend and weekday estimates when using the 1988 average of 109 counts per site per year (Figure 5).

The utility of the Lake Michigan creel survey data would be enhanced if sampling intensities consistently permitted detection of a 30% change in fishing effort with 75% certainty. At 1988 sampling levels, this could be achieved only for effort estimates of pier anglers (weekday and weekend) and weekend boat anglers.

Relationship between Northern and Southern Fisheries

We examined the standardized, approximate 95% confidence limit of mean fishing effort for boat and pier fisheries as a function of the number of days creel clerks collected data at northern and southern sites (Figure 6). The relationship between the relative precision of the estimate of mean angler hours and the number of days an area was surveyed in northern and southern ports generally was not linear. This was true for boat fisheries at northern (r = -0.595, $P > 0.05$) and southern sites (r = -0.770, $P > 0.05$) and for pier fisheries at northern sites (r = -0.491, $P > 0.05$). We found a significant linear relationship between precision of fishing-effort estimates for pier anglers and the number of days southern sites were surveyed (r = -0.940, $P < 0.05$). However, we only inferred trends from these data because of the limited number of observations (five per area per mode of fishing). Southern boat fisheries had the narrowest relative confidence limits for mean angler hours and it appeared that relative precision did not improve even when the number of days counted was increased from approximately 125 to 190 (Figure 6). An increase in the number of survey days appeared to improve the confidence limits on boat-angler hours for northern sites as well as pier-angler hours for both northern and southern sites (Figure 6).

Relative precision of the estimated mean catch rate for chinook salmon, coho salmon, lake trout, rainbow trout, and brown trout tended to improve with a greater number of days surveyed for northern and southern boat fisheries (Figure 7). Although r ranged from -0.544 to -0.894 and was significant for two cases, we only inferred general trends from the data because of the limited number of observations. The relative precision of the estimated catch rate for the coho salmon and brown trout pier fisheries tended to improve as the number of survey days increased (Figure 7). The pattern was not apparent for chinook salmon, lake trout, or rainbow trout catch rates estimated for pier fisheries because trends were reversed at either northern or southern sites.

Estimates of fishing effort for 1985 through 1989 were compared for boat (April through September) and pier (April through October) anglers at northern and southern sites (Figure 8). Because the northern area comprised only three sites and the southern area comprised four sites, absolute differences did not necessarily indicate differences on a site-specific basis. We were interested primarily in comparisons of total fishing effort, total catch, and catch rates between the two areas. We fitted a least-squares, third-degree polynomial regression model to the data to visually compare trends in fishing activities at northern and southern sites. It appeared that estimated fishing effort (angler hours) has decreased through time (Figure 8). Except for 1985, it may be possible to estimate fishing effort at the four southern sites from data collected at the northern sites.

We fitted least-squares polynomial regressions to the data on total catch of the five major salmonids and found similar trends at northern and southern sites for coho salmon boat catch, lake trout boat catch, and rainbow trout pier catch (Figure 9). However, it would be difficult to predict changes in estimated harvest for the remaining fisheries from data collected only at the northern sites. Rainbow trout boat catch, chinook salmon pier catch, coho salmon pier catch, and lake trout pier catch varied widely among years, and no apparent trend or relationship was evident between the northern and southern sites (Figure 9). In general, chinook salmon boat catch, brown trout boat catch, and brown trout pier catch were higher at northern ports than at southern ports (Figure 9).

Estimates of mean annual catch rates (number of fish/hour) for chinook salmon boat and pier fisheries appeared to decrease over time at both northern and southern sites (Figure 10). Similar trends in catch rates at northern and southern sites were observed for coho salmon boat anglers, brown trout pier anglers, and rainbow trout pier anglers. Other estimated catch rates at northern and southern sites were highly variable (Figure 10). Estimates of mean annual catch rates for chinook salmon, brown trout, and rainbow trout were higher for northern than for southern boat fisheries. Since 1985, catch rates for lake trout and rainbow trout increased steadily for boat anglers at northern sites. This may have occurred because of the decreasing catch rates for chinook salmon and brown trout (Figure 10). In addition, catch rates for coho salmon taken by boat anglers rose sharply at both northern and southern ports in 1989.

Lake trout, brown trout, and rainbow trout catch rates for boat fisheries at southern sites remained rather steady, whereas coho salmon catch rates fluctuated and began to increase in 1989 (Figure 10). The decrease in boat-angler catch rates for chinook salmon at southern ports were partially offset by the increase in catch rate for coho salmon (Figure 10). The effect of decreases in boat-angler catch rates of chinook salmon was manifested differently at northern and southern sites. Boat anglers at northern ports appeared to pursue rainbow trout, lake trout, and coho salmon as chinook catch rates declined, whereas boat anglers at southern ports may have sought coho salmon.

The only long-range trend evident for pier fisheries was an apparent decrease in chinook salmon catch rates at all sites and an increase in coho salmon catch rates at southern ports (Figure 10).

Discussion

Proposed design modifications of the Lake Michigan creel survey would variously affect the utility of the information gained from angler surveys. A fiscally mandated reduction in operational costs led fishery managers to consider several alternatives, which we evaluated in this study. We also evaluated the validity of pooling subsites and reporting the combined fishing effort of shore, boat, and pier anglers. The pooling of subsites within the sites of Escanaba, East Grand Traverse Bay, and West Grand Traverse Bay confounded statistical comparisons of fishing effort because estimates of mean annual effort at individual subsites were significantly different in each of the years tested (1985 and 1986). Thus, the significant yearly differences observed for estimates of annual fishing effort of shore anglers in West Grand Traverse Bay may have resulted from unequal sampling frequencies at the subsites across years. The same may be true for estimates of annual fishing effort of boat anglers in East Grand Traverse Bay and Escanaba. If we assume that sampling frequencies at subsites were equal across years (unfortunately, the manner in which data were recorded prevents us from verifying this), then fishing effort must be estimated and reported by mode of fishing. For example, annual differences in mean fishing effort were significant for boat anglers but not for shore anglers in East Grand Traverse Bay.

When we determined the sample size (number of counts) necessary to detect 30% and 50% changes in fishing effort, we found that required sample size varied over an order of magnitude depending upon mode of fishing. It appeared that 1988 sampling strategies rarely permitted detection of a 50% change (or less) in shore angling effort with 75% certainty. Weekday fluctuations required more days of sampling to detect a given difference than weekend fluctuations. Reduction in the number of clerk days (especially weekday sampling frequency) as an economy measure would decrease our ability to detect a change in shore and boat angler fishing effort as great as 30%. If at least the 1988 level of clerk activity is maintained, we suggest that counts of pier anglers be reduced and additional counts be directed towards shore anglers.

An increase in the number of clerk days appeared to improve the precision of estimates of fishing effort for both boat and pier fisheries. Interval widths seemed to vary widely when sample size was approximately 85-140 d, but they appeared to level off or stabilize at 180 d for boat fisheries and 200 d for pier fisheries. Calculations revealed that a total of 8 d per month per site was required to achieve this sampling intensity for southern boat fisheries—180 d divided by 24 site-months (4 sites times 6 months). Approximately 10 d per month per site yielded similarly precise estimates of boat fishing effort at northern sites (180 d divided by 18 site-months). Improved precision of pier-angler effort at northern sites were realized by sampling 7 d per month per site at southern ports and 10 d per month per site at northern ports. These sampling levels amounted to no more than 1 weekend day plus 1 weekday per week for southern sites, and 1.25 weekend days plus 1.25 weekdays per week for northern sites. For a creel survey to be reliable, it seems reasonable to sample at this intensity. If the Lake Michigan creel survey were altered to include only four southern and three northern sites, then this would be the minimally required sampling intensity. Increases in the number of clerk days per site would improve precision of the estimates of catch rates of the five major salmonid species. Greater precision in catch-rate estimates becomes more desirable in light of how fisheries have changed as anglers responded to decreased abundances of the preferred salmonids.

Redesigning the creel survey to sample only the northern sites would reduce costs while still providing estimates of fish harvests from the treaty waters of Lake Michigan. Trends in fishing effort from 1986 to 1989 at southern sites appeared similar to those at northern sites. If this relationship continues, then it may be possible to estimate fishing effort at the four southern ports based on the estimate for the three northern ports.

Trends in estimated total catch for coho salmon and lake trout appeared similar for boat anglers at northern and southern sites. Rainbow trout catch estimates followed a similar pattern for pier anglers at northern and southern sites. Trends in catch rates were similar only for coho salmon boat anglers, brown trout pier anglers, and rainbow trout pier anglers at northern and southern sites. Decreases in chinook salmon catch rates have prompted anglers to seek other salmonids. This may in part explain the increase in catch rates for rainbow trout, lake trout, and coho salmon among northern boat fisheries and coho salmon among southern boat fisheries. Although trends in Lake Michigan catch rates for a few salmonids could be observed by monitoring only the northern sites, the lack of area-specific catch and effort data would make it impossible to predict changes in angler habits. If we had examined data from only the northern sites, we would have underestimated the importance of coho salmon to pier anglers during years of depressed chinook salmon harvests, and we would have underestimated the fishing pressure on coho salmon stocks in Lake Michigan.

Acknowledgments

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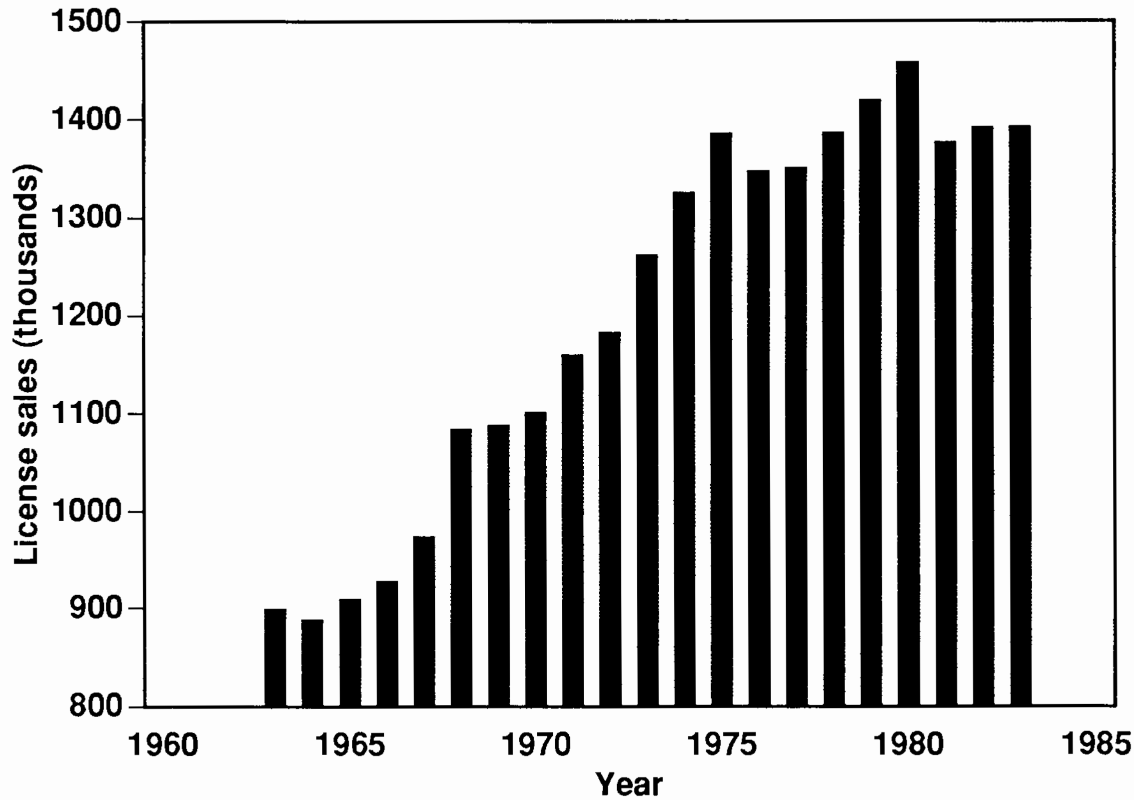

Figure 1.—Number of licenses sold to anglers in Michigan from 1963-1983. License sales include resident and nonresident purchasers. Data from the Michigan Department of Natural Resources, Fisheries Division, Lansing.

Figure 2.—Major port sites sampled in the Lake Michigan creel survey. The Michigan-Wisconsin border is indicated by the long-dash line; the southern and northern boundaries of Michigan treaty waters are indicated by the dashed lines near Grand Haven and Escanaba.

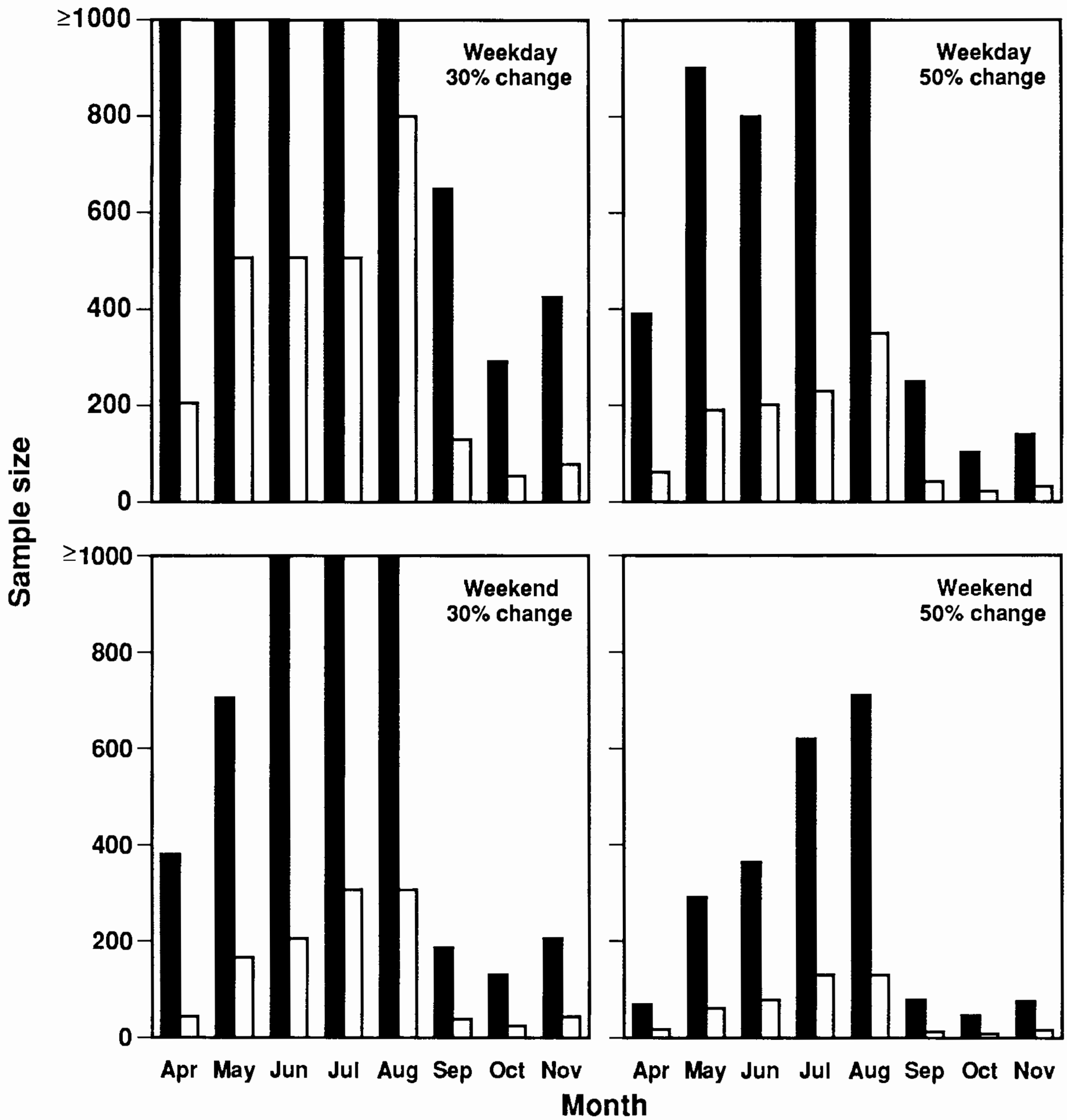

Figure 3.—Sample sizes necessary to detect a 30% (left panels) and 50% (right panels) change in estimated effort by shore anglers with 95% (solid bars) and 75% (open bars) certainty, for weekday (top panels) and weekend (bottom panels) estimates of effort for April through November. Sample size is the number of angler counts required per month for 22 sites; data represent mean effort from 1985-1988 totaled over 22 sites.

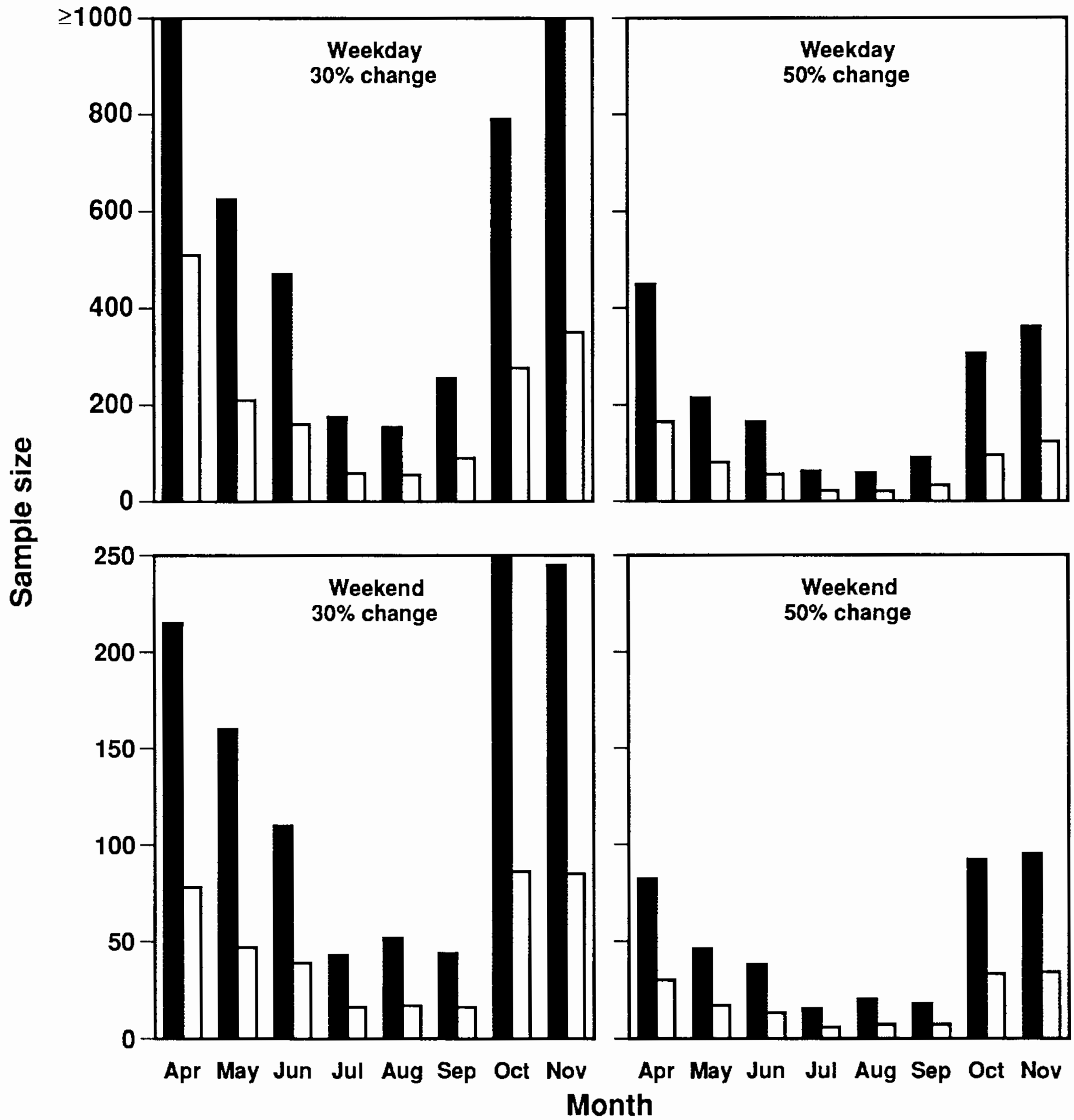

Figure 4.—Sample sizes necessary to detect a 30% (left panels) and 50% (right panels) change in estimated effort by boat anglers with 95% (solid bars) and 75% (open bars) certainty, for weekday (top panels) and weekend (bottom panels) estimates of effort for April through November. Sample size is the number of angler counts required per month for 16 sites; data represent mean effort from 1985-1988 totaled over 16 sites.

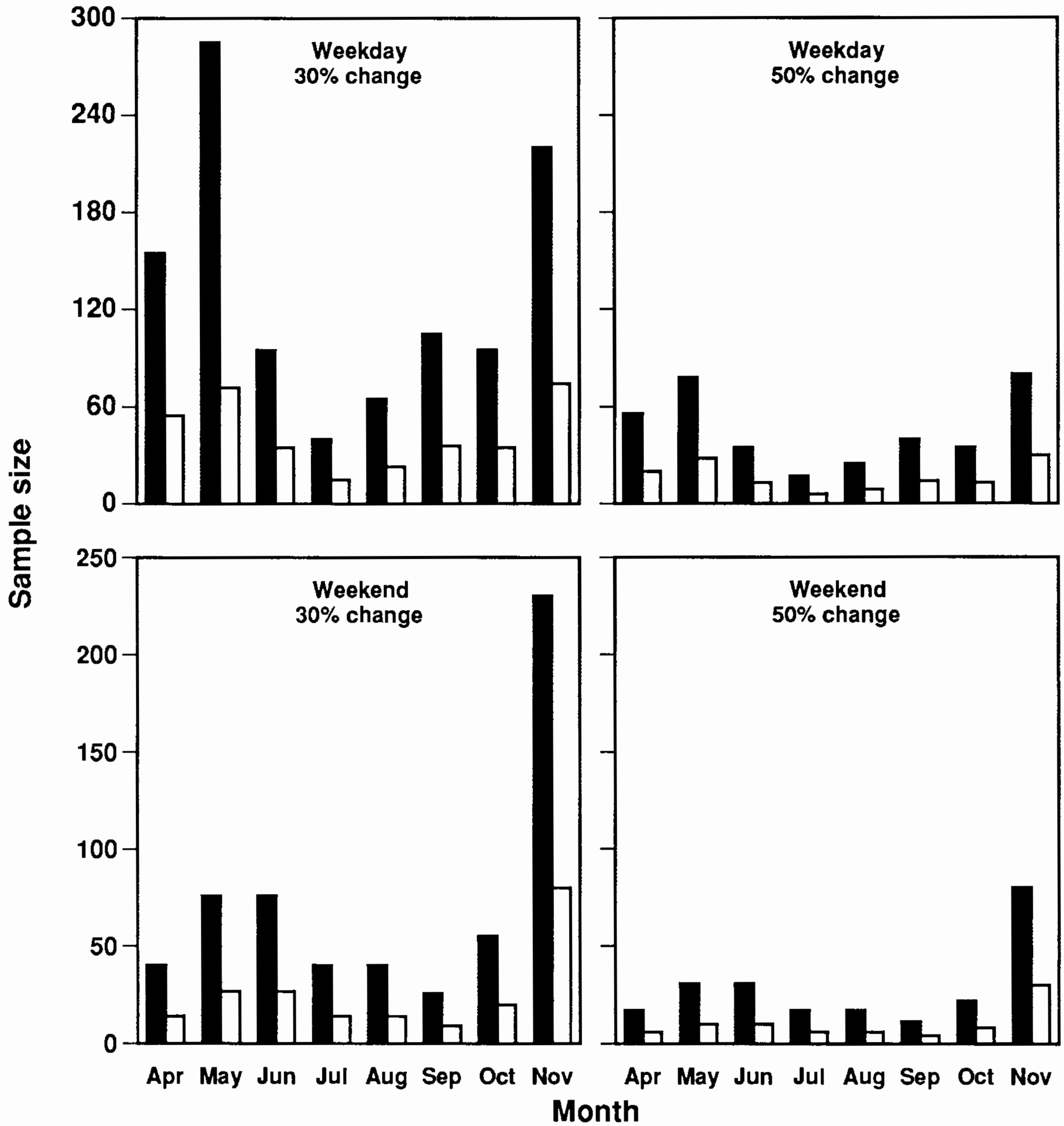

Figure 5.—Sample sizes necessary to detect a 30% (left panels) and 50% (right panels) change in estimated effort by pier anglers with 95% (solid bars) and 75% (open bars) certainty, for weekday (top panels) and weekend (bottom panels) estimates of effort for April through November. Sample size is the number of angler counts required per month for 13 sites; data represent mean effort from 1985-1988 totaled over 13 sites.

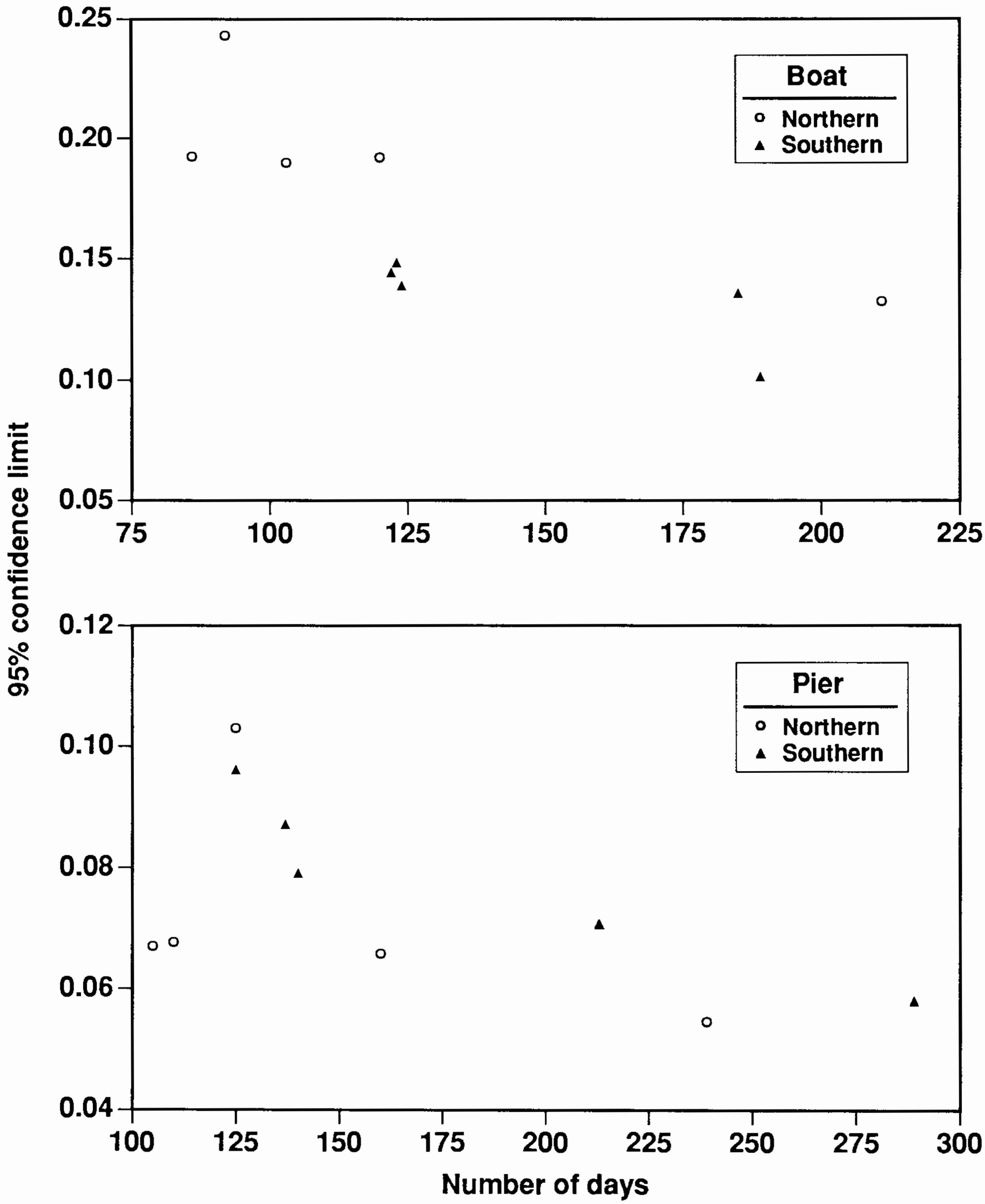

Figure 6.—Approximate, standardized 95% confidence limits (precision) of estimated angler effort (hours) achieved by performing the creel survey for a given number of days at three northern sites (circles) and four southern sites (triangles). Each point represents data from April through September for boat fisheries (upper panel) or April through October for pier fisheries (lower panel), 1985 through 1989. See text for description of method used to estimate standardized confidence limits.

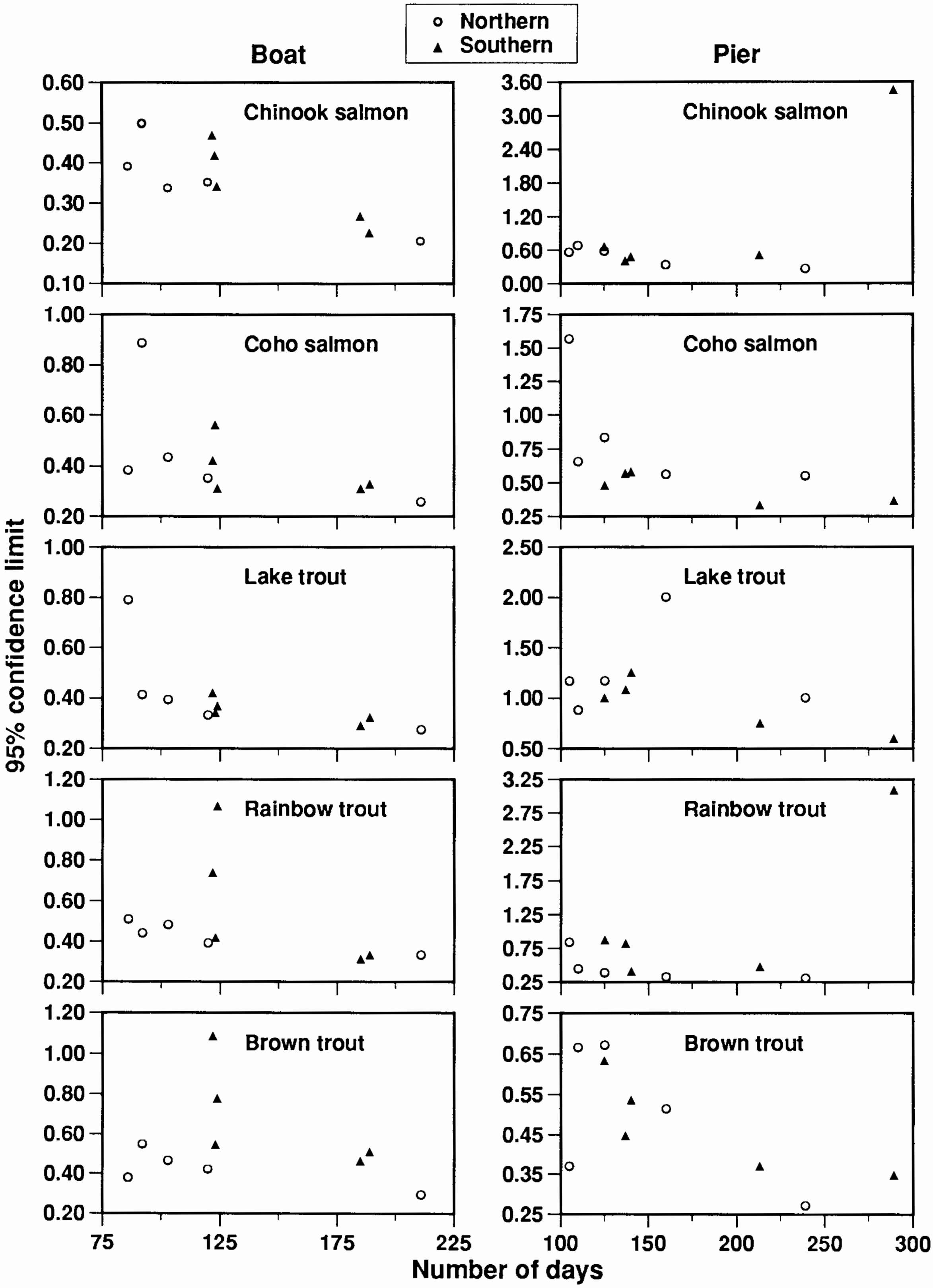

Figure 7.—Approximate, standardized 95% confidence limits (precision) of mean catch rates of chinook salmon, coho salmon, lake trout, rainbow trout, and brown trout achieved by performing the creel survey for a given number of days at three northern sites (circles) and four southern sites (triangles). Each point represents data from April through September for boat fisheries (left panels) or April through October for pier fisheries (right panels), 1985 through 1989. See text for description of method used to estimate standardized confidence limits.

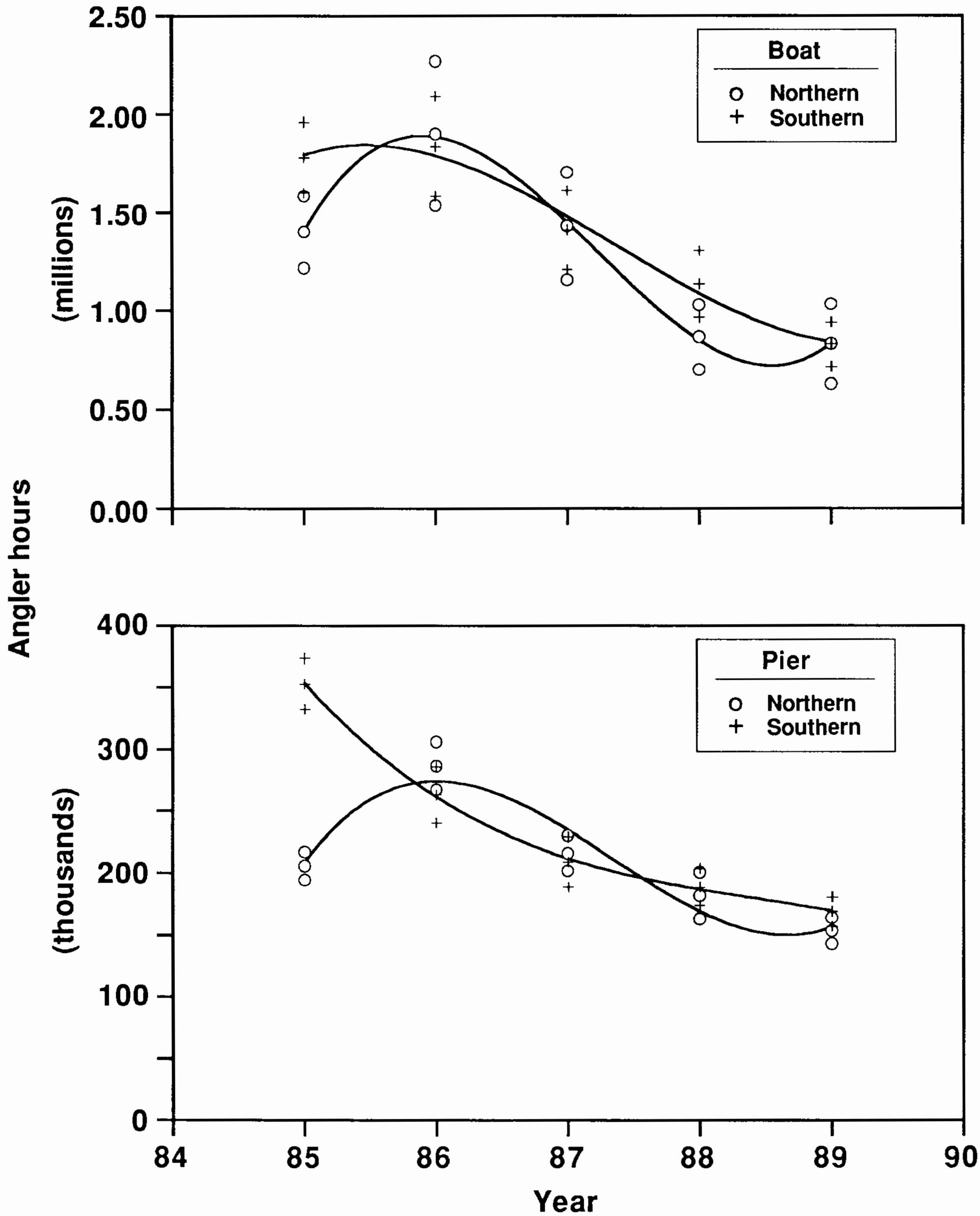

Figure 8.—Fishing effort (angler hours) for three northern sites (circles) and four southern sites (crosses) from 1985 through 1989. The means were estimated from creel data collected April through September for boat fisheries (upper panel) and April through October for pier fisheries (lower panel). The three points for each year represent the estimate and ±2 standard errors; curves were fit with a least-squares polynomial regression model (SLIDEWRITE graphics program).

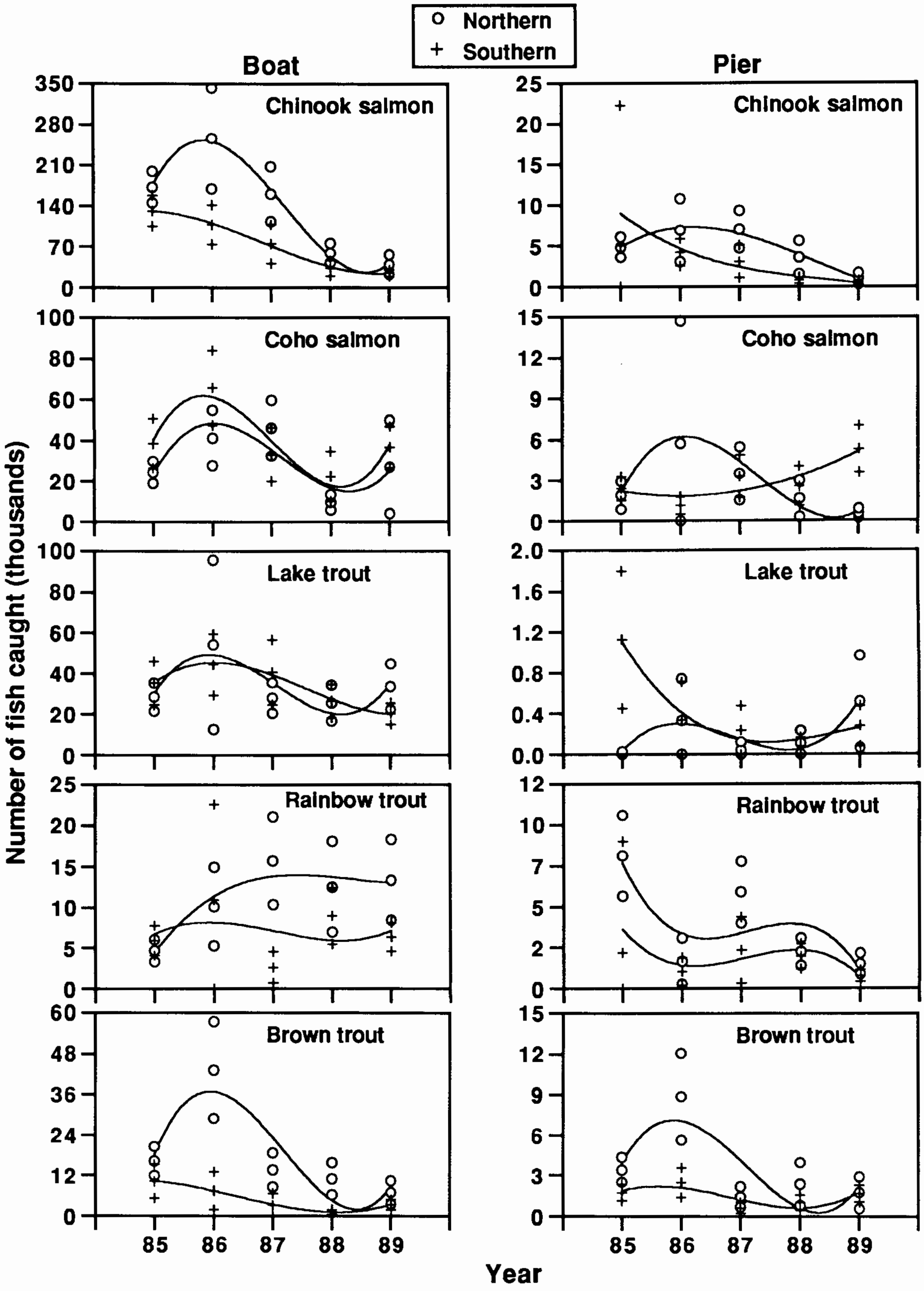

Figure 9.—Number of chinook salmon, coho salmon, lake trout, rainbow trout, and brown trout harvested at three northern sites (circles) and four southern sites (crosses) from 1985 through 1989. The statistics were estimated from creel data collected April through September for boat fisheries (left panels) and April through October for pier fisheries (right panels). The three points for each year represent the estimate and ±2 standard errors; curves were fit with a least-squares polynomial regression model (SLIDEWRITE graphics program).

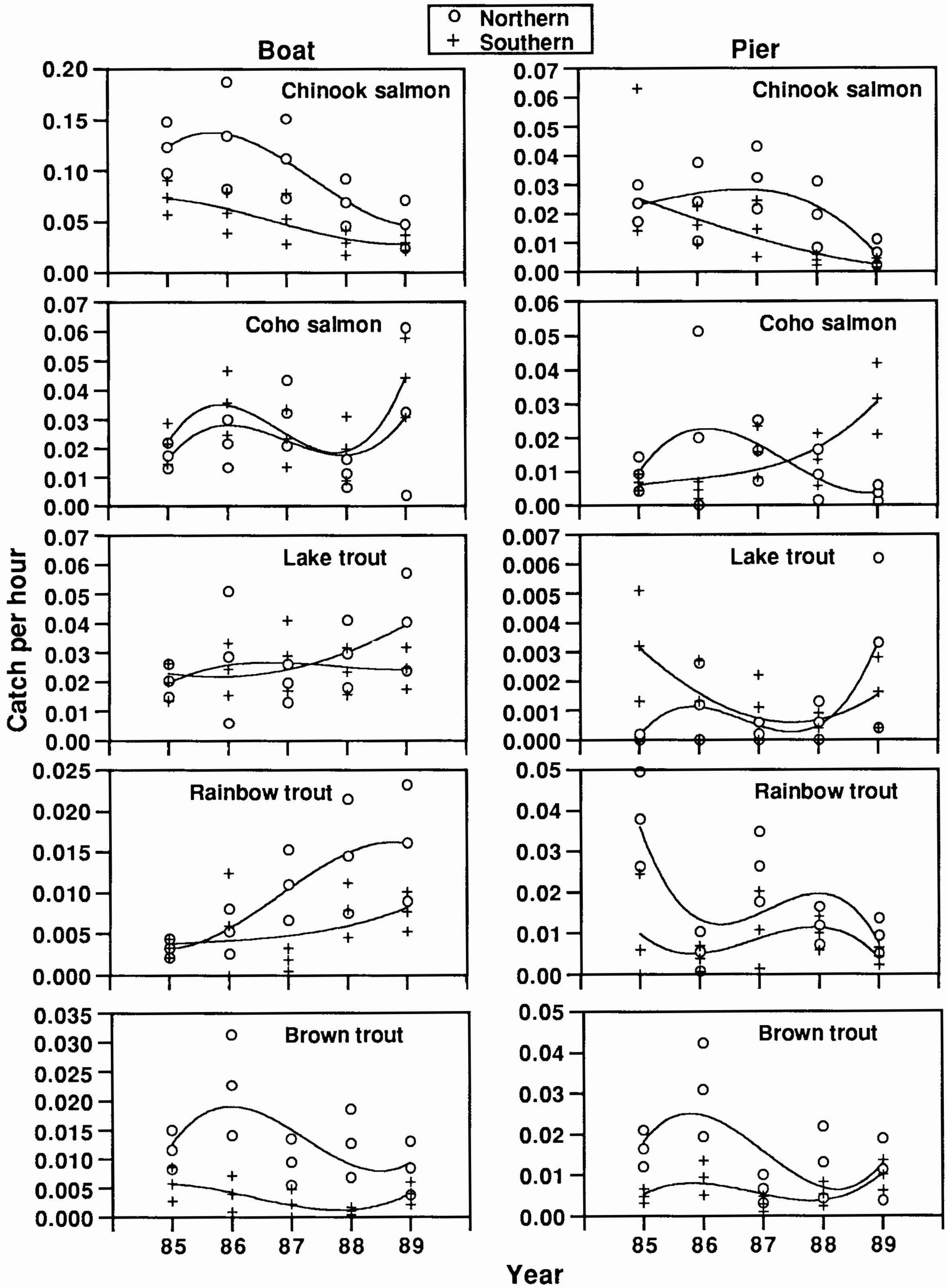

Figure 10.—Mean annual catch rates for chinook salmon, coho salmon, lake trout, rainbow trout, and brown trout at three northern sites (circles) and four southern sites (crosses) from 1985 through 1989. The means were estimated from creel data collected April through September for boat fisheries (left panels) and April through October for pier fisheries (right panels). The three points for each year represent the estimate and ±2 standard errors; curves were fit with a least-squares polynomial regression model (SLIDEWRITE graphics program).

Table 1.—Number of instantaneous counts of Lake Michigan anglers by fishing mode for sites surveyed from 1985-1988.

Mode of fishing	Year 1985	1986	1987	1988	Number of sites
Shore	2,758	1,744	2,020	1,606	22
Boat	2,380	1,834	2,230	1,914	16
Pier	2,471	979	1,203	989	13
Total	7,609	4,557	5,453	4,509	---

Table 2.—Distribution of count frequency for all sites on Lake Michigan by year and fishing mode.

Year	Mode of fishing	Frequency of counts per day One	Two	Three	Four
1985	Shore	1,335	6,632	---	---
	Boat	1,209	6,418	2	---
	Pier	347	2,856	2	---
1986	Shore	151	3,724	3	4
	Boat	118	3,960	3	8
	Pier	50	1,168	---	4
1987	Shore	23	1,990	---	8
	Boat	23	2,140	---	12
	Pier	17	1,270	---	12
1988	Shore	42	1,576	---	---
	Boat	23	1,772	---	---
	Pier	16	1,188	---	---

Table 3.—Analysis-of-variance results for differences in mean shore and boat fishing effort among nine (1985) and four (1986) subsites in the East Grand Traverse Bay area, by day type (weekend day and weekday). Boat fishing effort was estimated from instantaneous counts at the various ports.

	Mean effort for shore anglers				Mean effort for boat anglers			
	1985		1986		1985		1986	
Site	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
95	0.038	0.214	0.012	0.073	0.875	1.833	0.675	1.582
96	0.488	0.442	0.153	0.189	2.500	5.815	1.353	2.709
97	0.713	1.019	0.341	0.453	0.375	1.389	0.329	0.600
98	0.013	0.019	0.024	0.000	0.573	0.611	0.268	0.818
99	0.000	0.333	---	---	---	0.000	0.000	---
329	0.207	0.000	---	---	2.658	9.963	---	---
338	0.224	0.056	---	---	3.159	8.442	---	---
339	0.000	0.370	---	---	0.939	3.833	---	---
340	0.012	0.000	---	---	0.787	3.333	---	---
N	649	432	332	214	650	436	332	220
F	5.94	3.36	5.25	4.55	12.38	15.76	16.25	13.96
P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 4.—Analysis-of-variance results for differences in mean shore and boat fishing effort among eight subsites in the West Grand Traverse Bay area for 1985 and 1986, by day type (weekend day and weekday). Boat fishing effort was estimated from instantaneous counts at the various ports.

	Mean effort for shore anglers				Mean effort for boat anglers			
	1985		1986		1985		1986	
Site	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
100	0.000	0.316	0.000	---	0.063	0.000	0.000	---
101	0.085	0.250	0.059	0.164	4.268	17.436	4.082	12.790
103	0.709	1.333	0.179	0.400	4.048	8.417	2.333	6.544
104	6.699	13.439	3.906	5.182	0.125	0.333	0.059	0.228
106	0.183	0.600	0.060	0.164	3.780	6.306	2.512	6.912
107	0.024	0.000	0.000	0.000	4.146	5.000	4.536	7.088
108	0.012	0.000	0.012	0.000	1.646	2.033	1.373	2.386
110	0.050	0.183	0.024	0.000	2.346	2.966	1.835	3.596
N	576	427	594	385	577	429	592	399
F	34.90	38.26	80.02	78.18	13.33	20.27	9.69	23.37
P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 5.—Analysis-of-variance results for differences in mean shore and boat fishing effort among five subsites in the Escanaba area for 1985 and 1986, by day type (weekend day and weekday). Boat fishing effort was estimated from instantaneous counts at the various ports.

	Mean effort for shore anglers				Mean effort for boat anglers			
	1985		1986		1985		1986	
Site	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
20	2.261	3.828	3.439	8.185	9.563	15.098	1.671	1.673
21	0.746	1.218	1.660	1.421	4.443	7.515	2.155	2.200
22	2.985	4.361	1.017	.455	20.855	30.250	5.949	5.963
23	1.355	3.000	0.018	0.083	9.676	13.682	3.071	1.678
24	2.415	3.188	2.268	3.132	8.119	10.222	9.816	12.317
N	269	244	323	225	323	293	372	257
F	4.77	3.53	13.81	2.69	9.58	7.03	9.50	13.71
P	<0.01	0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01

Table 6.—Analysis-of-variance results for differences in mean shore and boat fishing effort between 1985 and 1986 for the East Grand Traverse Bay, West Grand Traverse Bay, and Escanaba areas, by day type (weekend day and weekday). Boat fishing effort was estimated from instantaneous counts at the various ports.

Area	Day type	Mean effort 1985	Mean effort 1986	*N*	*F*	*P*
Shore anglers						
East Grand Traverse Bay	Weekday	0.185	0.133	981	0.82	0.37
	Weekend	0.269	0.178	646	0.87	0.35
West Grand Traverse Bay	Weekday	0.997	0.606	1,170	4.59	0.03
	Weekend	2.129	0.844	812	11.29	<0.01
Escanaba	Weekday	2.000	1.836	592	0.40	0.53
	Weekend	3.180	3.240	469	<0.01	0.95
Boat anglers						
East Grand Traverse Bay	Weekday	1.466	0.663	982	24.16	<0.01
	Weekend	4.323	1.427	656	39.30	<0.01
West Grand Traverse Bay	Weekday	2.884	2.382	1,169	3.87	0.05
	Weekend	6.037	5.649	828	0.37	0.54
Escanaba	Weekday	10.703	4.863	695	30.46	<0.01
	Weekend	5.782	5.132	550	34.88	<0.01

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